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Worker Safety, Health, and Well-Being in the USA

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Message from the Guest Editors

The future of work is being shaped by rapid changes in the workplace, work, and workforce. Driven by advances in industry, this movement is marked by the accelerated pace of developments connecting people, places, and things. All these advances and developments have implications for worker safety, health, and well-being and require innovative and responsive occupational safety and health strategies. One such strategy is the *Total Worker Health*® framework, which recognizes work as a social determinant of health and prioritizes the principles of healthy work design to protect and advance worker safety, health, and well-being. Such efforts improve both our understanding of and capacity to address factors that present possible risks to today's and tomorrow's workforce, leading to empowered workers who thrive and contribute productively at work, at home, and across the U.S.A.

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Message from the Editor-in-Chief

Addressing the environmental and public health challenges requires engagement and collaboration among clinicians and public health researchers. Discovery and advances in this research field play a critical role in providing a scientific basis for decision-making toward control and prevention of human diseases, especially the illnesses that are induced from environmental exposure to health hazards. *IJERPH* provides a forum for discussion of discoveries and knowledge in these multidisciplinary fields. Please consider publishing your research in this high quality, peer-reviewed, open access journal.

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Article

Worker Perspectives on Incorporating Artificial Intelligence into Office Workspaces: Implications for the Future of Office Work

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Abstract: Workplace environments have a significant impact on worker performance, health, and well-being. With machine learning capabilities, artificial intelligence (AI) can be developed to automate individualized adjustments to work environments (e.g., lighting, temperature) and to facilitate healthier worker behaviors (e.g., posture). Worker perspectives on incorporating AI into office workspaces are largely unexplored. Thus, the purpose of this study was to explore office workers' views on including AI in their office workspace. Six focus group interviews with a total of 45 participants were conducted. Interview questions were designed to generate discussion on benefits, challenges, and pragmatic considerations for incorporating AI into office settings. Sessions were audio-recorded, transcribed, and analyzed using an iterative approach. Two primary constructs emerged. First, participants shared perspectives related to preferences and concerns regarding communication and interactions with the technology. Second, numerous conversations highlighted the dualistic nature of a system that collects large amounts of data; that is, the potential benefits for behavior change to improve health and the pitfalls of trust and privacy. Across both constructs, there was an overarching discussion related to the intersections of AI with the complexity of work performance. Numerous thoughts were shared relative to future AI solutions that could enhance the office workplace. This study's findings indicate that the acceptability of AI in the workplace is complex and dependent upon the benefits outweighing the potential detriments. Office worker needs are complex and diverse, and AI systems should aim to accommodate individual needs.

Keywords: workspace; office work; computer workstations; artificial intelligence

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1. Introduction

Most office workspaces do not adequately support office worker health, nor do they maximize work performance. Indoor environmental factors, such as temperature, air quality, and lighting, which do not fit the individual's needs or support occupational requirements, can directly affect office workers [1–3]. In the U.S., most heating, ventilation, and air conditioning (HVAC) systems are centrally controlled within a narrow range; exposure to greater temperature variability may support improved health (e.g., glucose handling, cardiovascular performance) [4]. Moreover, offices maintained at thermal levels that are too cold or too warm can negatively impact productivity and require workers to exert more effort to complete tasks [5]. In addition to temperature, lighting can negatively impact alertness, mood, and performance [6], cause eye strain and lead to problems with visual acuity [7], and disrupt an individual's natural circadian rhythm [8]. Finally, ambient noise, such as that from office equipment and coworkers talking, can be counterproductive, cause increased frustration, and lead to declines in worker well-being [9,10].

In addition to direct effects of the workplace physical environment, these and a variety of other factors intersect to affect worker health and well-being in office workers. Poor lighting, temperature, and other environmental factors can lead to maladaptive postures by causing an individual to hunch or move closer to the task [11], further exacerbating one of the most common health issues in office workers, musculoskeletal disorders. In fact, musculoskeletal conditions are the most commonly referenced health problems, with an annual prevalence of musculoskeletal pain in as many as 63% of office workers [12]. Factors such as job satisfaction and affective well-being can play a mediating role between the physical work environment and a worker's absenteeism or presenteeism, a relationship that is further impacted by an individual's work patterns [13]. Among all of the individual work patterns, the most common concern is that office workers spend an average of 11.6 h of their day in sedentary activity [14], which is directly associated with numerous adverse health impacts, including musculoskeletal disorders and metabolic syndromes [15–17]. Beyond detriments to health, sedentary behavior has been associated with lower cognitive performance [18,19].

Fluctuations in social and organizational practices, changes in worker demographics, and advances in technology are rapidly reshaping the future of office work in ways that may amplify these potential detriments to worker health and well-being [20]. While the contemporary trend in offices was to offer open environments with shared workstations (e.g., hot-desking) [21,22], the COVID-19 pandemic has recently led organizations to consider alternative workflows and work arrangements [23,24]. Of note is an increasing use of digital technologies to support remote work that has led to an increase in computer workstation use, with workers spending up to 1.5 h per day longer at their workstations than when working in-person [25]. Future work design that includes higher frequency of remote work creates additional risks to worker health and well-being. These factors go beyond the physical workspace and include social and personal factors such as the frequency of communication with co-workers and interruptions from other individuals in the home workspace [25].

The plethora of health and performance issues associated with office work are likely to continue and expand in future work and workplaces [21,26]; thus, it is ever important to identify solutions to the challenges of mitigating risk and improving well-being within office work [27]. Environmental modifications such as sit-stand desks have been found to reduce sedentary work behavior in the short term, but no studies examining these modifications have demonstrated long-term effectiveness of reducing sedentary behavior [28] nor any effects in reducing pain-related disability in office workers [29]. Workplace wellness programs have also been developed to address health and performance issues; however, retention of positive change is difficult, and predictors of successful intervention are not yet well-understood [30,31]. Such interventions are difficult because the workplace environment, the individual, and other contextual factors all affect engagement in preventive behaviors in the workplace [32]. Furthermore, changing workplace behavior requires altering habits that people have developed in their workspaces over time. Once formed, habits can dictate how a person engages with their environment, even when those behaviors have negative health impacts [33]. These factors are further amplified by the ever-increasing diversity in the workforce, work design, and work settings, and there is a growing need for a multifaceted approach that can support worker health and well-being [20,34].

Artificial intelligence (AI) may be a viable solution for delivering such multifaceted large scale, yet individualized, interventions to address environmental conditions and worker behaviors to promote healthy, supportive office workspaces. Automation in the workplace has been primarily focused on incorporating machines in service-oriented industries or jobs requiring manual labor to supplement or replace the actions of human workers [35]; however, some autonomous support systems are being developed to support worker health, such as to encourage exercise, or to support worker productivity, such as in decision-making tasks [36–38]. Unfortunately, most of these systems tend to take workers away from their work tasks to provide information or communicate with the

system [39]. There is a growing need to develop AI systems that can support worker health and productivity without interrupting job performance. Moreover, despite the increasing prevalence of automated systems in the workplace, there remains speculation and varying levels of acceptance of AI due to factors such as fear of the AI [40] and privacy concerns [41].

There is a clear opportunity for integrating an AI system that can learn individual needs, improve the work environment, and support behavior change over time within office workspaces. We previously completed and published a comprehensive review of current evidence and gaps in knowledge relative to developing an AI system for this purpose [42], through which we determined that it is necessary to begin by understanding office workers' perspectives, needs, and preferences. Specifically, there is limited knowledge of how the implementation of AI would alter the occupational context for workers in an office setting and how to develop an acceptable AI system that could become fully incorporated without being obtrusive. To examine these concepts, we conducted focus group interviews to explore office workers' perspectives on introducing AI into their workspace. In these focus groups, participants were not reacting to or providing feedback on a specific AI system; rather, these discussions were used to generate ideas and better understand how to design an AI system that would be most effective at achieving outcomes of importance to office workers such that the design would be acceptable to end-users.

2. Materials and Methods

2.1. Framework of the Study

The long-term goal of our research is to develop an AI-enabled office workstation that can support the health and well-being needs of office workers. We will do so by integrating sensors and feedback systems into the office environment that will enable the worker and AI to work synergistically [42]. At the outset of this broader project, we engaged with office workers to identify their perspectives so that we might design a system that could be easily translated into practice for maximum effects on the intended outcomes. Thus, we implemented a descriptive qualitative approach using focus group interviews with office workers. Qualitative approaches allow for deeper exploration of individual and group perspectives on a topic of interest than cannot be gained through quantitative means [43]. AI in the workspace can be a foreign concept for office workers who have become accustomed to their traditional workplace environments. A focus group method was chosen to gain a deeper understanding of worker preferences regarding AI in their workplace environments that cannot be as easily gathered through quantitative or survey methods. Although not guaranteed, successful focus groups can capitalize on group dynamics and lead to rich discussions [44]. Furthermore, focus groups may allow for richer understanding by mitigating the researcher's authority and giving space to the participants [45]. Focus group interviews were conducted in person or through video conferencing to enable as much interaction in real time and space as possible. The University of Southern California's institutional review board approved the protocols and procedures (Study ID: UP-18-00131). The study was conducted in accordance with the Declaration of Helsinki, meeting both the U.S. and European Union requirements for human subject research. All participants provided informed consent to participate in the focus groups, including permission to be audio-recorded.

2.2. Participants

Six focus group interviews were conducted between January 2019 and May 2019 We recruited participants through network sampling, where our research team asked office workers within their professional circles to volunteer their time. A total of 45 office workers participated. Three group interviews were conducted with a total of 27 employees of Arup Group Ltd., an independent architecture and design firm specializing in complex built environments. Participants from Arup identified their occupations as engineers, architects, and other building consultants. Three additional group interviews were conducted with a total of 18 staff members from varying departments of University of Southern California

(USC). These university participants were not faculty with teaching roles; rather, participants described having roles in management, administration, finance, and office assistant positions. There were more males in the Arup groups and more females in the university interviews (10 females and 17 males, 14 females and 4 males, respectively). While all participants reported spending the majority of their workday at desks, there was a range of office arrangements. Many engineers reported having an open office space with hot-desking, that is, the ability to work at a workstation of their choice, and a few participants reported having sit-to-stand desks. Three engineers and three university staff reported splitting their time between different office spaces (i.e., work from home).

2.3. Focus Group Procedures

Of the six focus groups, four occurred in-person with employees from either USC or Arup working in Los Angeles, and two were conducted using video conferencing with Arup employees working at the company's primary offices in London. During the focus groups, participants were asked open-ended questions related to integrating AI within their office workspace. An interview guide facilitated these semi-structured interviews and ensured that each group interview covered the same topics (Appendix A). Specifically, instead of feedback on an existing AI system, we framed these discussions around the proposed development of a new AI-enabled, smart office workstation that could provide support for improving health and work performance through automated feedback and environmental modifications [42]. At the start of each focus group, the moderator provided the following prompt to set the foundation for group discussion:

> *"We are looking at opportunities around making the work environment healthier for people. For example, there might be an artificial intelligence (AI) system that asks you to do healthier things like change the office temperature, change the room lighting, improve your posture, or change your position from sit to stand. We will use this data to inform the development of such technology."*

Following this introduction, participants were asked to imagine that AI was integrated into their office workspace to support their work performance and individual health. Participants were asked how they would like the AI to make changes or preferences related to receiving feedback from an AI workspace that could adjust the office environment (i.e., temperature and lighting), as well as the workstation itself (i.e., sitting or standing desk). This conversation was followed by questions that aimed to understand the worker's level of comfort and preferences regarding sensors or other means for obtaining data that could be used by a smart workstation to monitor the worker's health and the environment. At the end of each focus group, moderators asked participants what other options they would like in a "dream workstation." Throughout the session, multiple follow-up prompts were used to probe for information on specific concepts and topics within the feedback, sensing, and additional features segments.

Each focus group interview was scheduled for 60 min, and the sessions lasted between 41 and 75 min. After each focus group interview, the research team discussed initial findings and modified the interview guide to pursue emerging topics not outlined in the original interview guideline. All interviews were audio recorded and later transcribed to text. Each transcript was coded with the location and employer (i.e., Arup or USC), and individual participant identities were blinded in the transcripts by coding each comment with a participant's sex.

2.4. Data Analysis

Analysis of the focus group transcripts was completed by two researchers who were not involved in the interview guide's initial development and did not moderate the interviews. Basic qualitative thematic analysis was conducted using an inductive data coding process using a systematic, four-step text condensation procedure [46]:

(1) Total impression—from chaos to themes: During an initial reading, the smallest meaning units were identified and notated with minimal interpretation. Two researchers independently read all six interviews after the initial calibration of notation.
(2) Identifying and sorting meaning units—from themes to codes: The two researchers discussed preliminary impressions and findings from the initial coding process, and they developed categorical codes through an iterative process.
(3) Condensation—from code to meaning: Both researchers coded all six interview transcripts using the developed categories. This coding process involved a constant comparative method where the two researchers modified the codes according to the transcript data and discussions and questions that arose during the process [47].
(4) Synthesizing—from condensation to descriptions and concepts: Using the coded transcripts, the two researchers identified themes and patterns in the data. Prominent themes relevant to the research questions were revisited and summarized to produce the final results and interpretation.

The researchers who moderated focus group sessions were consulted between the initial code development and finalization of the codes to ensure the credibility of the independent coders. Based on the team's feedback, the independent coders then developed final themes and conducted an initial interpretation of the data. The full research team reviewed the interpretation and provided final feedback to ensure the accuracy, credibility, and trustworthiness of the findings.

2.5. Researcher Bias and Assumptions

The focus group moderators were interdisciplinary researchers engaged in developing AI solutions for office settings, including experts in human-computer interaction, engineering and design, and occupational science and ergonomics. Two investigators who did not engage in the focus group interviews conducted the qualitative review of the transcripts to minimize bias. One analyst is an occupational therapist and an occupational science PhD student research assistant affiliated with the broader study that funded this project but had not been involved in any aspect of the focus group interviews before reading the transcripts. To further increase the trustworthiness and rigor of the analysis, the second analyst was an outsider to the research project and an expert in qualitative methodology. She is an occupational scientist and occupational therapist who has written extensively on dynamic systems and occupation.

3. Results

We examined differences across groups to see if comments varied among those who worked at Arup versus USC, between groups conducted in London versus Los Angeles, or between participants of different sexes. We did not identify any significant differences in the discussions across groups conducted with engineering or university workers, between the two different geographic locations, or among workers with different job types or sexes. Two constructs emerged from the transcripts. First, participants shared perspectives related to their preferences and concerns regarding communication and interactions with AI technology within an office setting. Second, numerous conversations highlighted the dualistic nature of a system that collects large amounts of data; that is, the potential benefits for behavior change to improve health and the perils of trust and privacy. Further, across both constructs, there was an overarching discussion related to the complexity of work performance and its implications for incorporating AI into office settings. Finally, participants shared numerous thoughts relative to future AI solutions that could enhance the office workplace. Rich discussions revealed the need to individualize AI workstations to various user preferences and how the acceptability of an AI workstation is complex and affected by the person, context, and individual occupations.

3.1. Communication over Feedback

Although our interview guide was developed to obtain information on feedback preferences from the system to the user, participants more commonly discussed the two-way exchange of information, or communication, between the user and the AI system rather than a one-way feedback process. Participants expressed numerous preferences related to the ease, amount, invasiveness, and method of communication. In particular, easily communicating with the AI system was a priority for many people, especially in ways that would allow the user to control the system without interruption. Similarly, excess communication was viewed as burdensome, as demonstrated by the following statement: *"I think there's a very fine line between the system asking for information and that [communication] taking you away from being productive"* (Female, London).

The amount of communication preferred by the participants varied and depended upon the amount of automation. Some participants indicated they would only want to actively communicate with the AI when information or feedback was required and did not want the system to know any information that they did not willingly input, stating, *"I don't like things scanning things and knowing more about me than I told it"* (Female, Los Angeles). Others said they would rather have the system constantly gathering feedback or information without active user communication, resulting in full automation:

> *"I think I would prefer if everything just happened for me. I don't like messing with settings or trying to figure out what the best way to do it is. I'd rather it just dim [the lights] or change color at the right time."* (Female, Los Angeles)

Most people were somewhere in the middle, with one participant stating, *"like if you're driving in your car. Then, like you have control over the temperature, the AC in your car. Then, kind of comparable to that"* (Male, London). There was general agreement that the system could sense and self-adjust to enhance the environment (e.g., temperature changes). Still, the worker should have ultimate control over the AI system for other types of changes in the workspace, such as physical movement of the workstation.

The communication topic led to discussions about ways to ensure that communication with the system would not disrupt work and flow. Participants were generally agreeable to using a calibration period when first engaging with an AI system that might require frequent prompts followed by periods of less frequent interruptions, as long as the user would have prior knowledge and control over the calibration process. As stated by one participant, *"I wouldn't be averse to [calibration] if I just knew when it was going to happen so that I could go like, 'Okay, it's happening on Monday, Thursday, and then next Thursday, and I will be getting those prompts'"* (Female, London). Beyond scheduled calibration, another suggested a method to decrease disruptive communication was to combine both user input and system sensing to understand a worker's concentration level. One participant stated,

> *"I think it would be important if it had some ability to sense how focused you were at the moment because if I was in flow and it prompted me, I'd be really pissed off. I'd be like, 'Get this thing out of my cubical immediately!'"* (Male, Los Angeles)

Participants acknowledged that measuring focus and concepts like "flow" would be difficult because work tasks vary, and productivity looks different both within and between individuals.

Individual preferences for a method of communication with an AI system varied greatly (Figure 1). While some participants voiced a preference for communication that is integrated with a separate device, such as a phone, tablet, or wearable device, others stated they would like all contact with an AI system to be managed through a computer on which they are working. In addition to the device used, ideas for how to best engage in communication also ranged considerably, from buzzing chairs to pop-ups on the monitor. While there was more variety in preferences than anticipated, this rich discussion into communication demonstrated the complexity behind user preferences for communication with an AI workstation.

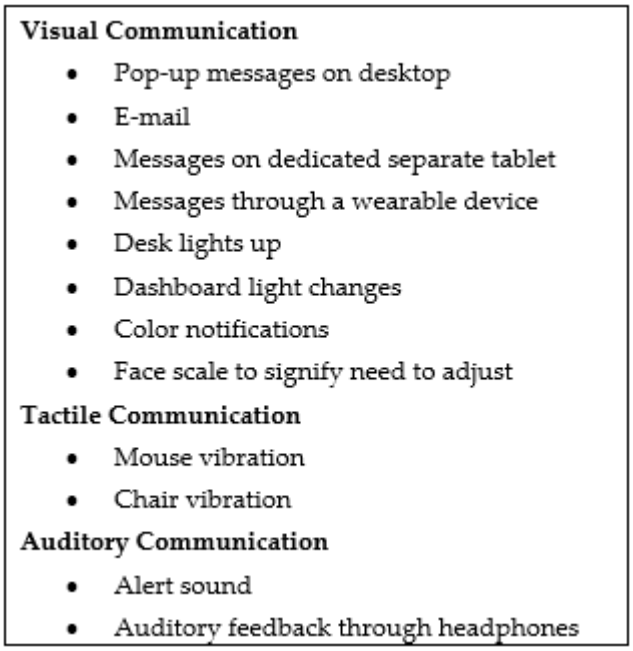


Figure 1. Potential methods of notification and communication by an AI workstation identified by focus group participants.

3.2. Big Data: Benefits and Perils of Monitoring

Although participants expressed a desire for fluid communication between a worker and the AI system, many also expressed concerns over the large amounts of collected data necessary for the system to learn a user's individual needs. Specifically, several participants discussed the potential invasion of privacy and unintended uses of the data against them. In general, acceptability seemed to depend on the purpose behind data logging or tracking, as one participant noted, *"If the purpose is solely about health and well-being, definitely. But, if it is about a 'Big Brother' type of management . . . or your boss generalizes what percentage of the time you spend on what . . . That might be counterproductive"* (Male, London).

Participants had multiple suggestions for increasing the acceptability of data collection by an AI system. A common recommendation was to ensure de-identification of the data, along with clear transparency in how data were being logged, monitored, or used. Of note were comments indicating that data collection for research was considered more acceptable than data being obtained for business or commercial uses. As a minimum threshold, there was general agreement that outside companies should not be able to access the data, with one participant stating:

> *"A written contract that the employer or whoever is guarding the data is going to reassure us that it's going to stay with this company or stay within this administration and that it's not going to be sold to anyone else outside of this administration."* (Male, Los Angeles)

Some participants stated that acceptability might be increased if they could see and maintain ownership of their data. Furthermore, individuals noted that having an option to output data into an offline format that would be robust against hacking might be beneficial. One participant stated:

> *"It might be a question of where the data is stored. If it could be stored somewhere where you essentially own the data and it's not going off to some sort of big brain, or maybe you'd plug your ID pass into a computer or something, and then it reads from that. So, at the end of the day, you take that away with you, and no one else has that data but you. That might be a little more palatable for people."* (Male, London)

There was a range of acceptability of the amount of data collected by the system. On one end of the spectrum, some participants noted that certain AI-supported functions could convince them to share as much data as needed. This sentiment is exemplified by

one participant who stated, *"I personally would sign away any information you want to never overheat at my desk again"* (Male, London). This level of acceptability was in stark contrast to other participants who said they do not want any data being collected or logged for any more than immediate use by the AI system.

> *"I think not recording it would be good, as in, if [the system] just gives you live updates and doesn't store any of the data beyond five minutes. That would be really reassuring cause then they can't, you know, do anything with five minutes; well, you could, but five minutes of data is not that much."* (Female, London)

Finally, participants imagined some other personal uses for data collected by an AI system in the office setting. Some participants noted that having access to the accumulated data or aggregate data reports could serve as a motivator to facilitate health behavior change related to certain work productivity, stress responses, or postural outcomes that might be monitored. These discussions were compared to similar existing technologies, such as smartphone applications, smartwatches, and other wearable fitness devices. Participants noted that these data could be used as positive reinforcement, or the system could gamify those data reports to develop competition with co-workers.

3.3. Work Performance and AI

Throughout all conversations related to communication and big data, work-related productivity emerged as a frequently recurring theme. Although moderators asked questions related to environmental factors and behaviors that could impact health and well-being, the interview guide did not focus on productivity; however, discussions frequently included this aspect of work performance. Participants indicated that they would like the technology to support their productivity and that communication from the technology should not interrupt their productivity in any way. Moreover, they indicated that AI should not attempt to monitor or measure productivity, particularly given the complexity of measuring work performance across different types of tasks and work contexts. Connections between productivity and well-being in terms of work performance were also raised within the focus group sessions.

Acknowledging the complexity and diversity of office work performance, participants highlighted how an AI system could either hinder or enhance engagement. Preventing negative effects on work performance was a priority for many participants, as was the desire for an AI system to support focus and productivity. While participants were wary of too much personal data being collected, a workstation that enhances productivity was a motivating factor for allowing data collection. One participant stated, *"I would definitely be interested to know what times of day I had the highest productivity, and what I was doing for those phases because I can try to integrate that in more of my day"* (Female, Los Angeles). Participants suggested different ways of surveying the worker and sensing the worker's behaviors for the system to understand work performance and enhance productivity. *"I think you just have to ask people. You'd have to be like, 'Are you productive?', set a score, then look at all the data and say, 'These are the trends that correlate to the highest productivity'"* (Male, London).

While enhancing productivity was a desirable outcome of an AI system, participants expressed reservations about whether productivity could accurately be assessed via objective, external measures. Behavior may not be a reliable indicator, as one participant noted:

> *"That is a hard problem . . . you mentioned earlier, 'Oh, he stopped typing for a bit'; that means you're thinking . . . which means he may be walking around, right? That seems reasonable but, on the other hand, sometimes when thinking my best thoughts, I'm not touching a computer. I'm just sort of staring into the void."* (Male, Los Angeles)

Another participant stated similarly, *"unproductivity shows up differently in different people . . . cause when I'm trying to avoid my work procrastinating, I'll just be checking my emails all day"* (Female, London). This variability in understanding and measuring productivity raised questions about whose perspective should be considered:

> *"You have your own feeling, and then your boss has a feeling, and the company has a feeling . . . how you define a productive day. Is it that you read a few research papers and you've taken in the information that helps you with tasks? Or is it that you've done 20 tasks and therefore you've had a productive day?"* (Male, London).

Fundamentally, perceptions reflected the reality that work performance is most accurately understood by considering interactions among physical, cognitive, psychological, and contextual factors. Acknowledging this complexity of worker performance and productivity, participants expressed interest in understanding the relationship between performance and well-being. As summarized by one participant:

> *"I would be very interested in exploring the links between health and well-being and productivity. For example, last week, a colleague of mine told me that there is a very strong direct correlation between dehydration and lack of cognitive skills . . . . I read a very interesting article in the Harvard Business review precisely about sitting desk vs. standing desk . . . Those with a sitting desk were outperformed by 50 percent by those with a standing desk. So, it suggests that there is a relationship between health and well-being and productivity."* (Male, London).

3.4. Idealizations for AI in Office Workplaces

When asked to comment on a "dream workstation," participants most frequently identified technologies and environmental modifications that could be incorporated into an AI system to optimize work performance. Of particular note, participants across all focus groups discussed ways to minimize ambient noise (e.g., quieter keyboards, warning systems for loud co-workers). Participants who hot-desk spoke of AI data logging and transfer that could support a seamless transition between workstations. There were frequent suggestions from participants that an AI system should incorporate existing technologies that support productivity (e.g., voice recognition, task tracking software) and health (e.g., fitness trackers). Similarly, many discussions related to how an AI system might use reinforcement, punitive, or mandatory processes to encourage health behaviors. One participant suggested the use of mandatory muscle stretches to gain access to the computer stating, *"because I have tendonitis, I need to [stretch]. And [I would be more compliant] if it's forcing me to do it"* (Female, Los Angeles). While a good motivator for an individual with pain or other health conditions, others indicated mandatory solutions could be frustrating to someone without any current health condition or discomfort. Many discussions focused on the trade-offs between smart features that may support one goal but could detract from other goals. For example, if an AI-enabled system could automatically refill a cup on the desk with water, one participant immediately noted, *"then you won't go walk to get your water"* (Female, Los Angeles).

During idealization, conversations often moved to AI systems that extended beyond the individual workstation or cubicle and instead were integrated into the building or considered larger-scale approaches. Participants frequently noted the benefits of integrated monitoring between the individual AI workstation and the building, such as knowing the building's temperature or the amount of lighting coming from a window versus overhead lights. An individual AI workstation connected to the window blinds could automatically adjust the amount of natural light relative to overhead or workstation lights. Integration could also address concerns between individual workstations, such that sitting next to a person with opposing preferences might not nullify the individual workstations' effects, as one person stated, *"I don't think your desk temperature is going to make that big of a difference. You're just going to cancel each other out, you know?"* (Female, Los Angeles). In three of the six focus groups, participants raised concern regarding negative consequences, environmental impacts, financial costs, and contextualized considerations for an AI system implemented at the scale of an entire building. One particularly poignant comment noted that efforts by an AI system to imitate nature within the indoor work environment would be wasteful when all that is necessary may be a walk outside. However, this led to debate, as other

participants pointed out that not everybody has access to a safe and pleasant environment outside of the office building.

4. Discussion

In this study, we conducted focus group interviews to understand office workers' perspectives on incorporating AI into the workplace as a means for improving environmental conditions and providing behavioral support to improve office worker health and well-being. Rich discussions highlighted the complexity of understanding individual needs and preferences regarding AI in office settings. There remains much speculation and caution of AI in society. Prior studies on acceptance of automation have demonstrated that safety, benefits, compatibility, privacy, and trust were common factors that influence acceptance [48,49]. These components were prevalent in our findings. We noted that the acceptability of an AI system depends on the benefits to the individual outweighing the potential detriments of a system that monitors and communicates with the user. In particular, people who were already experiencing detrimental health effects from their current work environments (i.e., tendonitis, back pain, lower cognition due to cold office temperatures) were more open to a system requiring more worker engagement. Data transparency and confidentiality, practical and concise communication, and control over the system were common desires in an AI workstation that would increase acceptability for introducing AI into office settings among the participants of this study.

Although the moderators initially inquired about using AI to support office worker health and well-being, many groups found a connection between wellness and productivity, and many discussions of work performance emerged. These topics were particularly prevalent when participants discussed communication between the user and the AI system. In fact, participants emphasized the effect that the communication process might have on work performance, rather than on the actual mechanism through which the communication would occur. Providing communications in an effective way and well-timed within the individual work context is complex and requires careful consideration to ensure that employees are able to maintain appropriate attention to their work and feel/be productive [50]. Our findings point to a need for AI not only to sense the office environment and the position or posture of the worker but also to recognize and understand how the worker is engaging in his or her work. In addition to appropriate timing, increased communications from an AI system should be carefully considered, as the number and type of communications a worker must manage throughout a workday can directly impact overall worker well-being [51].

With projections of AI being increasingly used as autonomous support systems in the workplace [35], there is a need to understand how incorporating an AI system may affect work behavior. Machine learning has been applied to sense human activity through wearable accelerometers to computer vision techniques [52,53]. However, office work behavior is complex, and the process for understanding work performance through sensing has yet to be developed or validated. As a foundation, it is necessary to analyze office worker behavior to know how an AI system might effectively sense worker engagement to support office work performance. Rather than viewing the person and their environment as separate entities, a transactional perspective that focuses on the interplays among the worker, technologies, and workplace environment would be a useful approach for developing such workplace AI solutions [54]. This type of approach would be beneficial in the ongoing training of an AI system that must learn and change based on the user to achieve the ultimate goal of altering a worker's behaviors [55].

In addition to the benefits to worker health and well-being, developing effective automation within office environments may have broader organizational and environmental benefits. Of importance at an organizational level are opportunities to improve the financial bottom-line due to increased worker satisfaction and well-being and decreased absenteeism or presenteeism, all of which can lead to increased performance and productivity [56]. In particular, automation has been shown to save energy and lower operating costs [57,58].

Participants in our focus groups briefly mentioned ways in which AI incorporated at individual workstations may be able to connect to adjustments at the building level that could benefit all workers and energy costs (e.g., automated adjustment of window coverings). In addition, AI systems integrated into individual workstations could turn off lights, personal comfort devices, and other electronic devices when the presence of the worker is not noted as a means of conserving energy [42]. Future study is needed to explore the transactions that occur among a worker, the workspace, and an AI system to better understand these interplays and the implications of worker health, work performance, and other organizational or environmental impacts within future office work contexts [26]. Such a multifaceted approach could result in robust, efficacious workplace worker health solutions [20,34] with additional far-reaching benefits.

Findings of this study should be considered with multiple limitations in mind. These focus groups were conducted as part of a broader study examining the development of an AI-enabled office workstation to enhance office worker health and productivity. While open discussions were encouraged, focus group questions were framed around relevant topics of interest in the broader AI development project, which may have limited participants from suggesting ideas or discussing issues that diverged from the study's focus. Although we did compare discussions by the employer and geographic location, we did not collect detailed demographic information of our participants beyond their sex. As such, we were not able to conduct any robust analysis of other individual worker characteristics (e.g., age, health status). To minimize potential respondent bias, no individuals with knowledge of the specific research study aims or individuals with a direct working relationship to the moderators were included in the focus groups. However, due to network sampling, many participants worked in jobs that involved research and engineering, potentially making them more open to new technologies than other contemporary office workers. It is not clear if users less familiar with AI solutions or working in office settings that are not accustomed to research and development would share these perspectives and preferences. Moreover, the specific findings reported by these workers may not translate to workers in other countries, regions, or cultures.

5. Conclusions

In this study, we explored office worker preferences for incorporating AI into the office workspace. Our findings indicate there is a wide range of individual preferences and areas of concern. While likely beneficial for improving healthy and productive engagement in the workplace, rich discussions among office workers demonstrated how the acceptability of AI within an office setting is complex and affected by the person, the work, and the organizational context. The key components that emerged from focus group interviews were preferences around data security, communication with the system, and impact on work performance and productivity. Future studies should explore trust in technology and work performance related to AI systems to offer further insight into designing AI systems within office settings to support work performance and worker well-being.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to potential privacy concerns that may arise based on conversations held within the focus group sessions. For individuals wishing to conduct further analysis, access to transcripts is available through a data sharing agreement approved by the relevant intuitional review boards.

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Appendix A

Focus Group Interview Guide.

Introduction, Moderator Statement: We are looking at opportunities around making the work environment healthier for people. For example, there might be an artificial intelligence (AI) system that asks you to do healthier things like change the office temperature, change the room lighting, improve your posture, or change your position from sit to stand. We will use this data to inform the development of such technology. We ask you not share anything that is said as part of this focus group outside the room. To start things off, could you each please tell us a little bit about yourself, your role at [Arup, USC], and what your office set-up looks like.

Feedback Options, Moderator Statement: Imagine there was AI in your office workspace. This AI could help manage things in your office to help you be healthier and more comfortable. It might change the office temperature, change the room lighting, ask you to change your posture or position at the desk. How might you like the AI to provide feedback to you or ask you about these changes?

Follow-up prompts:

- If not mentioned or respondents need examples, ideas mention: phone notification, pop-up on the computer screen; vibration/buzzer on the desk; blinking lights on the desk; notifications on a different dedicated screen placed on the desk (like a tablet); a virtual agent who you can talk to that might appear on multiple mediums (e.g., computer monitor, phone, computer, tablet).
- Regarding changes to the environment (e.g., lighting, temperature, noise) would you prefer that the system ask or automatically adjust the environment based on what it thinks you need or prefer without requesting feedback? For example, turning on a fan when you might be too warm, turning on a space heater when you might be too cold, adjusting the lights or monitor brightness when you are squinting or there is glare from an outside source;
- Regarding posture or position changes, would you prefer feedback or for the AI to automatically make changes to the workstation? For example, raising the desk when you've been sitting too long, raising or tilting the monitor when you are looking up or there is glare from an outside source;
- Which feedback options that we've talked about do you like the best? Least? Why?
- Are there any additional problems you can think of with the feedback options? Additional benefits?

Sensing Options, Moderator Statement: To be able to make intelligent suggestions regarding the environment (e.g., lighting, temperature, noise) and your behaviors (e.g., posture, positioning), the AI would also need to sense things about your health, like your body temperature or muscle tension, and the way in which you are positioned or engaging at your workstation. We would like to hear your thoughts about how and AI system might obtain these data, consider sensors that you might wear or that might be placed at the workstation to monitor your health. What kinds of sensors that you know of would you feel most comfortable with?

Follow-up prompts:

- If not mentioned or respondents need examples, ideas include: a smart watch or fitness tracker; thermal cameras on the desk (no pictures; no identifiable info); Kinect camera or webcam to identify postures or activities; muscle activation sensors (e.g., EMG electrodes); light sensors; occupancy sensors to detect if the desk is used or not; sensors on peripheral devices connected to the desk or workstation;
- Which of these sensor options that we've talked about do you like the best? Least? Why?
- Are there any additional problems you can think of with the sensor options? Additional benefits?

Other Features and Capabilities, Moderator Statement: An AI system in your workspace could also have additional features and capabilities that go beyond adjusting the environment or promoting healthy posture or positioning. If it could include anything you might image, we would like to know what kinds of features or capabilities you would like for an AI system to have. We are most interested in ways in which an AI system could address problems and unmet needs in your work environment. What other problems or unmet needs can you think of in your work environment, and what kinds of features or capabilities in an AI system might help?

Follow-up prompts:

- If not mentioned or respondents need examples, ideas include: appointment, meeting, or important deadline reminders; acts as a personal assistant (e.g., orders lunch, makes reservations, auto-replies to e-mail requests); plays your favorite music to cheer you up you are down; playing calming music when you are stressed;
- Which of the features or capabilities that we've talked about do you like the best? Least? Why?
- Are there any additional problems you can think of with these features? Additional benefits?

Conclusion, Moderator Statement: We have talked about a lot of ideas related to how an AI system could be incorporated in your office workstation to promote health and comfort, including options for the system to provide feedback, ways such a system could sense your health or needs within the environment, and your ideas for other things that you might want an AI system to do. Does anyone have any final comments or ideas across any of these areas before we conclude?

References

1. Clausen, G.; Wyon, D.P. The combined effects of many different indoor environmental factors on acceptability and office work performance. *HVAC R Res.* **2008**, *14*, 103–113. [CrossRef]
2. de Croon, E.M.; Sluiter, J.K.; Kuijer, P.P.F.M.; Frings-Dresen, M.H.W. The effect of office concepts on worker health and performance: A systematic review of the literature. *Ergonomics* **2005**, *48*, 119–134. [CrossRef]
3. Wong, S.K.; Lai, L.W.C.; Ho, D.C.W.; Chau, K.W.; Lam, C.L.K.; Ng, C.H.F. Sick building syndrome and perceived indoor environmental quality: A survey of apartment buildings in Hong Kong. *Habitat Int.* **2009**, *33*, 463–471. [CrossRef]
4. van Marken Lichtenbelt, W.; Hanssen, M.; Pallubinsky, H.; Kingma, B.; Schellen, L. Healthy excursions outside the thermal comfort zone. *Build. Res. Inf.* **2017**, *45*, 819–827. [CrossRef]
5. Hedge, A.; Miller, L.; Dorsey, J.A. Occupant comfort and health in green and conventional university buildings. *Work* **2014**, *49*, 363–372. [CrossRef]
6. van Bommel, W.; van den Beld, G. Lighting for work: A review of visual and biological effects. *Light. Res. Technol.* **2004**, *36*, 255–266. [CrossRef]
7. Boyce, P.R.B. The impact of light in buildings on human health. *Indoor Built Environ.* **2010**, *19*, 8–20. [CrossRef]
8. Heydarian, A.; Pantazis, E.; Carneiro, J.P.; Gerber, D.; Becerik-Gerber, B. Lights, building, action: Impact of default lighting settings on occupant behaviour. *J. Environ. Psychol.* **2016**, *48*, 212–223. [CrossRef]
9. Mak, C.; Lui, Y. The effect of sound on office productivity. *Build. Serv. Eng. Res. Technol.* **2012**, *33*, 339–345. [CrossRef]
10. Di Blasio, S.; Shtrepi, L.; Puglisi, G.E.; Astolfi, A. A cross-sectional survey on the impact of irrelevant speech noise on annoyance, mental health and well-being, performance and occupants' behavior in shared and open-plan offices. *Int. J. Environ. Res. Public Health* **2019**, *16*, 280. [CrossRef] [PubMed]
11. Joines, S.; James, T.; Liu, S.; Wang, W.; Dunn, R.; Cohen, S. Adjustable task lighting: Field study assesses the benefits in an office environment. *Work* **2015**, *51*, 471–481. [CrossRef]

12. Janwantanakul, P.; Pensri, P.; Jiamjarasrangsri, V.; Sinsongsook, T. Prevalence of self-reported musculoskeletal symptoms among office workers. *Occup. Med.* **2008**, *58*, 436–438. [CrossRef] [PubMed]
13. Soriano, A.; Kozusznik, M.; Peiró, J. From Office environmental stressors to work performance: The role of work patterns. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1633. [CrossRef] [PubMed]
14. Tudor-Locke, C.; Leonardi, C.; Johnson, W.D.; Katzmarzyk, P.T. Time spent in physical activity and sedentary behaviors on the working day: The American Time Use Survey. *J. Occup. Environ. Med.* **2011**, *53*, 1382–1387. [CrossRef]
15. Biswas, A.; Oh, P.I.; Faulkner, G.E.; Bajaj, R.R.; Silver, M.A.; Mitchell, M.S.; Alter, D.A. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults a systematic review and meta-analysis. *Ann. Intern. Med.* **2015**, *162*, 123–132. [CrossRef] [PubMed]
16. De Rezende, L.F.M.; Rey-López, J.P.; Matsudo, V.K.R.; Luiz, O.D.C. Sedentary behavior and health outcomes among older adults: A systematic review. *BMC Public Health* **2014**, *14*, 1–9. [CrossRef]
17. Edwardson, C.L.; Gorely, T.; Davies, M.J.; Gray, L.J.; Khunti, K.; Wilmot, E.G.; Yates, T.; Biddle, S.J.H. Association of sedentary behaviour with metabolic syndrome: A meta-analysis. *PLoS ONE* **2012**, *7*, e34916. [CrossRef]
18. Falck, R.S.; Davis, J.C.; Liu-Ambrose, T. What is the association between sedentary behaviour and cognitive function? A systematic review. *Br. J. Sports Med.* **2017**, *51*, 800–811. [CrossRef] [PubMed]
19. Baker, R.; Coenen, P.; Howie, E.; Williamson, A.; Straker, L. The short term musculoskeletal and cognitive effects of prolonged sitting during office computer work. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1678. [CrossRef]
20. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
21. Millward, L.J.; Haslam, S.A.; Postmes, T. Putting employees in their place: The impact of hot desking on organizational and team identification. *Organ. Sci.* **2007**, *18*, 547–559. [CrossRef]
22. Cooper, P.B.; Maraslis, K.; Tryfonas, T.; Oikonomou, G. An intelligent hot-desking model harnessing the power of occupancy sensing data. *Facilities* **2017**, *35*, 766–786. [CrossRef]
23. Parker, L.D. The COVID-19 office in transition: Cost, efficiency and the social responsibility business case. *Account. Audit. Account. J.* **2020**, *33*, 1943–1967. [CrossRef]
24. Green, N.; Tappin, D.; Bentley, T. Working From Home Before, During and After the Covid-19 Pandemic: Implications for Workers and Organisations. *N. Z. J. Employ. Relat.* **2020**, *45*, 5–16. [CrossRef]
25. Xiao, Y.; Becerik-Gerber, B.; Lucas, G.; Roll, S.C. Impacts of working from home during COVID-19 pandemic on physical and mental well-being of office workstation users. *J. Occup. Environ. Med.* **2020**. [CrossRef]
26. Felknor, S.; Streit, J.; Chosewood, L.; McDaniel, M.; Schulte, P.; Delclos, G. How will the future of work shape the OSH professional of the future? A workshop summary. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7154. [CrossRef]
27. Pereira, M.J.; Johnston, V.; Straker, L.M.; Sjøgaard, G.; Melloh, M.; O'Leary, S.P.; Comans, T.A. An investigation of self-reported health-related productivity loss in office workers and associations with individual and work-related factors using an employer's perspective. *J. Occup. Environ. Med.* **2017**, *59*, e138–e144. [CrossRef]
28. Shrestha, N.; Kukkonen-Harjula, K.T.; Verbeek, J.H.; Ijaz, S.; Hermans, V.; Bhaumik, S. Workplace interventions for reducing sitting at work. *Cochrane Database Syst. Rev.* **2018**, *6*. [CrossRef]
29. Parry, S.P.; Coenen, P.; Shrestha, N.; O'Sullivan, P.B.; Maher, C.G.; Straker, L.M. Workplace interventions for increasing standing or walking for decreasing musculoskeletal symptoms in sedentary workers. *Cochrane Database Syst. Rev.* **2019**, *11*. [CrossRef]
30. Song, Z.; Baicker, K. Effect of a workplace wellness program on employee health and economic outcomes: A randomized clinical trial. *JAMA J. Am. Med. Assoc.* **2019**, *321*, 1491–1501. [CrossRef] [PubMed]
31. Muir, S.D.; Silva, S.S.M.; Woldegiorgis, M.A.; Rider, H.; Meyer, D.; Jayawardana, M.W. Predictors of success of workplace physical activity interventions: A systematic review. *J. Phys. Act. Heal.* **2019**, *16*, 647–656. [CrossRef] [PubMed]
32. Lecours, A. Using an occupational perspective to understand behaviours fostering the prevention of work-related health problems: A proposed conceptual model. *J. Occup. Sci.* **2020**, *27*, 222–235. [CrossRef]
33. Clark, F.; Sanders, K.; Carlson, M.; Blanche, E.; Jackson, J. Synthesis of habit theory. *OTJR Occup. Particip. Health* **2007**, *27*, 7s–23s. [CrossRef]
34. Chari, R.; Chang, C.C.; Sauter, S.L.; Sayers, E.L.P.; Cerully, J.L.; Schulte, P.; Schill, A.L.; Uscher-Pines, L. Expanding the paradigm of occupational safety and health: A new framework for worker well-being. *J. Occup. Environ. Med.* **2018**, *60*, 589–593. [CrossRef] [PubMed]
35. Wisskirchen, G.; Biacabe, B.T.; Bormann, U.; Muntz, A.; Niehaus, G.; Soler, G.J.; Von Brauchitsch, B. *Artificial Intelligence and Robotics and Their Impact on the Workplace*; International Bar Association Global Employment Institute: London, UK, 2017.
36. Manuvinakurike, R.; Velicer, W.F.; Bickmore, T.W. Automated indexing of Internet stories for health behavior change: Weight loss attitude pilot study. *J. Med. Internet Res.* **2014**, *16*, e285. [CrossRef] [PubMed]
37. Wang, Y.; Khooshabeh, P.; Gratch, J. Looking real and making mistakes. In *Proceedings of the Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*; Springer: Berlin/Heidelberg, Germany, 2013; Volume 8108, pp. 339–348.
38. Blascovich, J.; McCall, C. Social Influence in Virtual Environments. In *Oxford Handbook of Media Psychology*; Dill, K.E., Ed.; Oxford University Press: Oxford, UK, 2013; ISBN 9780195398809.

39. Traum, D.; Swartout, W.; Marsella, S.; Gratch, J. Fight, flight, or negotiate: Believable strategies for conversing under crisis. In *Proceedings of the Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*; Springer: Berlin/Heidelberg, Germany, 2005; Volume 3661, pp. 52–64.
40. Ernst, E.; Merola, R.; Samaan, D. Economics of artificial intelligence: Implications for the future of work. *IZA J. Labor Policy* **2019**, *9*. [CrossRef]
41. Buchanan, B.G. A (Very) Brief History of Artificial Intelligence. *AI Mag.* **2005**, *53*. [CrossRef]
42. Aryal, A.; Becerik-Gerber, B.; Anselmo, F.; Roll, S.C.; Lucas, G.M. Smart desks to promote comfort, health, and productivity in offices: A vision for future workplaces. *Front. Built Environ.* **2019**, *5*, 76. [CrossRef]
43. Hammarberg, K.; Kirkman, M.; De Lacey, S. Qualitative research methods: When to use them and how to judge them. *Hum. Reprod.* **2016**, *31*, 498–501. [CrossRef]
44. Kamberelis, G.; Dimitriadis, G. Focus groups: Contingent articulations of pedagogy, politics, and inquiry. The Sage handbook of qualitative research. *SAGE Handb. Qual. Res.* **2011**, *4*, 545–563.
45. Kamberelis, G.; Dimitriadis, G. *Focus Groups*; Routledge: Abingdon, UK, 2013; ISBN 9781135069629.
46. Malterud, K. Systematic text condensation: A strategy for qualitative analysis. *Scand. J. Public Health* **2012**, *40*, 795–805. [CrossRef]
47. Maykut, P. *Beginning Qualitative Research*; Routledge: Abingdon, UK, 2002.
48. Motamedi, S.; Wang, P.; Zhang, T.; Chan, C.Y. Acceptance of full driving automation: Personally owned and shared-use concepts. *Hum. Factors* **2020**, *62*, 288–309. [CrossRef]
49. Lau, J.; Zimmerman, B.; Schaub, F. Alexa, are you listening? Privacy perceptions, concerns and privacy-seeking behaviors with smart speakers. *Proc. ACM Hum. Comput. Interact.* **2018**, *2*, 1–31. [CrossRef]
50. Mark, G.; Iqbal, S.; Czerwinski, M.; Johns, P. Focused, aroused, but so distractible: A temporal perspective on multitasking and communications. In *Proceedings of the 2015 ACM International Conference on Computer-Supported Cooperative Work and Social Computing*; Association for Computing Machinery, Inc.: New York, NY, USA, 2015; pp. 903–916.
51. Bordi, L.; Okkonen, J.; Mäkiniemi, J.P.; Heikkilä-Tammi, K. Communication in the digital work environment: Implications for wellbeing at work. *Nord. J. Work. Life Stud.* **2018**, *8*, 29–48. [CrossRef]
52. Cha, S.H.; Seo, J.; Baek, S.H.; Koo, C. Towards a well-planned, activity-based work environment: Automated recognition of office activities using accelerometers. *Build. Environ.* **2018**, *144*, 86–93. [CrossRef]
53. Vrigkas, M.; Nikou, C.; Kakadiaris, I.A. A review of human activity recognition methods. *Front. Robot. AI* **2015**, *2*, 28. [CrossRef]
54. Dickie, V.; Cutchin, M.P.; Humphry, R. Occupation as transactional experience: A critique of individualism in occupational science. *J. Occup. Sci.* **2006**, *13*, 83–93. [CrossRef]
55. Aldrich, R.M. From complexity theory to transactionalism: Moving occupational science forward in theorizing the complexities of behavior. *J. Occup. Sci.* **2008**, *15*, 147–156. [CrossRef]
56. Nielsen, K.; Nielsen, M.B.; Ogbonnaya, C.; Känsälä, M.; Saari, E.; Isaksson, K. Workplace resources to improve both employee well-being and performance: A systematic review and meta-analysis. *Work Stress* **2017**, *31*, 101–120. [CrossRef]
57. Tientcheu, S.I.N.; Chowdhury, S.P.; Olwal, T.O. Intelligent energy management strategy for automated office buildings. *Energies* **2019**, *12*, 4326. [CrossRef]
58. Von Neida, B.; Maniccia, D.; Tweed, A. An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems. *J. Illum. Eng. Soc.* **2001**, *30*, 111–125. [CrossRef]

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Work Flexibility and Work-Related Well-Being

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Abstract: Work organization practices, including work flexibility, are changing and can affect worker well-being. Common work flexibility types include working at home, taking time off when needed, and changing one's work schedule. Given the changes in and the importance of work flexibility, the study assesses its prevalence and association with worker well-being in the United States. We used 2002–2018 General Social Survey—Quality of Worklife (GSS-QWL) data, descriptive statistics, and regression analyses to assess the reported likelihood of job stress, job satisfaction, healthy days, and days with activity limitations among workers reporting work flexibility. The prevalence of work flexibility remained relatively stable during the period examined. Working at home increased the likelihood of job stress by 22% and job satisfaction by 65%. Taking time off decreased the likelihood of job stress by 56% and days with activity limitations by 24%, and more than doubled the likelihood of job satisfaction. Changing one's schedule decreased the likelihood of job stress by 20% and increased the likelihood of job satisfaction by 62%. This study used all the available data from GSS-QWL and demonstrated the ongoing importance of work flexibility for well-being.

Keywords: future of work; healthy work design and well-being; work organization; work arrangements; demographic shifts; compensation and benefits; occupational stress

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1. Introduction

Work organization practices, including non-standard work arrangements, flexible schedules, and the use of technology and automation, are going through substantial changes globally [1–4]. In addition, the demographic, technological, and economic changes that have been molding the ways work is organized seem more pronounced than in the immediate past [5,6]. In recent years, the US working population has aged, and gender gaps in labor force participation are slowly being bridged, with women joining the workforce in large numbers [5,7]. During the past year, the gap in women's labor force participation increased, but it is not clear yet if the gap will persist [8]. These trends, combined with technological advancements that accommodate rapid reductions in certain types of economic transaction costs such as labor productivity monitoring costs, have altered organizational practices, including work flexibility [2,9].

While there is no standard definition of work flexibility [10], it often includes characteristics in terms of how, where, when, and for how long work is done [10–13], and it has been a priority need for some workers and employers alike [14]. The three most common types of flexibility available to US workers are the ability to: change work location; take time off; and change their work hours [10–15].

Work flexibility can have positive and negative consequences for workers and their families, employers, and society overall [15–28]. Work flexibility accommodates workers by enabling them to allocate resources between work and non-work domains according to their preferences [9–15]. For example, workers with access to flexible work schedules can ease some of the chronic time pressures and conflicts imposed by their non-work responsibilities. Workers seek flexibility to address their personal and family needs, including childcare,

eldercare, schooling, and healthcare [14]. The available evidence supports that work flexibility in terms of location [17] and work hours [19] gives workers some sense of job control, improves their engagement, and increases their job satisfaction, thereby improving their health and well-being [17–19]. Bond and Galinsky [2011] found that both high- and low-wage workers valued work flexibility in terms of work schedule, and that flexibility was a statistically significant contributor to job engagement and job satisfaction [23]. Golden (2008) found that flexibility was positively related to happiness [24]. Using US data from the General Social Survey (GSS), that study found that the contribution of flexibility in terms of control over schedule on happiness was higher for wage workers compared to salaried workers. Kim et al. (2020) used 2002–2014 GSS data to examine the associations between flexibility, measured with flexible schedules and working at home, and worker well-being, measured with job satisfaction, job stress, daily fatigue, and work-to-family conflict. The authors found benefits of flexible schedules and some benefits of working at home, even though working at home to catch up on work had disadvantages for worker well-being. The authors concluded that there were potential advantages and unintended consequences of different flexibility arrangements for workers, and that these implications might differ by gender [25]. Additional available evidence supports that some of the work–family conflicts associated with contingent work can be outweighed by the benefits of work schedule flexibility [16], but also that the blurring of work and non-work life boundaries can have negative consequences for workers and their families [20].

Employers also benefit from more productive and engaged workers [19,21,22], and work flexibility increases engagement, as mentioned above. From society's perspective, flexibility, especially location flexibility, can accommodate short- or long-term operational continuity if workplace closures become necessary.

Despite the importance of work flexibility for both workers and employers, the understanding of its prevalence over the years remains limited. A 2016 survey of 920 employers with 50 or more employees [26] found that, between 2012 and 2016, only 4 of 18 types of flexibility examined statistically significantly changed. These four types of flexibility, expressed as the percentage of employers allowing at least some employees access to them, included: returning to work gradually after childbirth or adoption (increased from 73% in 2012 to 81% in 2016); receiving special consideration after a career break for personal or family responsibilities (increased from 21% in 2012 to 28% in 2016); working some of their regular paid hours at home on a regular basis (increased from 33% in 2012 to 40% in 2016) and taking time off during the workday to attend to important family or personal needs without loss of pay (decreased from 87% in 2012 to 81% in 2016). The change in the percentage of employers allowing at least some employees to change starting and finishing times on a daily basis was not statistically significant during the same time period (increased from 39% in 2012 to 42% in 2016). Data from the Bureau of Labor Statistics (BLS) American Time Use Survey (ATUS) show an upward trend in flexibility in terms of access to working at home and access to flexibility in schedules. In 2003 and 2007, 18.6% and 19.9% worked at home, respectively [29]. According to the 2017–2018 ATUS, 28.8% of workers could work at home and 24.8% did work at home [30]. Note, however, that survey questions have changed over time and pre- and post-2017 data are not fully comparable [31]. Fifty-six percent of workers were able to adjust their work schedules or location of their main jobs instead of taking time off from work in 2011 [32]. During 2017–2018, 57% of wage and salary workers had a flexible schedule, in which they were able to vary the times they began and stopped working [33]. In 2020, paid sick leave was available to 78% of all workers [34], an improvement compared to 2011(55%) [35]. It is evident from the information presented above that there is a growing interest in studying work flexibility, particularly in terms of its contribution towards overall worker well-being.

The purpose of this study is to understand flexibility trends in the US and its association with well-being. This study examined the following research questions: (1) What are the trends of flexibility over time (using descriptive analysis)? (2) What are the population prevalence rates by flexibility indicators and selected demographic and socioeconomic

characteristics (using descriptive analyses)? (3) What are the well-being outcomes of flexibility (using logistic and zero-inflated negative binomial regressions, and controlling for covariates)? The study used US data from GSS—Quality of Worklife (QWL) to assess the prevalence of work flexibility and its association with worker well-being. This research advances the understanding of work flexibility and its effects in several ways, including by expanding on the findings by Kim et al. (2020). We used more years of GSS-QWL data than previous studies. We included three indicators of flexibility: (i) ability to work at home (location flexibility), (ii) ability to take time off for family needs (leave flexibility), and (iii) ability to change starting and finishing times (schedule flexibility). We used four indicators of well-being, including (i) job stress, (ii) job satisfaction, (iii) number of healthy days during the previous thirty days, and (iv) number of days with activity limitations due to poor health in the last thirty days. In addition, this study used descriptive statistics on flexibility by year, demographic and socioeconomic characteristics, industry, work arrangement, and four indicators of well-being.

The sections that follow present materials and methods, results, discussion including limitations, and conclusion.

2. Materials and Methods

2.1. Data

As mentioned earlier, this study used GSS-QWL data (for details, see NIOSH 2013 [36]). Funded by the National Science Foundation, GSS is a biannual, nationally representative cross-sectional survey of US households conducted through face-to-face personal interviews by the National Opinion Research Center (NORC). GSS utilizes a multistage probability design yielding a representative sample of the civilian, non-institutionalized, English-speaking, US adult population [37]. Developed by the National Institute for Occupational Safety and Health (NIOSH) with contributions by its partners, the QWL module assesses an array of psychosocial working conditions, such as job demands and autonomy [37], and quality of worklife topics among GSS respondents who are either employed or looking for work at the time of the survey. The QWL module is administered every four years.

This study used GSS-QWL data for all currently available years, including 2002, 2006, 2010, 2014, and 2018. We used weights provided by GSS-QWL, so that the data represent the US working population. This is important because we assess the prevalence of flexibility practices across the years. For the regression analysis, we used pooled data from all five years.

We used GSS-QWL responses from only those who reported being employed at the time of the survey. After adjusting for sampling probabilities, including subsampling for non-respondents (approximately 70% response rate each survey year) and correcting for the number of adults in the household, the nationally representative sample we used in our analyses consisted of approximately 7400 observations distributed more or less evenly across the five years.

2.1.1. Indicators of Flexibility

We assessed work flexibility using location, leave, and schedule flexibility variables. We measured location flexibility by the frequency of working at home according to responses to the question: *How often do you work at home as part of your job?* Due to the analytical approach we followed, we converted the 6-point Likert scale responses, as well as all other Likert scale responses to questions we used in this study, into a dichotomous variable, following Grosch et al. (2006) and Ray et al. (2017): "work at home" for responses always, more than once a week, and about once a week, and "do not work at home" for responses once a month, a few times a year, and never [37,38]. We measured leave flexibility according to responses to the question: *How hard is it to take time off during your work to take care of personal or family matters?* We converted the 4-point Likert scale responses into a dichotomous variable: "take time off" for responses not at all hard and not too hard, and

"do not take time off" for responses somewhat hard and very hard. We assessed schedule flexibility according to responses to the question: *How often are you allowed to change your starting and quitting times on a daily basis?* We converted the 4-point Likert scale responses into a dichotomous variable: "change schedule" for responses often and sometimes, and "do not change schedule" for responses rarely and never. This question was not included in the 2018 QWL module, resulting in fewer available observations.

2.1.2. Indicators of Well-Being

We measured job stress using responses to the question: *How stressful is your work?* We converted the 5-point Likert scale responses into: "stressed" for responses always and often, and "not stressed" for responses sometimes, rarely, and never. We measured job satisfaction according to responses to the question: *All in all, how satisfied would you say you are with your job?* We converted the 4-point Likert scale responses into: "satisfied" if very satisfied and somewhat satisfied, and "not satisfied" if not too satisfied and not at all satisfied.

We also used three items from GSS-QWL that assess the Centers for Disease Control and Prevention (CDC) Health-related Quality of Life (HRQOL)-4 index. Developed in the 1980s, the HRQOL-4 has been used to derive metrics for government-wide initiatives such as Healthy People 2010 and 2020 [39] and assess the health status of the US population both at the national and state levels. Variables from the HRQOL-4 have been used in national-level surveys such as CDC's Behavioral Risk Factor Surveillance System and the National Health and Nutrition Examination Survey. The four core questions from the HRQOL-4 were: (1) *Would you say that in general, your health is excellent, very good, good, fair, or poor?*; (2) *Now thinking about your physical health, which includes physical illness and injury, for how many days during the past 30 days was your physical health not good?*; (3) *Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?*; and (4) *During the past 30 days, for about how many days did poor physical or mental health keep you from doing your usual activities, such as self-care, work, or recreation?* Out of the responses to these four questions, we used responses to the first one as a covariate to control for the overall health status of the respondent. We converted Likert scale responses to dichotomous: "health status good" for excellent, very good, and good, and "health status not good" for fair and poor health status. To measure healthy days, one of our well-being outcome variables, we used responses to questions 2 and 3. We added the number of days reported in responses to these questions to estimate the number of days within the previous 30 days for which a respondent was not in good physical and mental health. If the sum exceeded 30 days, we recorded 30 days. The sum of these "unhealthy days" when subtracted from the overall last 30 days, produces the reported number of "healthy days" by a respondent during this period. This construct of healthy days, although simple, has been tested for construct validity, concurrent validity, and HRQL predictive validity [40]. We used responses to question 4 to estimate "days with activity limitations".

2.1.3. Other Indicators of Interest

This study assessed flexibility practices by industry by grouping respondents into ten broad industries based on broadly defined National Occupational Research Agenda (NORA) industrial sectors (for more information, see CDC 2018B [41]).

In order to assess flexibility practices across different work arrangements, we distributed the study sample into five mutually exclusive groups based on responses to the question: *How would you describe your employment arrangement in your main job?* Response categories were: (1) independent contractor/independent consultant/freelance worker (contractor), (2) on-call worker/works only when called (on-call), (3) paid by temporary agency (temporary), (4) working for a contractor who provides workers and services to others under contract (under contract), and (5) regular permanent employee (standard). We

estimated the number and proportion of workers in each arrangement category according to their responses to the flexibility questions, as described above.

The available evidence supports that family–work interference is associated with job stress [42]. To control for spilling over of "outside work" stress on stress at work, we controlled for responses to the family–work interference question: *How often do the demands of your family interfere with your work on the job?* We converted the 4-point Likert scale responses into a dichotomous variable: "Family interferes with work" for responses frequently and sometimes, and "family does not interfere with work" for responses rarely and never.

In the GSS-QWL, respondents are asked whether they consider their work part-time or full-time. Approximately 17% of our sample responded working part-time. We found that, compared with full-time workers, part-time workers had higher flexibility in terms of being able to take time off and change their schedules, but had lower flexibility in terms of working at home. The difference was statistically significant for the ability to take time off. In terms of the well-being variables we examined, we found that part-time workers reported being less stressed. In this study, our objective was to assess whether flexibility was associated with well-being. We assumed that the effect of part- and full-time work was endogenous through the flexibility itself in measuring the effect on job stress. To check our assumption, we included working part-time as a covariate in our regression analyses of the effect of flexibility variables on job stress and found no statistically significant changes in our estimated odds ratios. Hence, we did not include the variable in our current analysis. However, we controlled for hours worked per week. The GSS asks respondents about their usual number of work hours in a week. We used that as a control variable.

2.2. Analyses

2.2.1. Descriptive Analyses

We conducted descriptive analyses to assess: (1) trends of flexibility over time; (2) population prevalence rates by flexibility indicators and selected demographic and socioeconomic characteristics (age, sex, race and ethnicity, education, family income, health status, marital status, family-work interference, and hours worked per week); (3) well-being outcomes (job stress, job satisfaction, healthy days, and days with activity limitations); (4) flexibility by NORA sector; and (5) flexibility by work arrangement.

2.2.2. Regression Analyses

Next, we assessed the impact of individual work flexibility variables on work-related well-being variables using several regression models and controlling for age, sex, race and ethnicity, education, family income, health status, marital status, family–work interference, and hours worked per week. We used two types of regression analyses depending on the nature of the dependent variable: for categorical outcome variables such as job stress and job satisfaction, we used logistic models; for the healthy days and days with activity limitations, which are count variables, we used zero-inflated negative binomial models as described below. Age and the logarithmic transformation of family income were continuous variables, education was a categorical variable (1–7 years of school, 8 years of school, 9–11 years of school, high school graduate, 13–15 years of school, bachelor's degree, postgraduate), and the rest of the variables were dichotomous. The reference group for sex was "male", for race and ethnicity "non-Hispanic White", for health status "not good", for marital status "married and living with spouse", and for family–work interference "family does not interfere with work".

Logistic regressions: We estimated the effect of flexibility variables on job stress and job satisfaction, controlling for the covariates mentioned above. Previous studies showed that the demographic variables we included might contribute to stress and affect physical and mental health [23–25]. Previous studies also showed the importance of work–family conflict for stress [27,28]. As the objective of this study was to assess how work flexibility was associated with job stress and satisfaction, we did not control for specific psychosocial

working conditions separately in the regression analysis. We acknowledge that there will be direct and indirect effects on job stress and satisfaction through stressful psychosocial working conditions such as job demand and control.

Zero-inflated negative binomial regressions: Following Zhou et al. (2014), we used zero-inflated negative binomial two-part models to estimate the effect of flexibility on healthy days and activity limitations, controlling for the covariates mentioned above [43]. As many study participants may have a zero count of healthy days or days with activity limitations, the data are not normally distributed, and the positive skew in their distribution cannot be resolved by data transformation. The zero-inflated negative binomial model provides a way of modeling the excess number of zeros as well as allowing for count data that are skewed and over-dispersed. It is a two-part model that combines the logistic regression model and the negative binomial model. The first part, logistic regression for excess zeros, predicts the probability of having excess zero unhealthy days or days with activity limitations. The second part, negative binomial regression for the full range of counts, including random zeros, predicts the frequency of the unhealthy day or day with activity limitation count. Incidence rate ratios (IRRs) derived from the coefficients of the negative binomial random effects regression model can be interpreted in a way similar to interpreting odds ratios.

3. Results

3.1. Descriptive Analyses

Overall, the prevalence of work flexibility changed minimally during 2002–2018. The ability to work at home increased from 2002 (29%) to 2018 (33%) and the percentage of workers working at home remained almost the same from 2010 onwards. In comparison, the ability to take time off increased from 2010 (72%) to 2018 (74%), and the ability to change one's schedule increased from 2010 (52%) to 2014 (55%). This is shown in Figure 1.

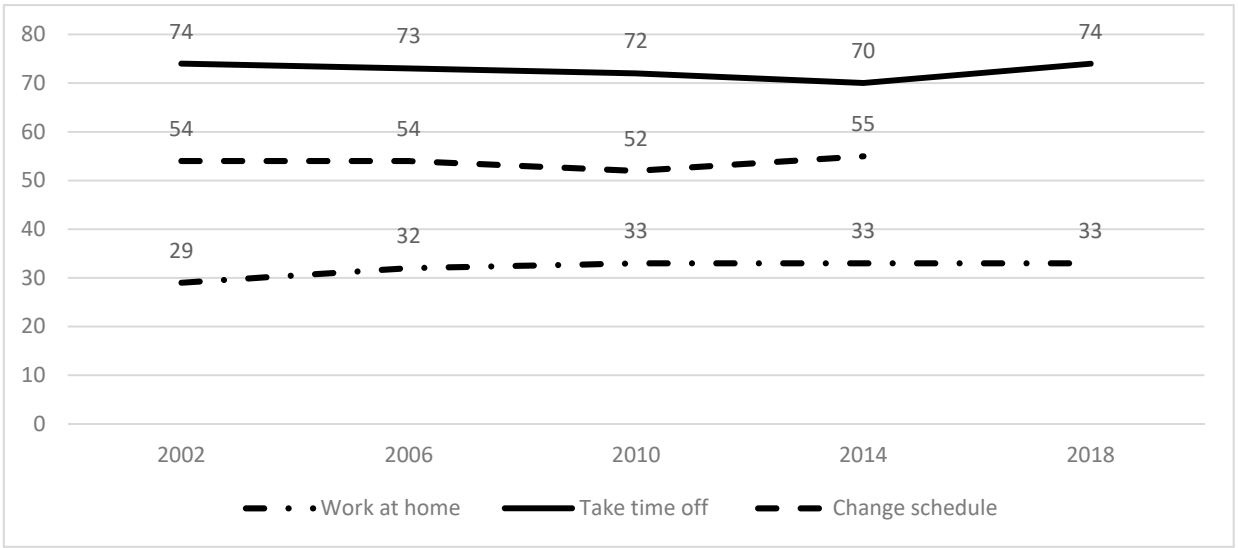


Figure 1. Prevalence of work flexibility over time (%), GSS-QWL data, 2002–2018.

Table 1 presents the prevalence of work flexibility by demographic and socioeconomic characteristics within the study population and several work flexibility indicators. Women accounted for 51.7% of the respondents. Among those who worked at home, 48.9% were women. In addition, 50.8%, and 48.8%, respectively, of those who reported being able to take time off and change their schedule were women. Hispanics accounted for 10.6% of all respondents, and 7.4%, 9.7%, and 8.4%, respectively, of the respondents reporting being able to work at home, take time off, and change their schedule. Among the respondents who answered the question on race and ethnicity, 66.0% were non-Hispanic Whites, and among

those with location, time, and schedule flexibility, 75.9%, 67.5%, and 74.0%, respectively, were non-Hispanic Whites. The percentage of those reporting that they were able to work at home increased with increasing levels of education, starting after 8 years of school. The pattern was less straightforward for the ability to take time off and change one's schedule by level of education, with the percentages increasing after 8 years of school and decreasing after 15 years of school. Similar patterns were observed for family income categories, with flexibility increasing with income up to USD 50,000, then decreasing, and finally increasing again for income above USD 75,000. Those who were married and living with their spouse accounted for 47.3% of those who responded to the marital status question but reported more access to location, time, and schedule flexibility than those who were not married and living with their spouse (56%, 48.4%, and 51.4%, respectively). Of those who responded to the family interference question, 28.7% indicated that family interfered with work, and 66.1% of those who worked at home, 43.0% of those who took time off, and 60.0% of those who changed their schedule, respectively, reported that family interfered with work. Finally, of those who responded to the hours worked per week question, those who reported working at home worked a mean of 43.5 h and those who took time off a mean of 40.4 h.

Table 1. Flexibility by demographic and socioeconomic characteristics, pooled GSS-QWL data.

Demographic Characteristics	Flexibility Indicators (% in Columns)			All (% in Column)
	Work at Home	Take Time off	Change Schedule	
Age (significance)	***	***	***	
Mean	46.0	43.5	43.8	42.8
Total	2325	5298	3188	7315
Sex (significance)	*	**	***	
Female	(48.9)	(50.8)	(48.8)	(51.7)
Total	2335	5310	3196	7339
Race and ethnicity (significance)	***	***	***	
Hispanic	(7.4)	(9.7)	(8.4)	(10.6)
Non-Hispanic				
White	(75.9)	(67.5)	(74.0)	(66.0)
Black	(7.5)	(13.3)	(8.6)	(13.1)
Asian or Pacific Islander	(5.3)	(6.4)	(5.8)	(07.0)
Multiracial	(3.7)	(2.6)	(2.8)	(02.7)
American Indian or Alaskan Native	(0.3)	(0.5)	(0.4)	(0.5)
Total	2320	5285	3182	7302
Education (significance)	***	***	***	
1–7 years of school	(0.8)	(1.2)	(1.2)	(1.4)
8 years of school	(0.7)	(0.9)	(0.8)	(1.0)
9–11 years of school	(3.4)	(7.3)	(5.7)	(7.8)
High school graduate	(15.5)	(25.4)	(21.7)	(25.5)
13–15 years of school	(23.0)	(29.7)	(28.9)	(29.9)
Bachelor's degree	(27.1)	(19.9)	(22.9)	(18.8)
Postgraduate	(29.9)	(15.6)	(18.7)	(15.6)
Total	2333	5305	3192	7329
Family Income (significance)	***	***	***	
USD 10,000 or less	(4.0)	(6.6)	(5.4)	(7.0)
USD 10,001–25,000	(10.0)	(18.5)	(15.0)	(19.0)
USD 25,001–50,000	(25.0)	(31.0)	(29.0)	(32.0)
USD 50,001–75,000	(24.0)	(20.0)	(21.0)	(19.0)
USD 75,000 and above	(37.0)	(25.0)	(30.0)	(23.0)
Total	2153	4886	2911	6757
Health status (significance)	**	***	**	
Overall health good	(87.9)	(87.4)	(88.2)	(86.1)
Total	2321	5303	3191	7319

Table 1. *Cont.*

Demographic Characteristics	Flexibility Indicators (% in Columns)			All (% in Column)
	Work at Home	Take Time off	Change Schedule	
Marital status (significance)	***	***	***	
Married and living with spouse	(56.6)	(48.4)	(51.4)	(47.3)
Total	2333	5309	3195	7337
Family-work interference (significance)	***	**	***	
Family interferes with work	(66.1)	(43.0)	(60.0)	(28.7)
Total	2312	5306	3182	7312
Hours worked per week (significance)	***	***	-	
Mean	43.5	40.4	42.0	42
Total	2335	5310	3196	7315

Note: *, **, and ***, respectively, denote statistical significance at the 10%, 5%, and 1% level.

Table 2 presents descriptive results for well-being by flexibility indicator. While 31.1% of respondents to the job stress question reported being stressed, 36.0% of those who responded working at home reported job stress. Of those who responded to the job satisfaction question, 89.8% reported being satisfied and at least 92.3% of those who had any type of flexibility reported being satisfied. Overall, more respondents had the ability to take time off, followed by those who could change their schedule, then those who had the ability to work at home. In terms of healthy days and days with activity limitations, there were small differences across flexibility types.

Table 2. Well-being by flexibility indicator, pooled GSS-QWL data.

Well-Being Indicators	Flexibility Indicators (% in Columns)			All (% in Columns)
	Work at Home	Take Time off	Change Schedule	
Job stress (significance)	***	***	-	
Stressed	(36.0)	(25.3)	(30.4)	(31.1)
Total	2318	5300	3188	7311
Job satisfaction (significance)	***	***	***	
Satisfied	(94.4)	(92.3)	(92.3)	(89.8)
Total	2318	5299	3187	7309
Number of days in good physical health (significance)	-	***	-	
Mean	27.3	27.7	27.5	27.4
Total	2314	5292	3184	7297
Number of days in good mental health (significance)	-	***	-	
Mean	26.8	27.0	26.7	26.5
Total	2320	5279	3176	7281
Healthy days (significance)	-	***	-	
Mean	24.4	24.9	24.5	24.2
Total	2314	5279	3176	7281
Number of days with activity limitations (significance)	-	***	-	
Mean	1.4	1.2	1.3	1.4
Total	2318	5293	3184	7299

Note: *** denotes statistical significance at the 1% level.

Table 3 presents results on flexibility by NORA sector. There was no single sector that dominated over the others across all the types of flexibility. Even though results by sector were not significant in terms of flexibility, we examined them to address NIOSH research priorities. Within sectors, the highest percentage reporting working at home were in agriculture, forestry, and fishing, followed by services; taking time off in construction followed by services; and changing their schedule in construction and agriculture, forestry, and fishing. Sectors in which workers reported having the least ability to work at home included mining (10.5%) and oil and gas extraction (11.1%), in which workers also re-

ported having the lowest ability to change their schedule (16.7%). Across sectors, services accounted for 46.4% of those who responded to the question on sectors.

Table 3. Flexibility by NORA industry sector, pooled GSS-QWL data.

NORA Sector	Flexibility % in Rows			All % in Column
	Work at Home	Take Time Off	Change Schedule	
Agriculture, forestry, and fishing	53.2	72.7	68.8	1.0
Construction	27.5	76.3	70.7	7.0
Healthcare and social assistance	19.8	70.4	50.3	14.0
Manufacturing	19.6	74.4	47.6	11.0
Mining	10.5	73.7	63.6	0.3
Oil and gas extraction	11.1	66.7	16.7	0.1
Public safety	11.3	68.8	35.5	2.2
Services	32.6	74.0	57.7	46.4
Transportation, warehousing, and utilities	13.0	67.6	45.0	6.2
Wholesale and retail trade	19.0	71.2	53.1	12.2
All sectors	25.8	72.8	54.3	100
Total (numbers in columns)	7176	7142	5765	7176

Table 4 presents results on flexibility by work arrangement. Compared to those in other work arrangements, contractors reported the highest percentages for all flexibility indicators. A higher percentage of on-call workers reported being able to change their schedule, but a lower percentage of those workers reported being able to work at home than those in standard arrangements. Those working for temporary help agencies reported the lowest percentages of ability to work at home (0.2%), take time off (65.8%), and change their schedule (33.9%).

Table 4. Flexibility by work arrangement, pooled GSS-QWL data.

Work Arrangement	Flexibility % in Rows			All % in Column
	Work at Home	Take Time Off	Change Schedule	
Significance	***	-	***	
Contractor	64.3	76.0	81.2	13.7
On call	21.7	72.3	55.8	2.8
Temporary	0.2	65.8	33.9	1.1
Under contract	27.2	69.1	54.1	3.0
Standard	26.8	72.4	49.4	79.4
Total (numbers in column)	2309	5286	3176	7293

Note: *** denotes statistical significance at the 1% level.

3.2. Regression Analyses

Tables 5–7 report results on the associations between flexibility and well-being indicators. The first two columns of each table include findings for reported job stress and job satisfaction expressed as odds ratios. The next two columns of results include findings for reported healthy days and days with activity limitations expressed as incidence rate ratios (IRRs).

Table 5. Ability to work at home and well-being, pooled GSS-QWL data.

	Job Stress Odds Ratio	Job Satisfaction Odds Ratio	Healthy Days IRR	Days with Activity Limitations IRR
Work at home	1.22 ***	1.65 ***	0.99 **	1.09
	1.08–1.37	1.33–2.04	0.97–1.00	0.90–1.30
Age	0.99 ***	1.03 ***	1.00 ***	1.00
	0.98–0.99	1.02–1.03	1.00–1.00	0.99–1.00
Sex [A]	1.38 ***	1.15	0.95 ***	1.12
	1.23–1.54	0.92–1.30	0.94–0.97	0.95–1.32
Race and ethnicity [B]				
Hispanic	0.68 ***	1.22	1.05 ***	0.61 **
	0.56–0.82	0.93–1.60	1.03–1.06	0.43–0.87
Black	0.60 ***	0.96	1.04 ***	1.15
	0.50–0.72	0.75–1.22	1.02–1.06	0.86–1.52
Native American	0.77	1.44	1.00	0.77
	0.35–1.68	0.44–5.03	0.93–1.08	0.54–1.12
Asian	0.64 **	0.80	1.04 *	0.77
	0.45–0.91	0.49–1.32	1.00–1.09	0.54–1.13
Multiracial	0.99	0.79	0.97 **	1.12
	0.81–1.22	0.59–1.05	0.94–0.99	0.89–1.41
Education	1.05 **	1.05	1.00	0.91 **
	1.00–1.19	0.98–1.12	0.99–1.00	0.85–0.99
Family income	1.105	1.22 ***	1.01 ***	1.00
	0.97–1.12	1.11–1.35	1.01–1.02	0.91–1.10
Health status [C]	0.64 ***	2.19 ***	1.16 ***	0.50 ***
	0.55–0.74	1.80–2.68	1.14–1.18	0.42–0.60
Marital status [D]	1.05 *	0.95 *	0.99 **	1.04
	1.01–1.08	0.89–0.99	0.99–0.99	0.99–1.08
Family-work interference [E]	1.38 ***	0.83 ***	0.98 ***	1.09 *
	1.30–1.47	0.75–0.91	0.97–0.98	1.02–1.19
Hours worked per week	1.03 ***	1.01 ***	1.00 *	1.11 **
	1.02–1.03	1.00–1.02	1.00–1.00	1.01–1.23
Constant	0.06 ***	0.14 ***	21.03 ***	8.37 ***
	0.02–0.13	0.05–0.41	19.01–23.25	2.70– 25.90

Notes: *, **, and ***, respectively, denote statistical significance at the 10%, 5%, and 1% level; [A]: reference group male; [B]: reference group non-Hispanic White; [C]: reference group not good health; [D]: reference group not married and living with spouse; [E]: reference group no family-work interference.

Table 5 presents the results for the ability to work at home. Working at home was associated with a 22% increase in job stress and a 65% increase in job satisfaction. Women were 38% more likely to report job stress and 5% less likely to report healthy days than men. Hispanic workers were 32% less likely to report job stress, 5% more likely to report healthy days, and 39% less likely to report days with activity limitations than non-Hispanic Whites. Black workers were 40% less likely to report job stress and 4% more likely to report healthy days, and Asian workers were 36% less likely to report less job stress and 4% more likely to report healthy days than non-Hispanic Whites. The likelihood of reported job satisfaction increased with family income, while the likelihood of reported healthy days increased and the likelihood of reported days with activity limitations decreased. The odds of job stress decreased by 36%, and the odds of job satisfaction increased more than two times as health status increased. Higher health status was associated with a 16% increase in healthy days and a 50% decrease in days with activity limitations. Being married and living with a spouse was associated with a 5% increase in job stress, a 5% decrease in job satisfaction, and a 1% decreased in the likelihood of reporting healthy days. For those reporting that family interfered with work, the likelihood of reporting job stress increased by 35%, job satisfaction decreased by 17%, heathy days decreased by 2%, and days with activity limitations increased by 9%. More hours worked were associated with a 3% increase in job stress, and 1% increase of job satisfaction, and an 11% increase in days with activity limitations.

Table 6. Ability to take time off and well-being, pooled GSS-QWL data.

	Job Stress Odds Ratio	Job Satisfaction Odds Ratio	Healthy Days IRR	Days with Activity Limitations IRR
Take time off	0.44 ***	2.15 ***	1.02 ***	0.76 ***
	0.39–0.50	1.81–2.55	1.01–1.04	0.63–0.92
Age	0.99 ***	1.03 ***	1.00 ***	1.00
	0.99–0.99	1.02–1.03	1.00–1.00	0.99–1.00
Sex [A]	1.31 ***	1.13	0.96 ***	1.09
	1.17–1.47	0.95–1.34	0.94–0.97	0.92–1.29
Race and ethnicity [B]				
Hispanic	0.65 ***	1.27 *	1.05 ***	0.61 ***
	0.53–0.78	0.96–1.67	1.03–1.07	0.44- 0.89
Black	0.60 ***	0.92	1.04 ***	1.16
	0.50–0.72	0.72–1.18	1.02 - 1.06	0.87–1.55
Native American	0.76	1.45	1.00	0.81
	0.34–1.68	0.43–4.92	0.93–1.08	0.31–2.13
Asian	0.57 **	0.87	1.04 **	0.78
	0.42–0.86	0.53–1.45	1.00–1.07	0.54 -1.12
Multiracial	0.95	0.81	0.97 **	1.13
	0.76–1.16	0.61–1.09	0.95–0.99	0.89–1.43
Education	1.09 ***	1.08 *	0.99	0.93 **
	1.04–1.14	1.01–1.16	0.99–1.00	0.86–0.99
Family income	1.08 **	1.21 ***	1.01 **	1.01
	1.01 –1.16	1.10–1.33	1.00–1.02	0.92–1.11
Health status [C]	0.64 ***	2.09 ***	1.17 ***	0.53 ***
	0.55–0.76	1.71–2.55	1.14–1.22	0.44–0.63
Marital status [D]	1.03 *	0.94 **	0.99 ***	1.03
	0.99–1.07	0.89–0.99	0.99–1.00	0.97–1.08
Family-work interference [E]	1.32 ***	0.89 *	0.98 ***	1.11 **
	1.24–1.41	0.80–0.97	0.97–0.98	1.00–1.22
Hours worked per week	1.02 ***	1.01 ***	1.00 **	0.99 ***
	1.02–1.03	1.01–1.02	1.00–1.00	0.99–0.99
Constant	0.07 ***	0.69 ***	20.91 ***	9.61 ***
	0.03–0.16	0.02–0.21	18.91–23.12	3.03–30.56

Note: *, **, and ***, respectively, denote statistical significance at the 10%, 5%, and 1% level. [A]: reference group male; [B]: reference group non-Hispanic White; [C]: reference group not good health; [D]: reference group not married and living with spouse; [E]: reference group no family-work interference.

Table 6 shows the results for the ability to take time off. Taking time off decreased the reported likelihood of job stress by 56%, more than doubled the reported likelihood of job satisfaction, increased the reported likelihood of healthy days by 2%, and decreased the reported likelihood of days with activity limitations by 24%. Women were 31% more likely to report job stress than men, 4% less likely to report healthy days, and 9% more likely to report days with activity limitations than men. Hispanics and non-Hispanic Blacks were less likely to report job stress and more likely to report healthy days compared with non-Hispanic Whites. Increases in education level and family income were associated with an increased likelihood to report job stress, job satisfaction, and healthy days. Hours worked per week did not result in substantial changes in work flexibility.

We report results on the association between the ability to change one's schedule and well-being in Table 7. The ability to change schedule decreased the odds of job stress by 20% and increased the odds of job satisfaction by 62%. Compared to men, the likelihood of women to report job stress increased by 32% and the likelihood of women to report healthy days decreased by 5%. Compared to non-Hispanic Whites, Hispanic and non-Hispanic Black workers who could change their schedule were less likely to report job stress and more likely to report healthy days. Those who could change their schedule reported increases in job stress with increases in education and income and decreases in job stress with improvements in health status. Compared to those who reported their health status was not good, those who reported their health status was good were more than twice as likely to report job satisfaction, more likely to report healthy days, and less likely to report days with activity limitations. Those with family–work interference were more likely to report job stress, healthy days, and days with activity limitations and less likely

to report job satisfaction. Hours worked per week did not result in substantial changes in work flexibility.

Table 7. Ability to change one's schedule and well-being, pooled GSS-QWL data.

	Job Stress Odds Ratio	Job Satisfaction Odds Ratio	Healthy Days IRR	Days with Activity Limitations IRR
Change schedule	0.80 ***	1.62 ***	1.01	0.88
	0.71–0.91	1.33–1.96	0.99–1.02	0.73–1.06
Age	0.99 ***	1.03 ***	1.00 ***	1.00
	0.99–0.99	1.02–1.04	1.00–1.00	0.99–1.01
Sex [A]	1.32 ***	1.06	0.95 ***	1.11
	1.17–1.50	0.88–1.28	0.94– 0.96	0.91–1.34
Race and ethnicity [B]				
Hispanic	0.75 ***	1.10	1.04 **	0.72
	0.61–0.93	0.81–1.49	1.01–1.06	0.47–1.10
Black	0.63 ***	0.84	1.03 ***	1.20
	0.51–0.77	0.64 -1.09	1.01–1.06	0.86–1.66
Native American	0.84	1.83	1.03	0.80
	0.35–1.99	0.42–8.01	0.95–1.11	0.20–3.15
Asian	0.78	0.85	1.04*	0.88
	0.53–1.16	0.48–1.53	1.00– 1.08	0.56–1.37
Multiracial	0.98	0.67 **	0.96 *	1.12
	0.79–1.26	0.49–0.93	0.93–0.99	0.83–1.50
Education	1.09 ***	1.06	1.00	0.92 **
	1.04–1.15	0.98–1.14	0.99–1.01	0.85–1.00
Family income	1.04	1.25 ***	1.01 ***	1.01
	0.96–1.22	1.12–1.38	1.01–1.02	0.91–1.13
Health status [C]	0.58 ***	2.14 ***	1.18 ***	0.52 ***
	0.49–0.70	1.70–2.68	1.14–1.22	0.42–0.64
Marital status [D]	1.02	0.96	0.99 **	1.05
	0.98–1.06	0.90–1.02	0.99–0.99	0.98–1.11
Family-work interference [E]	1.41 ***	0.80 ***	0.97 ***	1.13 **
	1.31–1.51	0.73–0.89	0.97–0.98	1.02–1.26
Hours worked per week	1.03 ***	1.01 ***	1.00	0.99 ***
	1.02–1.03	1.01–1.02	0.99–1.00	0.99–1.00
Constant	0.05 ***	0.10 ***	21.67 ***	6.03 ***
	0.02–0.14	0.03–0.30	19.82–23.70	1.65–22.03

Note: *, **, and ***, respectively, denote statistical significance at the 10%, 5%, and 1% level. [A]: reference group male; [B]: reference group non-Hispanic White; [C]: reference group not good health; [D]: reference group not married and living with spouse; [E]: reference group no family-work interference.

4. Discussion

As far as we know, this is one of very few studies that examined work flexibility defined as ability to work at home, take time off, and change schedule using GSS-QWL data from all the available years, and the first study to assess the relationship of HRQL and perceived flexibility indicators. Our results demonstrated several statistically significant associations among work flexibility and well-being indicators and can inform the well-being outcomes of the ongoing changes in the workplace, work, and workforce [44]. For example, continued changes in work organization practices and work arrangements are increasingly affecting the workplace, technological advances increasingly affect how work is conducted, and changes in demographics and skills are increasingly impacting the workforce. To understand and address these changes, the NIOSH Future of Work Initiative [45] describes an integrated approach to address worker well-being and prioritize forthcoming future of work research and resulting activities. A recent publication elaborates on the NIOSH perspective on the future of work [46].

We found that the prevalence of all three flexibility indicators we used remained relatively stable over time. In comparison, in the European Union countries, overall work flexibility is increasing [47]. However, the prevalence of work flexibility among countries is not fully comparable because the types of flexible work practices and the extent of their applications vary. Work flexibility is also specific to the culture, economic conditions, and national level work policies [48]. With the exception of a few countries including Sweden, Denmark, and the Netherlands, work practices are more flexible in the United States than

in other developed economies in terms of changes in location and schedule [49]. During the past year, the ability to work remotely increased in the United States. For example, in May 2020, 35.4% of workers teleworked [50]. However, it is hard to predict what the prevalence of telework will be in the longer term.

Our descriptive analyses with pooled data showed that 36% of those who responded they were able to work at home reported job stress. This could reflect the blurred lines between work and home, the perception that workers need to work even harder to prove they earned the right to work remotely, or higher demands in the types of jobs that permit working from home. Findings from the United States and Europe have demonstrated that work flexibility can promote work–family balance, and, in turn, job satisfaction, but it can also intensify work–family conflict by blurring the division between work and non-work domains [25,51,52].

We found that across work arrangements, contractors reported the highest percentages for all flexibility indicators. This is the group that includes independent contractors, consultants, and freelance workers and houses the largest share (67%) of workers in non-standard arrangements. There is evidence that contractors also seem to be better off than workers in other arrangements in terms of reported well-being [38]. Technological advances might add more workers to this category and allow higher levels of work flexibility among contractors. Similar trends are observed in Europe [47]. The prevalence of different types of non-standard work arrangements in the United States seems to be increasing [53]. While understanding of the complexities of newer work arrangements, such as those involving electronically mediated platforms, remains challenging, improved definitions of all work arrangements would help. The importance of work arrangements is recognized by the NIOSH Healthy Work Design and Well-being cross-sector program that includes this topic in its three priority areas [54]. In addition, NIOSH economists and epidemiologists are pursuing the collection of more detailed data on work arrangements by adding related questions in national surveys that clarify the specific elements of these arrangements beyond the broad categories that are currently available in GSS-QWL and other national surveys. This detailed information is organized in a taxonomy [55]. The elements of this taxonomy also include aspects of flexibility examined in this study.

Regression analyses on job stress showed that working at home increased the likelihood of reporting job stress but taking time off and changing one's schedule reduced the odds of job stress. Part of the increase in job stress could be attributed to overwork resulting from taking work home. As we could not account for that in this study, we did not distinguish among those who work at home as part of a contractual agreement versus those who are overworked and have to take work home. The reported odds of job satisfaction increased for all flexibility indicators. These results point to the mixed well-being outcomes associated with work flexibility.

For women in particular, all flexibility indicators were associated with an increased reported likelihood of job stress and days with activity limitations, and a decreased reported likelihood of healthy days. This points to the difference among male and female respondents in terms of healthy days. A recent publication elaborates on these issues [46]. It highlights challenges associated with gender, including that even though women comprised over half of the US workforce in 2018, they continue to face disparities in terms of workplace policies and earnings levels [56]. Working mothers, one of the fastest-growing segments of the US workforce, continue to struggle to balance work and family demands, especially if their earnings are low and their organizational support is low [57–60]. In terms of overall family interference with work, we found that working at home and changing one's schedule increased the reported likelihood of job stress and days with activity limitations and decreased the reported likelihood of job satisfaction and healthy days.

We found that with age, the reported likelihood of job stress decreased, and job satisfaction and healthy days increased. Additionally, work flexibility increases with age. This is welcoming news for the aging workforce. In the future, the multigenerational and aging workforce may face disproportionate challenges in terms of physical and cognitive

health. For example, the proportion of older workers is expected to continue to grow through 2050 [61]. When older workers suffer injuries and illness, their recovery is often slower [62].

We found that family income was associated with an increased reported likelihood of job stress and job satisfaction, pointing to mixed results, as well as a decreased reported likelihood of healthy days and days with activity limitations. Higher paying jobs may be more complex and have higher demands. Additionally, higher family income might imply the presence of a working spouse and higher needs for flexibility. Health status was associated with a decreased reported likelihood of job stress and days with activity limitations, and an increased reported likelihood of job satisfaction and healthy days.

The major contributions of this study included assessing the trends of three work flexibility indicators over time, the population prevalence rates by flexibility indicators and selected demographic and socioeconomic characteristics, and the well-being outcomes of flexibility. This is the only study that used GSS-QWL data from 2002 to 2018 and well-being indicators that included healthy days and days with activity limitations. We found that perceived work flexibility had not improved significantly during the time period examined. Our findings on the association between work flexibility and well-being are important for understanding how worker well-being may change in the future, as flexible work practices are currently expected to continue to rise. Additionally, work flexibility reflects one aspect of work arrangements, which is one of the core emphasis areas in the NIOSH Future of Work initiative [33]; the types of work arrangements have also continued to increase.

Limitations

Several limitations of our study relate to limitations of the data we used. Apart from the problems of working with subjective measures of flexibility, the data we used are cross-sectional and include a relatively small number of observations, which limits the ability to control for many covariates. In terms of specific variables, as mentioned in the discussion section, GSS-QWL includes only summary definitions of work arrangements. The GSS-QWL question about working at home does not reflect the variety of other locations a person could work and could have resulted in an underestimate of location flexibility in our results. Finally, we only had information on the respondents' main job and not all their jobs. In terms of the prevalence of flexibility indicators across the survey years, we understand that the macroeconomic conditions during and after the Great Recession of 2007–2009, especially unemployment, likely affect our results. Similarly, we did not control for workload or demand, which could explain to some extent the effect of work intensification on the relationship between working at home and job stress. However, we did control for the number of hours worked. Another shortcoming is our inability to study other well-being measures like that of subjective well-being [63]. The GSS-QWL data do not include items measuring hedonic well-being, while the item on evaluative well-being was added in 2018. The pooled data prohibit us from making across-years comparisons of the associations of work flexibility and well-being. While controlling for macroeconomic factors is beyond the scope of this study, it is a gap that could be addressed in future analyses.

5. Conclusions

This study demonstrated the importance of work flexibility for well-being, using three flexibility indicators (working at home, taking time off, and changing one's schedule) and four well-being indicators (job stress, job satisfaction, healthy days, and days with activity limitations). Key takeaways include that the ability to change one's schedule was associated with reduced reported likelihood of job stress and that we found a strong association between being able to take time off and three well-being outcomes, including a reduced reported likelihood of job stress, and an improved reported likelihood of job satisfaction and healthy days.

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References

1. De Stefano, V. The rise of the "just-in-time workforce": On-demand work, crowd work and labour protection in the "gig-economy". *Comp. Lab. L. Pol'y J.* **2015**, *37*, 471. [CrossRef]
2. Book, J. Technology has Made Flexible Work Possible, and That's Wonderful. December 2019. Available online: https://www.aier.org/article/technology-has-made-flexible-work-possible-and-thats-wonderful/ (accessed on 12 October 2020).
3. Ghislieri, C.; Molino, M.; Cortese, C.G. Work and Organizational Psychology Looks at the Fourth Industrial Revolution: How to Support Workers and Organizations? *Front. Psychol.* **2018**, *9*, 2365. [CrossRef]
4. Acemoglu, D.; Restrepo, P. Demographics and Automation. *Natl. Bur. Econ. Res.* **2019**. [CrossRef]
5. Toosi, M. Labor Force projections to 2024: The labor force is growing but slowly. *Mon. Labor Rev.* **2015**, *138*, 1. [CrossRef]
6. Brussevich, M.; Dable-Noriss, E.; Kamunge, C.; Karnane, P.; Khalid, S.; Kochhar, K. *Gender, Technology, and the Future of Work. Report No. SDN 18/07*; International Monetary Fund: Washington, DC, USA, 2018.
7. U.S. Bureau of Labor Statistics. Household Data Annual Averages 2018: Table 11b: Employed Persons by Detailed Occupation and Age. Available online: https://www.bls.gov/cps/cps_aa2018.htm (accessed on 21 December 2020).
8. Rothwell, J.; Saad, L. How Have U.S. Working Women Fared During the Pandemic? 8 March 2021. Available online: https://news.gallup.com/poll/330533/working-women-fared-during-pandemic.aspx (accessed on 15 March 2021).
9. Autor, D.; Mindell, D.; Reynolds, E. The Work of the Future: Shaping Technology and Institutions. 2019. Available online: https://workofthefuture.mit.edu/wp-content/uploads/2020/08/WorkoftheFuture_Report_Shaping_Technology_and_Institutions.pdf (accessed on 21 December 2020).
10. Hill, E.J.; Grzywacz, J.G.; Allen, S.; Blanchard, V.L.; Matz-Costa, C.; Shulkin, S.; Pitt-Catsouphes, M. Defining and conceptualizing workplace flexibility. *Community Work Fam.* **2008**, *11*, 149–163. [CrossRef]
11. Hill, E.J.; Carroll, S.J. Workplace Flexibility. In *Encyclopedia of Quality of Life and Well-Being Research*; Michalos, A.C., Ed.; Springer: Dordrecht, The Netherlands, 2014. [CrossRef]
12. Berg, P.; Kossek, E.E.; Misra, K.; Belman, D. Work-life flexibility policies: Do unions affect employee access and use? *ILR Rev.* **2014**, *67*, 111–137. [CrossRef]
13. Shwab, K. *The Fourth Industrial Revolution*, 1st ed.; World Economic Forum: Geneva, Switzerland, 2016; p. 184.
14. Dean, A.; Aeurbach, A. They Need Flexibility, but Only 47% Have It. 5 June 2018. Available online: https://hbr.org/2018/06/96-of-u-s-professionals-say-they-need-flexibility-but-only-47-have-it (accessed on 21 December 2020).
15. Golden, L. Flexible work schedules: What are workers trading off to get them? *Mon. Labor Rev.* **2001**, *124*, 50–67.
16. Golden, L.; Jaeseung, K. Irregular Work Shifts, Work Schedule Flexibility and Associations with Work-Family Conflict and Work Stress in the U.S. In *Work-Life Balance in the Modern Workplace. Interdisciplinary Perspectives from Work-Family Research, Law and Policy*; De Groof, S., Ed.; Wolters Kluwer: Frederick, MD, USA, 2017.
17. Kossek, E.E.; Hammer, L.B.; Thompson, R.J.; Burke, L.B. Leveraging workplace flexibility: Fostering engagement and productivity. In *SHRM Foundation's Effective Practice Guidelines Series*; SHRM Foundation: Alexandra, VA, USA, 2015.
18. Fenwick, R.; Tausig, M. Scheduling stress: Family and health outcomes of shift work and schedule control. *Am. Behav. Sci.* **2001**, *44*, 1179–1198. [CrossRef]
19. Halpern, D.F. How time-flexible work policies can reduce stress, improve health, and save money. *Stress Health* **2005**, *21*, 157–168. [CrossRef]
20. Almer, E.D.; Kaplan, S. The effects of flexible work arrangements on stressors, burnout and behavioral job outcomes in public accounting. *Behav. Res. Account.* **2002**, *14*, 1–34. [CrossRef]

21. Hill, E.J.; Hawkins, A.J.; Ferris, M.; Weitzman, M. Finding an extra day a week: The positive influence of perceived job flexibility on work and family life balance. *Fam. Relat.* **2001**, *50*, 49–58. [CrossRef]
22. Eaton, S.C. If you can use them: Flexibility policies, organizational commitment, and perceived performance. *Ind. Relat.* **2003**, *42*, 145–167. [CrossRef]
23. Bond, J.; Galinsky, E. Workplace Flexibility and Low-Wage Employees. Workforce Research: National Study of the Changing Workforce. 2011. Available online: https://cdn.sanity.io/files/ow8usu72/production/a90ea891e7eefcaf6cd746de78fd03e636d7ac3a.pdf (accessed on 21 December 2020).
24. Golden, L. Workplace Flexibility and Salaried Workers: Access, Gaps, and Effects on Work-Family. Presentation at Working for Change: A Conversation on Workplace Flexibility Research, Business Practice, and Public Policy: Georgetown Law, Washington DC, USA. 2008. Available online: https://scholarship.law.georgetown.edu/cpe/2003_to_2010/working_for_change/ (accessed on 21 December 2020).
25. Kim, J.; Henly, J.R.; Golden, L.M.; Lambert, S.J. Workplace Flexibility and Worker Well-Being by Gender. *J. Marriage Fam.* **2020**, *82*, 892–910. [CrossRef]
26. Matos, K.; Galinsky, E.; Bond, J.T. National Study of employers. Alexandria, Virginia: Society for Human Resource Management. 2017. Available online: https://www.shrm.org/hr-today/trends-and-forecasting/research-and-surveys/Documents/National%20Study%20of%20Employers.pdf (accessed on 19 December 2020).
27. Galinsky, E.; Peer, S.; Eby, S. 2009 Guide to Bold New Ideas for Making Work New York. 2009. Available online: http://www.familiesandwork.org/site/research/reports/2009boldideas.pdf (accessed on 21 December 2020).
28. Galinsky, E.; Bond, J.T.; Hill, E.J. *When Work Works: A Status Report on Workplace Flexibility*; Families and Work Institute: New York, NY, USA, 2004.
29. Bureau of Labor Statistics. Where People Worked, 2003 to 2007. June 2009. Available online: https://www.bls.gov/opub/btn/archive/where-people-worked-2003-to-2007.pdf (accessed on 15 March 2021).
30. Bureau of Labor Statistics. Table 1. Workers Who Could Work at Home, Did Work at Home, and Were Paid for Work at Home, by Selected Characteristics, Averages for the Period 2017–2018. 24 September 2019. Available online: https://www.bls.gov/news.release/flex2.t01.htm (accessed on 15 March 2021).
31. Bureau of Labor Statistics. Job Flexibilities and Work Schedules Technical Note. Economic News Release. 24 September 2019. Available online: https://www.bls.gov/news.release/flex2.tn.htm (accessed on 15 March 2021).
32. Bureau of Labor Statistics. Access to and Use of Leave—2011 Data from the American Time Use Survey Economic News Release 16 August 2012. Available online: https://www.bls.gov/news.release/archives/leave_08162012.htm (accessed on 15 March 2021).
33. Bureau of Labor Statistics. Job Flexibilities and Work Schedules Summary. Economic News Release. 24 September 2019. Available online: https://www.bls.gov/news.release/flex2.nr0.htm (accessed on 15 March 2021).
34. Bureau of Labor Statistics. Employee Benefits in the United States Summary. Economic News Release. 24 September 2020. Available online: https://www.bls.gov/news.release/ebs2.nr0.htm (accessed on 15 March 2021).
35. Bureau of Labor Statistics. U.S. Department of Labor, National Compensation Survey: Employee benefits in the United States. March 2018. Available online: https://www.bls.gov/ncs/ebs/benefits/2018/home.htm (accessed on 23 November 2020).
36. NIOSH. Quality of Worklife Questionnaire. Topic Page. 29 August 2013. Available online: https://www.cdc.gov/niosh/topics/stress/qwlquest.html (accessed on 15 March 2021).
37. Grosch, J.W.; Caruso, C.C.; Rosa, R.R.; Sauter, S.L. Long hours of work in the US: Associations with demographic and organizational characteristics, psychosocial working conditions, and health. *Am. J. Ind. Med.* **2006**, *49*, 943–952. [CrossRef] [PubMed]
38. Ray, T.K.; Kenigsberg, T.; Pana-Cryan, R. Employment arrangement, job stress, and health-related quality of life. *Saf. Sci.* **2017**, *100*, 46–56. [CrossRef]
39. Office of Disease Prevention and Health Promotion (ODPHP), U.S. Department of Health and Human Services (DHHS). 2020. Available online: https://www.healthypeople.gov/?_ga=1.3504240.1374049404.1458923710 (accessed on 20 November 2020).
40. CDC. Health-Related Quality of Life (HRQOL); Methods and Measures. 31 October 2018. Available online: https://www.cdc.gov/hrqol/methods.htm (accessed on 15 March 2021).
41. CDC. National Occupational Research Agenda (NORA). 28 March 2018. Available online: https://www.cdc.gov/nora/about.html (accessed on 15 March 2021).
42. Brotheridge, C.M.; Lee, R.T. Impact of Work-Family Interference on General Well-Being: A Replication and Extension. *Int. J. Stress Manag.* **2005**, *12*, 203–221. [CrossRef]
43. Zhou, H.; Siegel, P.Z.; Barile, J.; Njai, R.S.; Thompson, W.W.; Kent, C.; Liao, Y. Models for count data with an application to Healthy Days measures: Are you driving in screws with a hammer? *Chronic Dis.* **2014**, *11*, E50. [CrossRef]
44. The World Bank. The World Development Report (WDR) 2019: The Changing Nature of Work. 2019. Available online: https://www.worldbank.org/en/publication/wdr2019 (accessed on 12 May 2020).
45. NIOSH. The NIOSH Future of Work Initiative. 2019. Available online: https://www.cdc.gov/niosh/topics/future-of-work/default.html (accessed on 8 April 2020).
46. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.K.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]

47. Eurofound. *Regulations to Address Work–Life Balance in Digital Flexible Working Arrangements*; New Forms of Employment Series; Publications Office of the European Union: Luxembourg. Available online: https://www.eurofound.europa.eu/publications/report/2020/regulations-to-address-work-life-balance-in-digital-flexible-working-arrangements (accessed on 16 March 2021).
48. Chung, H. National-level family policies and the access to schedule control in a European comparative perspective: Crowding out or in, and for whom? *J. Comp. Policy Anal.* **2019**, *21*, 25–46. [CrossRef]
49. Eurofound and the International Labour Office. *Working Anytime, Anywhere: The Effects on the World of Work*; Publications Office of the European Union: Luxembourg; The International Labour Office: Geneva, Switzerland, 2017. Available online: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_544138.pdf (accessed on 10 March 2021).
50. BLS. One-Quarter of the Employed Teleworked in August 2020 because of COVID-19 Pandemic. 15 September 2020. Available online: https://www.bls.gov/opub/ted/2020/one-quarter-of-the-employed-teleworked-in-august-2020-because-of-covid-19-pandemic.htm (accessed on 11 March 2021).
51. Chesley, N. Information and communication technology use, work intensification and employee strain and distress. *Work Employ. Soc.* **2014**, *28*, 589–610. [CrossRef]
52. Schieman, S.; Milkie, M.; Glavin, P. When work interferes with life: The social distribu-tion of work-nonwork interference and the influence of work-related demands and resources. *Am. Sociol. Rev.* **2009**, *74*, 966–987. [CrossRef]
53. National Academies of Sciences, Engineering, and Medicine. In *Measuring Alternative Work Arrangements for Research and Policy*; The National Academies Press: Washington, DC, USA, 2020. Available online: https://doi.org/10.17226/25822 (accessed on 20 November 2020).
54. NIOSH. Healthy Work Design and Well-Being Program. 10 October 2019. Available online: https://www.cdc.gov/niosh/programs/hwd/burden.html (accessed on 15 March 2021).
55. Bushnell, T.; Scharf, T.; Alterman, T. Developing a Taxonomy of Work Arrangements to Examine Relationships with Worker Safety, Health, and Well-being. Poster Presented at the Work, Stress and Health 2017, Minneapolis, MN, USA. 2017. Available online: https://www.apa.org/wsh/past/2017 (accessed on 20 November 2020).
56. Bureau of Labor Statistics. Women in the Workforce. 2019. Available online: https://www.bls.gov/opub/reports/womens-databook/2019/home.htm (accessed on 12 May 2020).
57. Johnston, M.L.; Esposito, N. Barriers and facilitators for breastfeeding among working women in the United States. *J. Obstet. Gynecol. Neonatal Nurs.* **2007**, *36*, 9–20. [CrossRef] [PubMed]
58. Baker, M.; Milligan, K. Maternal employment, breastfeeding, and health: Evidence from maternity leave mandates. *J. Health Econ.* **2008**, *27*, 871–887. [CrossRef]
59. Rocheleau, C.M.; Santiago-Colon, A.; Hudson, H. Promoting Worker Well-Being through Maternal and Child Health: Breastfeeding Accommodations in the Workplace. *NIOSH Sci. Blog* **2019**. Available online: https://blogs.cdc.gov/niosh-science-blog/2019/02/11/breastfeeding-work/ (accessed on 20 March 2021).
60. Kozhimannil, K.B.; Jou, J.; Gjerdingen, D.K.; McGovern, P.M. Access to Workplace Accommodations to Support Breastfeeding after Passage of the Affordable Care Act. *Women's Health Issues* **2016**, *26*, 6–13. [CrossRef]
61. Toosi, M. *Projections of the Labor Force to 2050: A Visual Essay*; Bureau of Labor Statistics: Washington, DC, USA, 2012. Available online: https://www.bls.gov/opub/mlr//10/art1full.pdf (accessed on 14 April 2020).
62. Bohle, P.; Pitts, C.; Quinlan, M. Time to call it quits? The safety and health of older workers. *Int. J. Health Serv* **2010**, *40*, 23–41. [CrossRef]
63. Kahneman, D.; Krueger, A.B. Developments in the measurement of subjective well-being. *J. Econ. Perspect.* **2006**, *20*, 3–24. [CrossRef]

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Workplace Health in Kentucky: A Statewide Comparison

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Abstract: The objectives of this study were to assess the state of Kentucky's workplace health promotion and occupational safety and health programs, to ensure the ability to comprehend any possible trends over the past six years in the state's progress in offering workplace health promotion and health protection programs, to compare the results of this survey with the 2013 Kentucky statewide assessment, and to identify gaps in Kentucky's workplace health promotion and occupational safety and health based on Total Worker Health® (TWH) concepts. Using Qualtrics research software, the Workplace Health in America assessment was sent to companies located in Kentucky and having 10 or more employees. Participants were identified using Dun and Bradstreet's Hoover's database. The results showed that, as with the 2013 survey, larger workplaces significantly were more likely to offer workplace health promotion programs than smaller companies ($X^2 = 24.30$; $p < 0.001$). However, more companies (78%) reported offering programs compared to the 2013 assessment (49%). Given the results of the current study as compared to the statewide assessment conducted in 2013, Kentucky's WHP is moving in a positive direction; yet, there is still much to be done. There remains a strong need to provide cost-effective and accessible resources for all elements of TWH to small workplaces.

Keywords: keyword; workplace health promotion; Total Worker Health®; occupational safety and health

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1. Introduction

Chronic diseases, including heart disease, cancer, chronic lung disease, stroke, Alzheimer's disease, diabetes, and chronic kidney disease continue to be the leading causes of death and disability in the United States, costing $3.5 trillion in annual health care costs [1]. The key lifestyle risks for these chronic diseases are tobacco use, poor nutrition, lack of physical activity, and excessive alcohol use [1]. According to America's Health Rankings Annual Report [2], Kentucky ranks 50 out of 50 in physical inactivity, cancer deaths, and preventable hospitalizations. Kentucky also ranks 49 out of 50 in smoking and frequent mental health distress, while ranking 46 out of 50 in both drug deaths and obesity.

The labor force statistics [3] report that approximately 131 million Americans work full time. Due to the substantial amount of time individuals spend at work, the health of employees could be impacted by the environment of the workplace. Workplace policies, programs, and practices that support a culture of health have the potential to influence workers to make better health behavior choices [4].

The Centers for Disease Control and Prevention's National Institute for Occupational Safety and Health's (CDC/NIOSH) Total Worker Health® (TWH) program is the strategic coordination of policies, programs, and practices that integrate health promotion and health protection to promote workers' well-being in the workplace. The TWH concept addresses health issues that affect workers at both home and work [5].

Due to the growing research of the effectiveness of TWH [4] and the necessity to continue advancing the concept of TWH [5], the need to assess workplace health promotion programs and occupational safety and health programs has increased over the

past few years. By assessing the concepts of TWH, as well as the quality of the concepts offered related to occupational safety and health in Kentucky, gaps may be identified and interventions developed and implemented to improve the overall health of Kentucky workers. In a case study conducted in rural Kentucky [6], results found that improved knowledge of participants about the need and importance of integration, as well as more comprehensive interventions that included management, were needed to promote the TWH concept. Additionally, there has been a call for future assessments to compare data sets in a systematic process [7–9].

This study, using the same instrument as the national 2017 Workplace Health in America (WHA) Survey [10], was conducted in the state of Kentucky with several goals in mind. The first goal included assessing the state of Kentucky's workplace health promotion and occupational safety and health programs, which involved administering a state-wide survey. In order to review Kentucky's efforts in providing health promotion and health protection at the workplace, another goal was to compare the results of this state-wide survey to the national 2017 WHA assessment [7,8]. To ensure the ability to comprehend any possible trends over the past six years in the state's progress in offering workplace health promotion and health protection programs, a third goal was to compare the results of this survey with the 2013 Kentucky state-wide assessment. By tracking the progress and remaining gaps within the state, more targeted, quality interventions may be developed that aim to improve the health of Kentucky workers. The final goal of this study was to identify gaps in Kentucky's workplace health promotion and occupational safety and health based on TWH concepts. According to Kentucky's Vision for Worksite Wellness [11], "All public and private organizations will provide access to health food and physical activity opportunities to employees and their families through comprehensive worksite wellness programs". At the time of the 2013 study, it was found that approximately 48% of employers in Kentucky offered some element of a workplace wellness program, with about 6% offering a comprehensive program [8]. The percentage of Kentucky workplaces offering elements of workplace health promotion (WHP) programs and comprehensive WHP programs were lower than the national percentages, with nearly half of all employers in the U.S. offering some element of WHP programs and 17% offering comprehensive WHP [7]. This research will assess the progress made over the last 6 years toward Kentucky's vision for workplace wellness, as well as compare the percentages of workplaces offering elements of and comprehensive WHP to the national percentages.

2. Materials and Methods

Information on workplace health promotion program administration, occupational safety and health, disease management, incentives, work–life policies, barriers to implementation, evidence-based strategies, and health screenings was collected by utilizing the *Workplace Health in America* (WHA) survey [7]. This tool was selected due its inclusion of questions related to the quality and effectiveness of workplace health promotion (WHP) and occupational safety and health programs, in addition to emerging issues in workplace health, *Total Worker Health*® concepts, and traditional elements of WHP. The survey includes 204 core items and 41 supplemental items and was designed by a steering committee of experts in workplace health promotion (WHP) led by the Centers for Disease Control and Prevention (CDC) [10].

The Dun and Bradstreet Hoover's database was used to identify eligible participating workplaces. All businesses that contract with government agencies, as well as C corporations, partnerships, and LLCs, are required to have a data universal numbering system (DUNS) number. These unique identifiers, as well as company profiles (location, company size, industry, personnel), are included in the Hoover's database. The database houses information for approximately 100,000 workplaces in Kentucky. Once a company was identified for inclusion in the study, individuals at that workplace with titles related to workplace wellness/health promotion, occupational safety and health, human resources, upper management, and president were identified as the points of contact to receive the

survey participation request. Personnel with these titles were chosen based on the assumption that these individuals would be the most knowledgeable about WHP offerings. Prior to the dissemination of the electronic survey via the Qualtrics survey software, an email was sent to each eligible workplace inviting participation and alerting that a survey would soon follow. After the initial survey was sent, one follow-up email was sent per week for a total of 6 weeks. To be consistent with the national sample, the goal was a 10% participation rate. The sample included specific workplaces, rather than parent companies, to remain consistent with past national samples [7]. Inclusion criteria for workplaces included being located in the state of Kentucky and having 10 or more employees. Workplaces were further categorized based on size (10–24 employees, 25–49 employees, 50–99 employees, 100–249 employees, 250–499 employees, 500–749 employees, 750–999 employees, and 1000 employees or more). Additionally, workplaces were classified according to the North American Industry Classification System sectors.

This was a one-time, cross-sectional assessment. At the conclusion of the survey, participating workplaces had the option to enter a drawing to receive one training at no cost. Based on the findings of the survey, a priority area was identified and training was developed to address related gaps in occupational safety and health. Potential areas were the integration of health promotion and health protection, comprehensive workplace health promotion, various aspects of occupational safety and health, etc. Fifteen workplaces opted to be entered into the drawing to receive the training administered by the research team.

The WHA instrument was derived from a series of national workplace surveys. Key measures included the following: elements of a comprehensive WHP program, a workplace health promotion program administration, occupational safety and health, disease management, incentives, work–life policies, barriers to implementation, evidence-based strategies, and health screenings. Workplace demographics were also measured through a series of questions related to size based on number of employees, industry category, the percentage of the workforce that were full time employees (FTEs) and the percentage that were part time employees (PTEs), and whether the workplace was located at the company headquarters [7].

Statistical Package for the Social Sciences (SPSS) 26 and Qualtrics research software were used to analyze the data. Frequencies, graphs, and tables were used to describe the demographic characteristics. Descriptive statistics (means/percentages), standard errors, and 95% confidence intervals were calculated for each. Missing or incomplete data were removed from the analysis. A scale was created to analyze the comprehensiveness of WHP programs that included the 5 elements of a comprehensive WHP program: health education, links to employee assistance programs (EAPs), supportive physical and social environments, integration of health promotion into the organization's culture, and employee screenings. Analysis of Variance (ANOVA) with post hoc least square difference (LSD) analysis was used to determine differences in means among the workplace by size and industrial classification codes.

3. Results

Three hundred and sixty-five out of 1400 randomly selected companies completed a portion of the assessment beyond the background information for a 13% overall response rate. Of the 168 workplaces providing information about employee demographics, 19% had less than 50 full time employees (FTEs), 16% had between 50–99 FTEs, 27% had between 100–249 FTEs, 17% of companies had between 250–499 FTEs, and 21% had over 500 FTEs. Seventy-four percent reported being located at the organization headquarters. The majority of the workplaces were for profit (See Table 1).

Table 1. Workplace characteristics.

Element	Total # of Survey Responses	*n* (%)	
Demographics			
Number of FTEs	168		
10–24 FTEs		12 (7.1)	
25–49 FTEs		20 (11.9)	
50–99 FTEs		27 (16.1)	
100–249 FTEs		45 (26.8)	
250–499 FTEs		29 (17.3)	
≥500 FTEs		35 (20.8)	
Located at organization headquarters	192	143 (74.4)	
Business type	192		
For-profit		106 (55.2)	
Non-profit/governmental		49 (25.5)	
Non-profit/other		37 (19.3)	
Industry type	168		
Manufacturing		52 (30.9)	
Other services (except public administration)		26 (15.4)	
Health care and social assistance		25 (14.9)	
Educational services		21 (12.5)	
Transportation, warehousing, and utilities		14 (8.3)	
Professional, scientific, and technical services		10 (6.0)	
Retail/wholesale trade		5 (3.0)	
Public administration		5 (3.0)	
Mining, quarrying, and oil and gas extraction		3 (1.8)	
Agriculture, forestry, fishing, and hunting		2 (1.2)	
Arts, entertainment, and recreation		2 (1.2)	
Administrative support, waste management, and remediation services		2 (1.2)	
Accommodation and food service		1 (.6)	
Offered insurance to FTEs	216	207 (95.8)	
Full coverage		104 (48.1)	
Partial coverage		103 (47.7)	
No coverage		9 (4.2)	
Offered insurance to PTEs	167	59 (35.3)	
Change in employee proportion of insurance premiums compared to last year	185		
Premiums increased		51 (27.6)	
Premiums stayed about the same		123 (66.5)	
Premiums decreased		11 (5.9)	
Workplace health promotion (WHP)			
Established WHP program by workplace size	138	Yes	No
10–24 FTEs		3 (30.0)	9 (70.0)
25–49 FTEs		9 (64.3)	5 (35.7)
50–99 FTEs		15 (71.4)	6 (28.6)
100–249 FTEs		32 (82.1)	7 (17.9)
250–499 FTEs		20 (80.0)	5 (20.0)
≥500 FTEs		29 (20.8)	0 (0.0)
Total		108 (78.3)	30 (21.7)

Table 1. *Cont.*

Element	Total # of Survey Responses	*n* (%)
Age of established WHP program	109	
Less than 1 year		3 (2.8)
1 to 2 years		9 (8.3)
3 to 5 years		37 (33.9)
6 to 9 years		23 (21.1)
10 or more years		37 (33.9)
Management of WHP programs	117	
Staff employees		63 (53.9)
Third party vendor		30 (25.6)
Health insurance provider		24 (20.5)
At least one person assigned to WHP	128	103 (80.5)

Of the workplaces providing information on industry type, classifications were manufacturing (31%), other services (16%), health care and social assistance (15%), educational services (13%), transportation (8%), professional and technical services (6%), retail/wholesale (3%), public administration (3%), mining (2%), agriculture (1%), arts/entertainment (1%), administrative support/waste management/remediation services (1%), and food services (1%) (See Table 1). The majority (96%) of respondents indicated that their companies provided health insurance, either full-time or part-time coverage, to FTEs. Most participants reported that FTEs were asked to pay "about the same" proportion of personal health insurance premiums compared to the last 12 months, while 28% reported having to pay more and 6% reported that their proportions were lower. Only 35% of workplaces reported offering personal health insurance to part time employees (PTEs) (See Table 1).

Approximately 78% of the participating companies reported having a workplace health promotion (WHP) program. Workplaces with a greater number of FTEs were more likely to have a WHP program than smaller companies. Of the participating companies with over 500 FTEs, 100% reported having a WHP program, whereas only 30% participating businesses with 10–24 FTEs reported having a WHP program. Additional information regarding established WHP programs by workplace size is shown in Table 1.

Thirty-four percent of companies reported having a WHP program for more than 10 years, while only 3% of companies reported having a WHP for less than one year (Table 1).

The largest group of WHP programs (54%) were managed by staff employees, while 26% were managed by a third-party vendor and 21% were managed by the health insurance provider. Larger organizations were more likely to report that an employee managed the WHP program than smaller companies, with 39% of organizations with greater than 500 FTEs reporting employee management of the WHP program as compared to none of the organizations with 10–24 FTEs. Most organizations (81%) reported that there was at least one person assigned the responsibility for the WHP program (Table 1). Again, larger organizations were more likely to report that there was at least one person assigned the responsibilities of the WHP program than smaller companies, with 29% of organizations with greater than 500 FTEs reporting at least one employee responsible for the WHP program as compared to only 1 of the organizations with 10–24 FTEs.

Sixty-six percent of organizations reported that a health risk assessment (HRA) was offered to employees in the last 12 months. Most organizations provided either results or provided both results and feedback and education for the identified risk factors (74%). Among participating organizations, 42% reported that the employer offered the HRA, while 28% were offered it through the health insurance plan, and 21% were offered it by a third-party vendor (Table 2).

Table 2. Worksites offering elements of organizational support and comprehensive WHP programs.

Element	Total # of Survey Responses	*n* (%)
Organizational support offered		
Employee HRA	165	109 (66.4)
HRA offered by:	103	
Employer		43 (41.8)
Health insurance plan		29 (28.1)
Third-party vendor		22 (21.4)
Did not know		9 (8.7)
Senior leadership demonstrated commitment and support to WHP	120	105 (87.5)
Middle management demonstrated commitment and support to WHP	117	100 (85.5)
Annual specific goals and objectives for WHP	63	54 (85.7)
Utilized incentives to increase participation	85	67 (78.8)
Effectiveness of incentive offered:	58	
Extremely effective		5 (8.6)
Effective		18 (31.0)
Somewhat effective		22 (37.9)
Not at all effective		2 (3.5)
Did not know		11 (19.0)
Ongoing evaluations and data to evaluate success	89	64 (71.9)
Elements of comprehensive WHP		
Health education programs	176	121 (68.8)
Supportive social and physical environment	183	134 (73.2)
Integration of WHP into the organization's structure	163	105 (64.4)
Linkage to related programs like EAPs	173	145 (83.8)
Worksite health screening	178	118 (66.3)

The majority of organizations (88%) reported commitment and support to WHP from senior leadership. All reporting workplaces with less than 50 employees reported senior leadership commitment. Organizations also reported support from middle management, with 86% of participants indicating that middle management was visibly committed to employee health and safe work environments (Table 2). No differences were observed according to workplace size on the commitment of senior management or middle management. Larger companies were more likely to report a demonstrated organizational commitment to WHP than smaller companies, with 50% of companies with >500 FTEs indicating the commitment as compared to 56% of the companies with 250–499 FTEs, 31% of companies with 50–99 FTEs, and 20% of companies with 1–19 FTEs.

The majority of workplaces (86%) had annual goals and objectives for WHP. Larger organizations were more likely to report goals and objectives for WHP than smaller companies, with all organizations with 500 or more FTEs reporting goals and objectives for WHP compared to no organizations with 10–24 FTEs.

Approximately 79% of all workplaces offered incentives to employees to increase participation in WHP activities. Workplaces with a greater number of FTEs were more likely to offer incentives than workplaces with fewer FTEs. Almost 90% of organizations with more than 500 FTEs offered incentives for WHP participation compared to 33% of organizations with 25–49 FTEs. Almost 40% of workplaces felt that the incentives were effective or extremely effective in achieving the intended outcome (Table 2).

The majority of workplaces (72%) reported the use of data and ongoing evaluations to show WHP success. Again, larger workplaces were more likely to report ongoing evaluation than smaller workplaces.

The five key elements of a comprehensive WHP program are health education (e.g., skills development; behavior-change classes; and awareness building, such as brochures or posters), links to related employee services (e.g., referral to employee assistance programs (EAPs); supportive physical and social environments for health improvement (e.g., tobacco-free policies, subsidized gym membership); the integration of health promotion into the organization's culture (e.g., health promotion as part of a business mission statement); and employee screenings with adequate treatment and follow-up (e.g., HRAs and biometric screenings) [7].

Almost 70% of the participating organizations reported offering health education programs. Larger companies were more likely to offer these elements than smaller companies. Companies with more than 500 FTEs were most likely to offer health education as part of the WHP program. Approximately two-thirds of participating organizations offered supportive social and physical environments. Half of all companies with fewer than 50 FTEs reported supportive physical and social environments for health improvement compared to 74% of companies with 100–249 employees and 96% of companies with more than 500 or more employees. The integration of health promotion into the organization's culture was reported by 64% of respondents. Thirteen percent of companies with less than 25 employees, 42% of workplaces with 50–99 FTEs, and 82% of all companies with over 500 employees reported having this element as part of their WHP program. Most workplaces (84%) had linkages to related programs such as EAPs. All companies with more than 500 employees reported providing links to related employee services as compared to only 50% of companies with less than 25 employees. Companies with fewer than 25 employees were the least likely (30%) to report employee screenings with adequate treatment and follow-up as part of the WHP program, while companies with more than 500 employees were most likely (86%) to report the offering of this element. (See Table 2).

To further analyze the comprehensiveness of WHP programs, a scale was created that included the five elements of a comprehensive WHP program: health education, links to EAPs, supportive physical and social environments, the integration of health promotion into organization's culture, and employee screenings. The scores ranged from 0–5, with higher scores indicating a greater number of elements of a comprehensive WHP program reported. The mean score for all workplaces was 3.48 (SD = 1.80). ANOVA analysis showed a statistically significant difference among the groups ($F = 7.18$; $p > 0.001$), with larger workplaces offering more elements of comprehensive WHP than smaller companies.

This study had several limitations. The response rate of 13% could potentially affect external validity. There are possible differences between those workplaces that responded to the survey and those that did not. Some data may have been under- or over-reported due to the self-reporting nature of the instrument. The respondents of the survey may have also impacted the generalizability of the results.

4. Discussion

Trends such as an aging workforce, obesity, and increases in chronic health conditions, coupled with occupational injuries and accidents, are negatively impacting workplaces and impeding their ability to stay financially viable and maintain a healthy workforce [12]. Previous findings have shown that workplaces with established cultures of health have a healthier and safer workforce. Additionally, these companies tend to be more financially productive and maintain recruitment advantages [13–15].

This study aimed to determine if progress had been made in establishing cultures of health within Kentucky by comparing a survey from 2013 to the most recent survey administered. The distribution of participants in this study according to workplace size are similar to the 2013 Kentucky Statewide Assessment, with 19% of the participants having fewer than 50 FTEs [12], and the national WHA assessment, where 41% of all participating companies had fewer than 25 FTEs [7,8]. Results from the comparison show that Kentucky has seen improvements in the number of workplaces offering WHP programs. When comparing the findings of the current study to the previous assessment

of WHP in Kentucky [12], 49% (n = 90) indicated that a WHP program was in place in the organization. Among those reporting an established WHP program, the majority (94%; n = 85) indicated that their organization had offered the WHP program for less than 5 years. The findings from the current study also showed that this sample of Kentucky workplaces were more likely to offer a health or wellness program than the nationally representative sample of 46% [7]. This is further supported by 94% of the workplaces with established WHP programs reporting their program as less than five years old. However, small businesses within Kentucky still seem to be struggling, with 40% of those employing less than 100 people indicating that they do not have a WHP program. These findings are consistent with both the findings from the 2013 Kentucky Statewide Assessment and the national WHA study [6,11]. This is especially important in Kentucky, since most of the labor force, 50.4%, is employed by establishments of less than 100 people [16].

Prior research has shown that a key aspect of encouraging safety and health in the workplace is the commitment shown by senior leadership members [17]. More specific studies have found that safety and health behaviors were positively impacted by the commitment to safety shown by management, supervisors, and co-workers [18]. The most recent survey results indicated that organizations with a WHP program reported commitment and support from senior leadership (66%), as well as from middle management (87%). Of the participating workplaces in the 2013 study, 34% (n = 53) indicated a demonstrated organizational commitment and support of WHP at all levels of management. Again, these findings are consistent with the national sample, which indicated that senior leadership (84%) and middle management (83%) were committed to employee safety and health [7]. The commitment indicated within the current study shows that workplaces choosing to adopt WHP programs within Kentucky are doing so in a way that is likely to encourage both the safety and health of their workers.

In addition to leadership commitment, other key principles of a WHP program include incentives that showcase the program as a positive benefit of the company and evaluation to determine if the program is accomplishing its purpose [19]. In the 2013 study, approximately 43% of workplaces reported the use of incentives to increase employee participation. Nine out of ten, or 90%, of the participating workplaces with >500 FTEs reported the use of incentives as compared to 56% of the companies with 250–499 FTEs (n = 16), 30% of companies with 20–49 FTEs (n = 43), and 20% of workplaces with 1–19 FTEs (n = 15) [12]. Results from the most recent survey, as well as the 2013 survey, showed workplaces with more FTEs were significantly more likely to offer incentives than workplaces with fewer FTEs. The WHA study also showed that larger workplaces were more likely to offer incentives than smaller workplaces [7].

Important to note is that not all companies with WHP programs reported setting goals and objectives, which makes it hard for evaluation to be completed. Larger companies were more likely to have set goals and objectives than smaller companies, which helps to explain this trend in evaluation. This same trend was also seen in the evaluation of the WHP programs to determine if the goals and objectives of the program were successful. In the 2013 study, 22% of workplaces (n = 34) reported ongoing evaluations of health promotion programming using multiple data sources. There were significant differences based on workplace size, with over two-thirds of large workplaces conducting evaluation with multiple data sources as compared to none of the smallest workplaces [12].

5. Conclusions

Given the results of the current study as compared to the statewide assessment conducted in 2013, WHP in Kentucky is moving in a positive direction; yet, there is still much to be done. There remains a strong need to provide cost-effective and accessible resources to small companies. These companies continue to make up the largest proportion of the workplaces in Kentucky and offer the fewest elements of workplace health promotion. In the future, additional resources and efforts need to be targeted at establishing collaborations between small businesses and outside organizations to provide affordable and

user-friendly resources that improve the occupational safety and health of Kentucky's workforce. The results of this study may also be used to inform additional research in other locations, especially locations with high percentages of small workplaces. Additional research is needed to fully understand the best way to meet the needs of workers, both nationally and internationally.

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References

1. Centers for Disease Control and Prevention. Chronic Diseases in America [Infographic]. Available online: https://www.cdc.gov/chronicdisease/resources/infographic/chronic-diseases.htm (accessed on 13 March 2020).
2. America's Health Rankings, United Health Foundation. Kentucky Summary 2019. Available online: https://www.americashealthrankings.org/explore/annual/measure/Overall/state/KY (accessed on 20 April 2020).
3. U.S. Bureau of Labor Statistics. Labor Force Statistics from the Current Population Survey. Available online: https://www.bls.gov/cps/cpsaat08.htm (accessed on 20 January 2020).
4. Peters, S.E.; Grant, M.P.; Rodgers, J.; Manjourides, J.; Okechukwu, C.A.; Dennerlein, J.T. A cluster randomized controlled trial of a Total Worker Health®intervention on commercial construction sites. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2354. [CrossRef] [PubMed]
5. Tamers, S.L.; Chosewood, L.C.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.C. Total Worker Health®2014–2018: The novel approach to worker safety, health, and well-being evolves. *Int. J. Environ. Res. Public Health* **2018**, *16*, 321. [CrossRef]
6. Watkins, C.; Macy, G.; Golla, V.; Lartey, G.; Basham, J. The "Total Worker Health" concept: A case study in a rural workplace. *Occup. Environ. Med.* **2018**, *60*, 387–391. [CrossRef]
7. Linnan, L.; Cluff, L.; Lang, J.; Penne, M.; Leff, M. Results of the workplace health in America survey. *Am. J. Health Promot.* **2019**, *33*, 652–665. [CrossRef]
8. Watkins, C.; Macy, G.; Lartey, G.; Golla, V. Kentucky workplace health promotion 2014 survey results. *J. Workplace Health Manag.* **2016**, *9*, 398–410. [CrossRef]
9. DeJoy, D.M.; Dyal, M.A.; Padilla, H.M.; Wilson, M.G. National workplace health promotion surveys: The affordable care act and future surveys. *Am. J. Health Prom.* **2014**, *28*, 142–145. [CrossRef]
10. Centers for Disease Control and Prevention. Workplace Health in America Survey Instrument 2019. Available online: https://www.cdc.gov/workplacehealthpromotion/data-surveillance/docs/2017-WHA-Survey-Instrument-508.pdf (accessed on 12 November 2019).
11. Lovely, T.; Russell, E. Kentucky's Vision for Worksite Wellness n.d. Available online: http://www.fitky.org/wp-content/uploads/sites/2/2016/03/WW-Vision-Slidedoc_Approved.pdf (accessed on 29 April 2021).
12. Watkins, C.; Lartey, G.; Macy, G.; Golla, V.; Lovely, T. Results of the Kentucky workplace assessment: Utilization of the CDC's Health ScoreCard. In *Technical Report*; Western Kentucky University and the Kentucky Department for Public Health: Frankfort, KY, USA, 2014.

13. Hymel, P.A.; Loeppke, R.R.; Baase, C.M.; Burton, W.N.; Hartenbaum, N.P.; Hudson, T.W.; Larson, P.W. Workplace health protection and promotion: A new pathway for a healthier—and safer—workforce. *Occup. Environ. Med.* **2011**, *53*, 695–702. [CrossRef] [PubMed]
14. Seabury, S.A.; Lakdawalla, D.; Reville, R.T. The Economics of Integrating Injury and Illness Prevention and Health Promotion Programs. *RAND Working* **2005**, *243*. Available online: http://saif100.com/_files/CompNews/CNeconomoics.pdf (accessed on 14 March 2020).
15. Employers. Workplace Safety Can Give Small Business Owners a Recruiting Edge, Employers Survey Finds. Available online: https://www.employers.com/resources/press-releases/2017/workplace-safety-can-give-small-business-owners-a-recruiting-edge (accessed on 12 June 2019).
16. Cunningham, J.; Gester, K.; Keathley, S. Kentucky Labor Force Update. Kentucky Center for Statistics. 2018. Available online: https://kcews.ky.gov/Content/Reports/WP-LF_Update_November_2018.pdf (accessed on 20 March 2020).
17. HSE. Leadership for the Major Hazard Industries: Effective Health and Safety Management. Available online: www.hse.gov.uk/pubns/indg277.pdf (accessed on 12 June 2019).
18. Schwatka, N.V.; Rosecrance, J.C. Safety climate and safety behaviors in the construction industry: The importance of co-workers' commitment to safety. *Work* **2016**, *54*, 401–413. [CrossRef] [PubMed]
19. Sparling, P.B. Workplace health promotion: Principles, resources and challenges. *Prev. Chron. Dis.* **2010**, *7*, A25.

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Review

REDECA: A Novel Framework to Review Artificial Intelligence and Its Applications in Occupational Safety and Health

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Abstract: Introduction: The field of artificial intelligence (AI) is rapidly expanding, with many applications seen routinely in health care, industry, and education, and increasingly in workplaces. Although there is growing evidence of applications of AI in workplaces across all industries to simplify and/or automate tasks there is a limited understanding of the role that AI contributes in addressing occupational safety and health (OSH) concerns. Methods: This paper introduces a new framework called Risk Evolution, Detection, Evaluation, and Control of Accidents (REDECA) that highlights the role that AI plays in the anticipation and control of exposure risks in a worker's immediate environment. Two hundred and sixty AI papers across five sectors (oil and gas, mining, transportation, construction, and agriculture) were reviewed using the REDECA framework to highlight current applications and gaps in OSH and AI fields. Results: The REDECA framework highlighted the unique attributes and research focus of each of the five industrial sectors. The majority of evidence of AI in OSH research within the oil/gas and transportation sectors focused on the development of sensors to detect hazardous situations. In construction the focus was on the use of sensors to detect incidents. The research in the agriculture sector focused on sensors and actuators that removed workers from hazardous conditions. Application of the REDECA framework highlighted AI/OSH strengths and opportunities in various industries and potential areas for collaboration. Conclusions: As AI applications across industries continue to increase, further exploration of the benefits and challenges of AI applications in OSH is needed to optimally protect worker health, safety and well-being.

Keywords: artificial intelligence; worker health and safety; occupational safety and health; sensor devices; robotic devices; machine learning algorithms; future of work

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1. Introduction

Artificial intelligence (AI) is an extensive and diverse research field that has infiltrated every aspect of our lives and gained decisive importance over the years with over 20,000 publications in 2019 alone (Figure 1) [1]. In basic terms, AI is the ability of a computer to process information and generate outcomes that mimic how a human learns, makes decisions, and solves problems [2]. While research in AI is relatively new, the concept of AI can be traced back to as early as the 1940s where Alan Turing was one of the first mathematicians to explore the mathematical possibility of AI by posing "whether a machine can think like a human or not" [3]. The term "artificial intelligence" was proposed in a series of workshops at the Dartmouth Summer Research Project on Artificial Intelligence (DSRPAI) hosted by John McCarthy and Marvin Minsky in 1956 [4]. Academia and industry have applied AI to solve various problems such as decision making [5], environmental monitoring [6,7], lower operational costs [8], and increase productivity [9].

The advent of technological advances in robotics, sensors, data management, and computer technology on one hand, and powerful machine learning (ML) algorithms, on the other hand, have opened vast opportunities to apply AI in various fields (Figure 2). For example, ML algorithms are being used to: optimize the performance of a network of sensors used for detecting moving objects [10], select the location of radio frequency sensors used by police/firemen to detect indoor crews in the event of a fire or other threats [11], detect vocal disorder among workers who use their voice maneuvers extensively such as singers and teachers [12], and used to predict bankruptcy [13]. Other important AI applications include: facial recognition technology for law enforcement [14], improvement in marketing and customer service [15], and dramatic improvements in the accuracy of digital imaging [16,17]. These studies point to accumulating evidence that AI technology could effectively be used to detect, identify, and predict risky behavior in a potentially hazardous working environment.

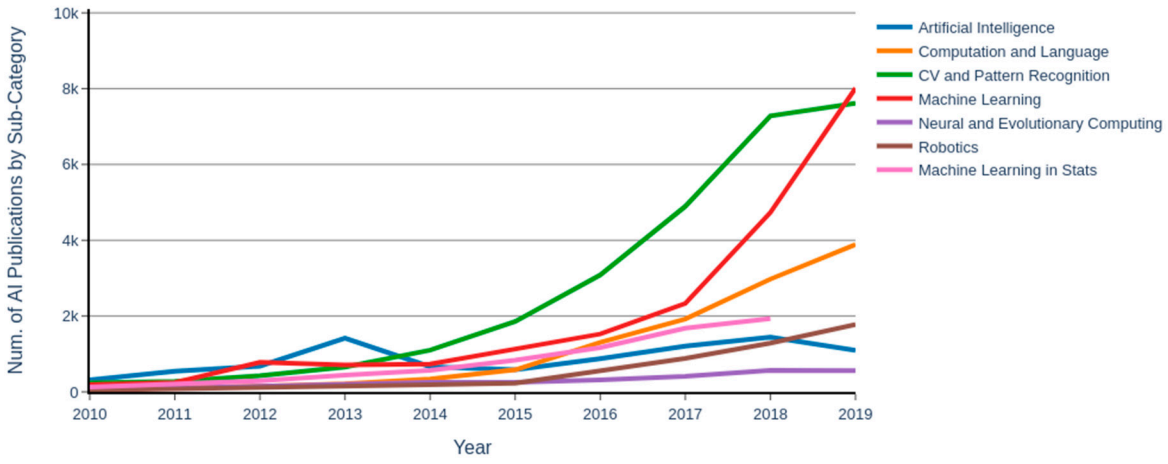


Figure 1. The number of AI papers on ArXiv over time by subcategory from 2010 to 2019. The *x*-axis of the graph is the year of publication (collected from 2010 to 2019) and the *y*-axis is the number of the AI papers on ArXiv split by sub-categories of AI research. The data is provided by "2019 AI Index Reports by Stanford" [1].

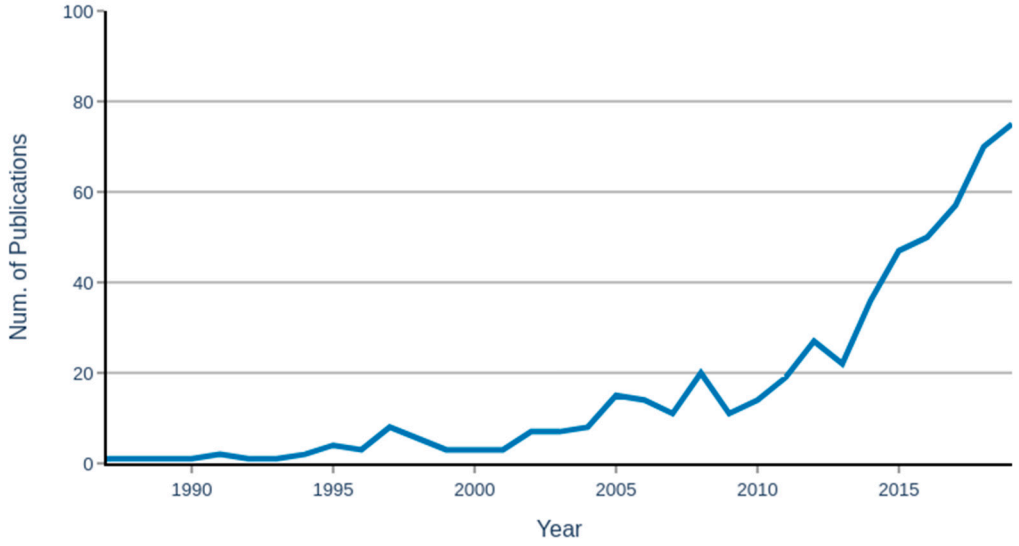


Figure 2. The number of publications demonstrating the use of AI in the OSH field from 1986 to 2019. The *x*-axis is the year of publication and the *y*-axis is the number of the AI papers published with an OSH application. All AI papers queried were individually reviewed to confirm the OSH application.

1.1. Basics of AI and ML

One of the definitions of AI is the study of an agent that receives data from the environment, analyzes the data, and performs an action based on the analysis [18–21]. The process could be initialized by a collection of the data from the environment by sensor devices, followed by analyzing the data through ML algorithms, and finally, performing the action by actuators (Figure 3). Sensor devices and actuators are considered as the autonomous part of the AI, while ML techniques are the algorithmic part of the AI. In general, ML is considered a sub-division of AI that provides the system with the ability to learn and improve from experiences automatically [21]. In other words, ML is a wide range of algorithms that build a mathematical model based on sample data or features to make predictions or decisions without being explicitly programmed to perform the task [22]. The ML algorithms are capable of learning by trial and error and improving their performance over time [2]. Throughout the paper, the usefulness of both the autonomous and algorithmic applications of AI in OSH for several industry sectors are presented. Since ML techniques play a crucial role in this process, it is essential to understand the algorithms associated with each application.

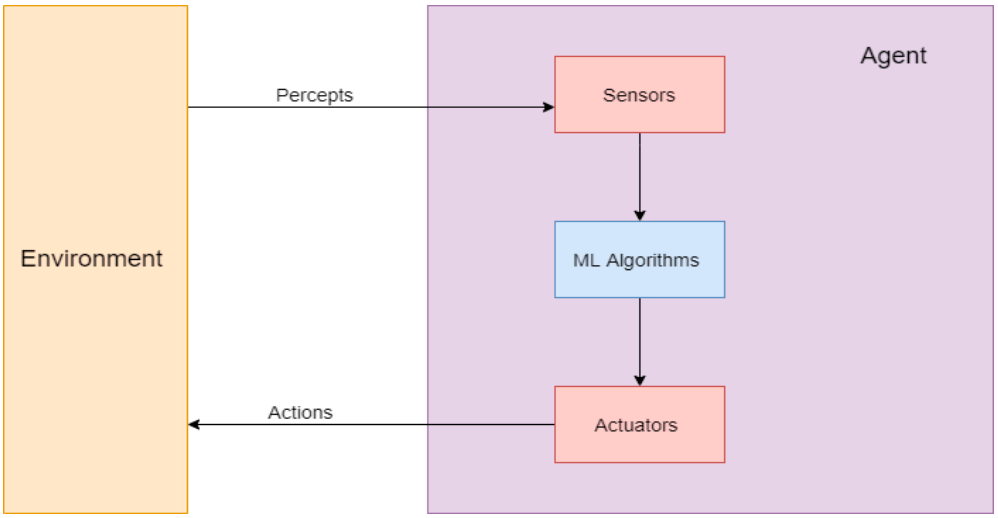


Figure 3. Components of an AI system. Data from the environment is inputted into the AI agent through sensors. This data is transformed/analyzed by ML algorithms that then instruct actuators to conduct certain actions on the environment.

1.1.1. Types of ML

The purpose of ML models is to make predictions, obtain cognitive insights, and support decision-making [2]. ML uses an advanced set of rules called algorithms to build models. ML algorithms can be divided into supervised learning, unsupervised learning, semi-supervised learning, reinforcement learning [23]. Table 1 shows the type of ML techniques as well as common algorithms for each of them. Each of these algorithms can be defined as follows:

- Supervised algorithms use labeled data that have been previously validated to train a model. The trained model is used to find patterns and make predictions on the unlabeled test dataset [24]. Supervised learning can be divided into regression and classification subsections. Regression predicts a single output value based on different continuous target variables input, for example, prediction of house prices based on different variables such as the location, and size of the house. On the other hand, classification organizes the outputs based on some categorical input variables, for example, predicting if a person is the defaulter of a loan or not.
- Unsupervised learning does not use labeled data for training. Unlabeled data are provided to the learning algorithm, and the model then describes the hidden structure of the data without human guidance, separating the data into clusters or classes [25].

An example of unsupervised learning is that the customers of any specific store or a company such as Amazon can be grouped into different categories based on their similarities in their purchasing histories.

- Semi-supervised learning algorithms analyze unlabeled data mixed with a small number of labeled data. By combining labeled and unlabeled data together, the accuracy of the ML models is improved, and it significantly reduces the costs of prediction of unlabeled test datasets through using supervised algorithms [26].
- Reinforcement learning is a form of sequential learning where the machine is generating its own training data through interaction with a dynamic external environment and optimizing the outcome [27]. Reinforcement models learn the correct outcomes through rewards and penalties using trial and error methods used by humans [2]. For example, if we have an agent, a reward, and many hurdles in between them, the agent will try to find all possible paths to reach the reward. After that, the agent chooses the path with the least number of hurdles to reach the reward [28].

Table 1. Type of ML techniques and the algorithms associated with each technique.

Types of ML Techniques	List of Most Common Algorithms
Supervised ML	Support Vector Machine (SVM), Naive-Bayes, K-Nearest Neighbor, Decision Trees, Random Forests (RF), Linear Regression, Logistic Regression, DL
Unsupervised ML	K-Means, Hidden Markov Model (HMM), Principal Component Analysis, Gaussian Model Mixture (GMM), DL
Semi- Supervised ML	Self-Training, Co-Training, Generative methods, Mixture models, Semi-supervised SVM, Graph-based methods
Reinforcement ML	Q-Learning, Temporal Difference, Deep Adversarial Networks

A major class of ML algorithms are constructed based on Neural Networks (NN). NN are designed based on the human brain with interconnected neurons. The NN mathematically adjust the probability weights between nodes in a layer which is called a hidden layer so that the difference between the input and output layers narrows until the actual output of the network matches the desired output [29,30]. Moreover, Deep Learning (DL) is a subdivision of ML that uses a neural network with multiple processing hidden layers of interconnected neurons between input and output layers to recognize a pattern. Convolutional Neural Networks (CNN), and Recurrent Neural Networks (RNN) are popular NN that are used for the implementation of DL algorithms [31].

1.1.2. Types of Metrics to Evaluate ML Models

ML algorithms can be evaluated with different metrics, which are given in Table 2. ML models can produce true positive, false positive, true negative, and false negative outcomes. True positive (TP) is an outcome where the model correctly predicts the positive class. False-positive (FP) is an outcome where the model incorrectly predicts the positive class. True negative (TN) is an outcome where the model correctly predicts the negative class. False-negative (FN) outcome where the model incorrectly predicts the negative class [31]. The results of the findings are used to calculate precision, specificity, sensitivity, accuracy, F_1 measure, and receiver operative character (ROC), in which the formulas for calculating these metrics are presented in Table 2. Precision is the proportion of positive prediction that was correct. Specificity is defined as the proportion of actual negatives, which got predicted as the negative (or true negative). Sensitivity is a measure of the percentage of actual positive cases that got predicted as positive (or true positive). Sensitivity is also termed as recall. Accuracy is the fraction of predictions the model got right among all outcomes. F_1-measure combines precision and sensitivity values. In the end, Sensitivity and Precision measures are used to plot the ROC curve.

Table 2. Evaluation Metrics.

Evaluation Metrics	Formula
Recall or sensitivity	$\frac{TP}{TP+FN}$
Precision	$\frac{TP}{TP+FP}$
Specificity	$\frac{TN}{EP+TN}$
Accuracy	$\frac{TP+TN}{TN+TP+FP+FN}$
F_1-measure	$\frac{2 \times precision \times recall}{precision + recall}$
ROC	$\sqrt{specificity \times sensitivity}$

1.1.3. Statistical Modeling versus ML Modeling

ML techniques are built upon statistical frameworks, but they are different from the traditional statistical modeling techniques, such as linear and logistic regressions. In statistical analysis, modeling is dependent on the distribution of the data, but in an ML approach, the development of a model is independent of the distribution of the data. Moreover, in statistical analysis, a model is mostly developed based on all the available data, however, in both the ML supervised and unsupervised learning techniques, a model is developed on a training dataset and will be evaluated using a separate dataset called the testing dataset. The decisions which can be made by statistical analysis are usually involved in a few decision steps; but by ML methods, complex decisions more similar to that of the human brain can be made. Statistical methods use the collected data to infer the relationships between variables, while ML obtains a general understanding of the data to make predictions [32]. The analysis of big datasets using standard statistical analysis is challenging, especially when the number of measurements exceeds the number of individuals and may be further complicated by missing data for some subjects and variables that are highly correlated [33]. ML techniques are especially very advantageous when dealing with such big data sets.

1.1.4. Available Datasets

Datasets are an integral part of the field of machine learning; they are essential as they provide us with the information used to construct the ML models. There are many freely available datasets in a variety of fields such as health care, education, and manufacturing which have been used as the inputs of the ML algorithms. An example of a primary freely available health care database is Medical Information Mart for Intensive Care (MIMIC). MIMIC-III is a clinical dataset owned by the MIT Lab for Computational Physiology, containing de-identified health data associated with intensive care unit admissions including demographics, vital signs, laboratory tests, medications, etc. [34]. Colombian Institute for the Evaluation of Education (ICFES) is a popular educational database with a variety of economic, social, and academic attributes of the students [35]. These attributes have been widely used to develop ML models to predict the performance of the students throughout the semester. The Manufacturing Execution System (MES) is a database that has provided real-time data for various manufacturing activities [36]. These data have been used to create ML methods to optimize production, process quality, and productivity. Another freely available example of databases is Kaggle. Kaggle is an open repository of published data and codes in a variety of fields [37]. These codes and datasets repositories allow users to make their own ML models as well as collaborate with other researchers to build even more powerful models and improve the results. However, no specialized datasets for occupational safety and health (OSH) are available.

1.2. AI and OSH

The field of OSH is a subdivision of public health science and integrates disciplines such as toxicology, epidemiology, and ergonomics to study the distribution of illnesses and

injuries in the workplace and implement strategies and regulations to prevent them [18]. There has been increasing interest in integrating AI research within the frameworks of OSH. The National Institute for Occupational Safety and Health (NIOSH) founded the Center for Occupational Robotics Research (CORR) to assess the impact of robotics and artificial intelligence on worker safety, health, and well-being in the work environment [19]. Similarly, the European agency for health and safety has also studied the use of AI-enhanced tools and applications in workplaces, looking at where they function and how this is occurring and what the implications are for workers' occupational safety and health [20]. The number of AI publications with OSH topics has dramatically increased and including several review papers on various industries (Figure 3). Several publications have reviewed the application of AI in OSH in various industries. However, they are limited in scope, and they don't provide an overall perspective on AI applications in OSH. As the number of AI applications in the workplace dramatically increases, there is a crucial need to gain a thorough understanding of AI methods and their potential impact on worker health and safety.

The objectives of this paper are: (1) define and apply a novel framework to evaluate AI literature in OSH; (2) identify research studies that highlight current applications of AI to improve the health and safety of workers in agricultural, oil and gas, mining, transportation and construction industries; and (3) describe, across these industries, the potential applications of AI in anticipating and controlling occupational hazards, and opportunities for future AI interventions.

2. Materials and Methods

2.1. Risk Evolution, Detection, Evaluation, and Control of Accidents (REDECA) Framework

Figure 4 describes a novel framework called Risk Evolution, Detection, Evaluation, and Control of Accidents (REDECA) developed by the authors to theorize how AI technologies and methods can be used to anticipate and control risk of exposure in a worker's immediate environment. The REDECA framework is constructed based on the fundamental underlying idea of the Swiss cheese model [38] that is a dominant paradigm for depicting how injury incidents in complex systems occur. Based on this model a given hazard can generate a safety incident when multiple layers of defenses and safeguards (or interventions) designed to prevent the incident or loss fail to properly act. While the Swiss cheese model conceptualizes that a safety incident occurs when multiple stages of safeguards fail, it is not capable of showing how AI can be used in each step of this process. To create this capability, we extend the Swiss cheese model by including new details that are necessary to describe how AI can be and has been used in detecting, preventing, and controlling the evolution of safety accidents. These details include the characteristics of each state visited when reaching from a safe state to an accident state, the probabilities and timing information associated to each state, and the interventions that can reverse or slow down such a process. We have shown all these details by the REDECA framework shown in Figure 4. We assume that a human worker, due to the nature of his work, can be at different levels of safety risk at any given time. These levels are shown by the three states of R1, R2, and R3 (shown by blue boxes in Figure 4). R1 is the ideal state where a worker has minimal to no risk of exposure to the hazard. Our goal as OSH professionals is to keep the worker in this state. However, this is often not achievable due to the work requirements, available technologies, environmental factors, budget, etc. In R2 the worker is at an increased risk of a harmful work-related exposure event but has not experienced a harmful event. R3 is the state when a harmful work-related event has already occurred impacting the health and safety of the worker. AI technology- based inputs can monitor and foresee the change in state of risk and impact movement between these states of risk to minimize damage from a harmful work-related event. To minimize the chance and negative consequences of safety incidents, we are interested in three types of information and actions related to the states R1, R2, and R3: 1—transition probabilities and times for moving from a lower risk states to a higher risk state (green boxes in Figure 4), 2—detection

of a state change (white boxes in Figure 4), and 3—interventions in each state that reduce the risk level or negative consequences of safety incidents (orange boxes in Figure 4).

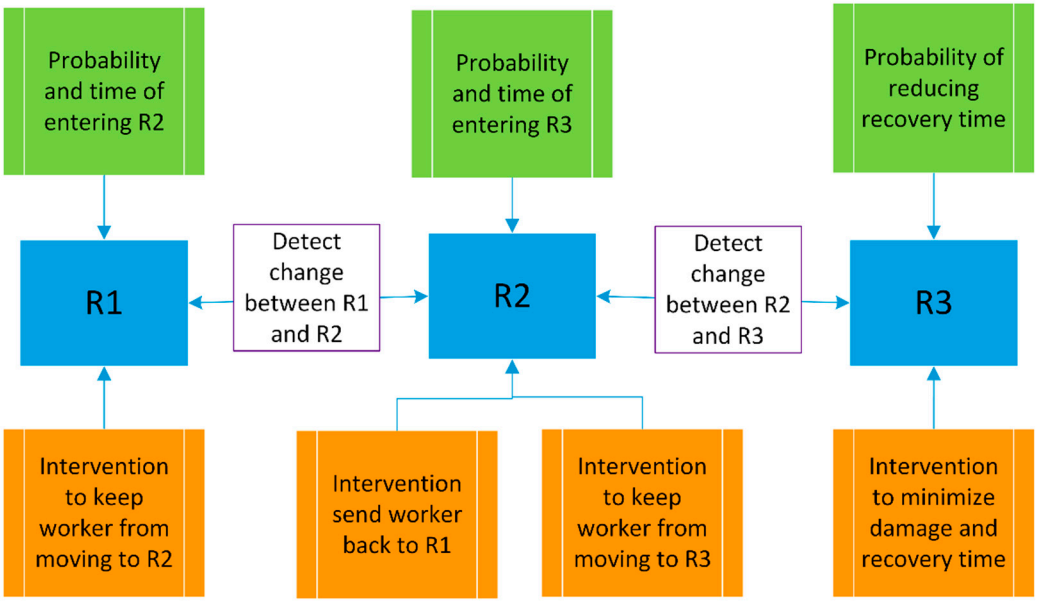


Figure 4. The Risk Evolution, Detection, Evaluation, and Control of Accidents (REDECA) framework for AI OSH. Blue boxes are the different states a worker can find themselves in. R1 is the state when a worker has minimal to no risk of exposure. R2 indicates exposure to hazard and an increased risk of injury. R3 indicates a harmful work-related event occurred. Green boxes indicate technologies that can predict the probability of transitioning into the next states. White boxes are technologies that can detect transitions between the states. Orange boxes indicate the intervention strategies to keep the worker safe or reduce the impact of a work-related event.

For a worker who is in state R1, we are interested in AI based models and technologies that help us with the followings: calculating the probability and/or time left for the worker to transition from the safe state (R1) to the hazard-exposed state of R2; detecting (sensing) the event that shows such a transition; and designing and implementing AI based technologies that keep the worker in R1 or at least reduce the probability of moving from R1 to R2.

For a worker in state R2, we are interested in the AI models/technologies that assist us with the followings: calculating the probability and time left for a worker transition from the hazard-exposed state of R2 to R1 or R3; detecting or sensing the events corresponding to these transitions; and the design and implementation of AI technologies and models that could send the worker back to the R1 state or at least reduce the probability of having a safety incident, i.e., moving from R2 to R3.

If a worker experiences an injury incident, then the worker's state is set to R3. In this state, we are interested in AI models/technologies that help in reducing the damage and recovery time of the worker, and in calculating the times and probability of recovery.

All the AI/OSH papers reviewed by the authors are related to at least one of the green, white or orange boxes shown in Figure 4. Therefore, we use this framework to classify AI/OSH literature related worker's safety in the five industries of agricultural, oil and gas, mining, transportation and construction.

2.2. Literature Search Strategy

The five most dangerous industries by fatal injuries are agricultural, mining, oil and gas, transportation, and construction respectively [39]. In 2019, according to the U.S. Bureau of Labor Statistics these industries experienced almost 2700 fatal injuries, 50% of all fatal injuries reported that year. These industries also had over 204,000 injuries that resulted in days away from work, approximately 25% of all injuries in 2019. Moreover, these industries

had the highest fatal injury rates of all other industrial sectors and were chosen for this review paper (Figure 5) [39]. The application of AI and ML algorithms, actuators and sensors in the OSH field for these industries were reviewed by using PubMed, Google Scholar, and Scopus search engines to find relevant research. Different keywords such as "artificial intelligence", "occupational safety and health", "agriculture", "mining", "oil and gas", "construction", "transportation", "ergonomic", "risk factors", "sensors devices", "robots" and their combinations were used to explore available papers in the fields of AI and OSH. For each selected paper, a backward and forward citation search was conducted to capture additional papers not found in the original queries. Over 650 abstracts were reviewed and only papers that were non-repetitive, English-based, relevant to OSH, AI and the five industrial sectors were chosen for further review. The full text of the remaining publications was then read and only papers that meet the criteria specified in our REDECA framework and within the five industries (agriculture, mining, oil and gas, transportation, and construction) were included in this paper.

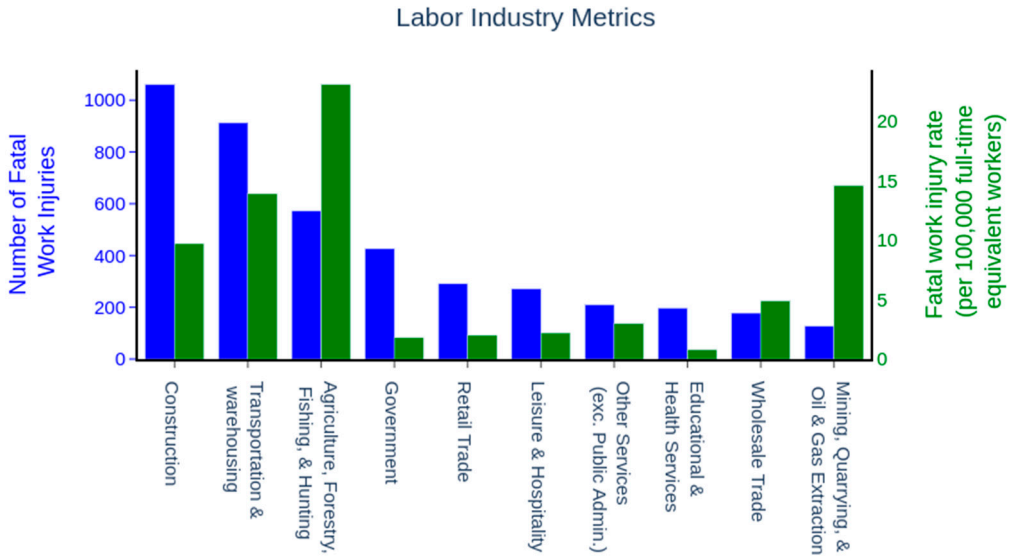


Figure 5. U.S. Bureau of Labor Statistics 2019 survey on the rate of fatal work injury by industry sector [39]. The *x*-axis is the fatal work injury rate and the *y*-axis is different industries.

Each paper was reviewed and classified using the REDECA framework (Figure 4) and AI system (Figure 3). The algorithms, sensors, actuators and environment used/described by the paper were organized by industry in tables highlighting where the majority of AI research in each industry is located within the REDECA framework and AI system. Each component of the REDECA framework was used in the tables using shorthand descriptions and components where there was no available research included in the tables to highlight potential research gaps (Table 3).

Table 3. REDECA components and shorthand notations used in industry Tables 4–8.

Prob. R2	Probability and time of entering R2
Detect R1→R2	Detect change between R1 and R2
Int. R1→R2	Intervention to keep worker from moving to R2
Int. R2→R1	Intervention send worker back to R1
Prob. R3	Probability and time of entering R3
Detect R2→R3	Detect change between R2 and R3
Int. R2→R3	Intervention to keep worker from moving to R3
Prob. Rec.	Probability of reducing recovery time
Int. R3	Intervention to minimize damage and recovery time

3. Results

3.1. Agriculture

While the agricultural industry has come a long way from its humble origins of subsistence farming to present-day farming, the fatal incident rate has stagnated since the 1990s and it is now considered the most dangerous industry in the US [39]. The number of fatal incidents has dropped from around 1000 cases in the early 1990s to less than 600 cases in 2019. However, the primary attribution of this drop is the reduction in the number of workers (thus less exposure) due to the implementation of more efficient machinery and systems [40]. Precision and digital agriculture research have grown tremendously in recent years due to technological advances in sensor technology, development in robotics human-robot interaction (HRI) [41], unmanned aerial vehicles (UAV) [42], and sophisticated machine learning algorithms. However, significant investments are needed to continue improvements in productivity and enhance health and safety in agricultural environments [43]. The emerging research into collaborative robots (co-robots) is gaining attention as a strategy to create a safe working agriculture environment. The field of human-robot interaction involves designing, developing, and evaluating strategies to help and improve human-robot capabilities and skills together [44]. HRI enabled robots are currently used in urban search and rescue [45].

The agricultural industry is repetitive, labor-intensive, and usually involves lifting heavy loads, which tend to increase the risk of injuries [46,47]. In addition, workers utilize hazardous machinery such as tractors, augers, power take-off (PTO) shafts, grain bins and have to deal with hazardous agents such as pesticides and manure [48–52]. Most agricultural tasks are performed by human-operated machines with some autonomous robots that can work on large-scale fields [53]. The most common injury incident type in the agriculture industry is a collision with a machine or machine parts, which is mainly associated with errors in human factors [54]. Thus, most AI/OSH papers in agriculture reviewed by the authors tended to revolve around HRI strategies that could improve agricultural processes, such as the hazardous tasks of spraying pesticides and the repetitive tasks of the detection of fruits and vegetables, grasping, detaching, and transport procedures [55,56] (Table 4). Three major research areas (robotics, drones, biological sensors) are explored further in this section.

3.1.1. Robotics

For agricultural workers to obtain successful crops, many factors will need to be controlled and monitored, and agricultural robots could be used to perform these repetitive tasks during planting, crop management, and harvesting efficiently and safely while reducing costs.

Yaghoubi et al. summarized a report on the introduction of robotic systems for land preparation [57]. The tasks that robotics systems could optimize include spraying and water irrigation procedures in farms [58–61], grafting and cutting [62], weeding [63], pruning [5], monitoring and inspection of crops [64–69], to map or monitor crop conditions, natural resources, regulating in weather conditions [70–74]. Freitas et al. have shown that a human working with a robot was able to trim trees faster (more than 2×) compared to humans working alone using a ladder-based approach [75]. Similarly, using robots with the relevant sensor utilizing ML algorithms would be able to reduce harvesting workload by handling heavy material and performing repetitive work. Harvest and storing crops at the right conditions via accurate detection and classification of crop quality are explained in the following research [76–78]. Bechar et al. were able to show that HRI could be used to improve automatic target recognition of melon on average between 94–100% at a 20% decrease in the time consumed compared to manual operation [55]. HRI collaboration does not need to be a static type. Tkach et al. developed a real-time dynamic switching between collaboration levels in a human-robot target recognition system (the ability to see and recognize what you are seeing). These developments enabled real-time adaptation of the combined human-robot system to make many possible changes in the environment,

as well as human operators, and robots initiated the operation. Their ability to correctly recognize what they are seeing was increased by up to 90% [79]. Furthermore, a localization system for HRI robots was developed where vehicle position is triangulated from low-cost wheel encoders and LiDAR sensors without the use of expensive satellite GPS systems [80]. This system allows the robot to track and control its position independently from the operator while spraying or crop detection.

Table 4. Agricultural AI/OSH algorithm, sensor and actuator research organized by the REDECA framework. Major technologies described by each paper is mentioned and linked to the relevant papers [39–98]. Summary of each paper is found in Appendix A.

REDECA Components	AI Algorithms (ML)	Sensors	Actuators	Environment (Type of Hazard)
Prob. R2	Linear Mixed Model: [59] Signal Detection theory (SDT): [79] *SVM:* [84] *Image Processing*: [85]	Laser: [58] Camera: [59,61,84,85] EEG: [94]	Robot: [41,57,60,61] UAV: [84,85] Tractor: [94]	Musculoskeletal Disorders: [41,57,61] Pesticide: [58–60,84,85] Machinery: [79,94]
Detect R1→R2		LIDAR: [91] Radar: [91] Camera: [91] Thermography: [91]	Robot: [91]	Machinery: [91]
Int. R1→R2	Linear Mixed Model: [59] Image Processing: [63]	Camera: [59–61,63,78,87–90] Ultrasonic: [62] GPS: [63] Infrared Laser: [78] Pressure [78] EEG: [93]	Robot: [59,60,62,63,78,87–90] Tractor: [93]	Pesticide: [59,60,87–90] Planting: [62] Weeding: [63] Harvesting: [78] Vibrations: [93]
Int. R2→R1				
Prob. R3		Accelerometer: [46] Vibrations: [95–97]		Musculoskeletal Disorders: [46,95–97]
Detect R2→R3				
Int. R2→R3				
Prob. Rec.				
Int. R3				

3.1.2. Drones and Remotely Operated Systems

UAVs or drones help in mapping and crop monitoring. Computer vision via sensors and ML algorithms can process data captured from drones flying over their fields [81,82]. Using drones reduces the need for farmworkers to be venturing into remote locations. In high-resolution imagery, shadows may cause problems in the soil and vegetation recognition, Al-Ali et al. used data obtained from a UAV with multispectral sensors to assess vegetation coverage using SVM and maximum likelihood algorithms [83]. The same multispectral camera fixed on UAV technology was used to collect the data, and ML algorithms were used to discriminate between weed and vegetation with an overall accuracy of 96% [84]. The efficiency spraying of pesticides was shown to be improved by using ML algorithms to detect the exact locations reducing the need for workers' exposure to pesticides [85].

To reduce the physical presence of workers in areas to be sprayed with pesticides, the performance of the robots and ML algorithms needs to be accurate. The following reports have proposed the use of semi-autonomous operation of a teleoperated pesticide-spraying robot [86–89]. The operator would be able to remotely control the robots using a mouse, a

remote, and digital, thus reducing the risk of exposure to hazardous pesticide exposure. For such a strategy to be successful, the following features should be optimized: visibility, safety, simplicity, feedback, extensibility, and cognitive load reduction. Adamides et al. assessed the awareness of the operator and HRI robot, where both should be aware of the status, activities, and the surrounding limitations of the other party [90]. To improve the ambient awareness of agricultural robots, Reina et al. proposed a multisensory perception system by using sensor technologies such as LiDAR, six radar, stereovision, and thermography to detect and avoid obstacles [91]. Berenstein et al. applied two parameters: human-robot collaboration levels and a spraying coverage optimization function (SCOF) in a case study of detecting non-uniform grape clusters in vineyards by allowing both the human and the robot to mark the area for pesticide spraying [92]. Bernstein et al. presented three types of human-robot collaboration: fully manual mode (robot suggests, and human approves), semi-manual (robot sprays and human supervise), or fully autonomous robot spraying modes.

3.1.3. Biological Sensors

Smart robots could also be used to monitor the health of human operators as well. Sensors such as electromyography (EMG) can measure the psychophysical feature of the human operator to modify tasks to improve safety or increase efficiency. For example, Gomez-Gil et al. used EMG readings to steer a tractor with almost the same accuracy as with manual steering [93]. Szczepaniak et al. developed models to assess the stability and steerability of agricultural machines that could be adapted to drivers' characteristics to improve safety [94]. Sensors were also developed to measure vibrations experienced by farmers using agricultural aircraft. The tri-axial accelerometer sensors were used to measure the acceleration occurring at the level of the seats [95]. Kociolek et al. showed that the operators on quad bikes were exposed to head and neck vibration higher than the permissible level of exposure [96]. Similarly, Calvo et al. used three different accelerometers to measure hand-to-arm vibration and occupational repetitive action (OCRA) level for farmers who always used power tillers and the result indicated the vibration exposure was far above the permissible level of exposure [97].

3.1.4. Summary

A summary of published articles shows that the utility of sensors, robots, and ML algorithms, which are all parts of AI, impact the two main agriculture processes: planting and maintaining the crops, and harvesting; and also human factors. The goals of these technologies are to improve the working conditions in the farms by reducing the need for humans in repetitive and hazardous tasks on farms. For an efficient design and training of sophisticated HRI systems, a detailed study of each task is needed by creating work models from operators to inform technology design and training [56]. Additionally, robotics could be designed to perform more than one task simultaneously to enhance crop and flower production on one hand [98], and harvesting on the other hand leading to improvements in the safety and health of the workers in agricultural environments. In addition to robotics, drones and biological sensors are expected to contribute to the safety and health of farmworkers.

3.2. Oil and Gas

The oil and gas industries are defined as any industry directly involved in extracting oil and gas material from the ground and related support activity. The industry uses processes and machinery for the exploration, extraction, refining, transporting, and marketing of petroleum products these days. The oil and gas industries are integrating various advanced sensor technology for collecting data to be analyzed by ML algorithms and to monitor and control the process involved in oil and gas production. The goal of using these technologies is to increase efficiency, reduce costs and at the same time maintain a safe working condition for workers in the oil and gas industry.

The procedure for obtaining oil and gas is divided into three main sectors: upstream, midstream, and downstream. The upstream sector is the exploration of underground and underwater sources of crude oil and natural gas using different apparatus and methods. Once oil or gas is found, it is removed to the surface. The transport of the extracted crude products to the refineries in the midstream sector. The downstream sector involves the refining of crude oil and natural gas and their retail distribution. It is essential to control, monitor, maintain, and secure these processes in every industry and ensure the safety and health of individuals involved in these processes [99].

Advances in ML algorithms, sensors, and robotic technologies to the oil and gas industry have resulted in significant improvements in the safety and health of the workers in their workplaces. A major part of operations in the oil and gas industry may take place in remote locations, hostile and rough terrains where the weather is inclement and harsh. These conditions seem to be worrisome for the safety and health of the workers. Therefore, most AI/OSH papers focused on monitoring, maintaining, and managing industrial operations as well as equipment to detect any potential condition that might be a risk to the safety and health of the workers (Table 5). Smart robots have been used for drilling, inspection, and erosion control in harsh environments in the oil and gas industry which have been useful in improving the safety and health of the workers [8]. Three major research areas (wireless sensor networks, internet of things, machine learning algorithms) are explored further in this section.

Table 5. Oil and Gas AI/OSH algorithm, sensor and actuator research organized by the REDECA framework. Major technologies described by each paper is mentioned and linked to the relevant papers [99–133]. Summary of each paper is found in Appendix B.

REDECA Component	AI Algorithms (ML)	Sensors	Actuators	Environment (Type of Hazard)
Prob. R2	SVM: [107,109] GMM: [107,109] KNN: [107,109] ANN: [128]	Temperature: [105,106,119] Pressure: [105–107,109,119] Transducers: [107] GPS: [112] Acoustics: [119]		Pipeline Leakage: [100,105–107,112,119] Gas Pressure: [105,106,119] Flow: [119] Noise: [119] Temperature: [119]
Detect R1→R2	SVM: [107,132] GMM: [107] KNN: [107] Transform: [113] Localization: [118]	Temperature: [105,106,111,120] Pressure: [105–107,109–111] Transducers: [107] Flow: [108] Acoustic: [110,111,113,132] Gas Sensor: [118,120] Humidity: [120] Windspeed: [120]		Pipeline Leakage: [105–111,113,132] Gas Pressure: [105,106,132] Noise: [110,111] Fire: [118] Chemical: [118,120]
Int. R1→R2	Localization: [118]	Temperature: [100,101,103] Pressure: [100,101,103] Gas Sensor: [102,118] RFID: [123]	Robot: [123]	Confined Space: [100] Well head: [101] Drilling: [102] Pipeline Leakage: [103,123] Fire: [118] Chemical: [118,123]
Int. R2→R1				
Prob. R3				
Detect R2→R3				
Int. R2→R3				
Prob. Rec.				
Int. R3				

3.2.1. Wireless Sensor Networks (WSN)

It is essential to maintain the health and safety of workers during the exploration of oil and natural gas as the increase in temperature or gas levels could indicate a defect in the wells. A WSN was developed by Barani et al. and Ibrahim et al. to remotely monitor the conditions of oil wells using the level, temperature, and gas sensors [100,101]. Aliyu et al. developed a wireless gas safety and monitoring system (WG-SMS), a gas leakage warning system, containing a WSN made up of wireless environmental sensors that are shown to detect toxic and combustible gases accumulating in gas wells. The sensors were solar and battery-powered to reduce energy requirements and were shown to communicate with a command center which would warn of gas leakage and locate workers in danger via GPS [102]. There are several reports of WSN systems used to monitor the different stages of transporting and storing oil and gas in the midstream sector. Disruption of the midstream operations could lead to oil spills and gas leakage with detrimental consequences to the wildlife, environment, and safety of the workers in this industry as well as other humans. Gas leaks occur every year, with many of them leading to injuries, and deaths of humans, equipment damage, and often disastrous environmental effects. The following reports demonstrate the use of real-time data captured from pipeline sensor nodes (PSN) measuring structural stability of the pipelines, oil and gas leakage, and analyses weather and environmental conditions to generate a risk management protocol [103–114]. Ding et al. developed a monitoring system to detect pipeline leakage through the negative pressure wave (NPW) features which were collected through the pressure sensors and ZigBee technology [7].

The WSN technology could also be applied to downstream operations of refining crude oil and natural gas and then its retail distribution. Imran et al. used the WSN technology to autonomously monitor and detect any defects in the different downstream operations [115]. Watching the machine conditions to expose any errors was proposed by Hou et al. by using sensor nodes on the machine [116]. Algorithms were developed to analyze data from the sensors for fault classifications. Jung et al. proposed and implemented a WSN based monitoring system for pipe rack safety using data collected from field nodes connected to remote servers by radio frequency transmission modules [117]. Chraim et al. developed and evaluated a wireless gas leak detection and localization solution by using a monitoring network of wireless devices and detection and localization algorithms. A detection rate of 91% is achieved [118].

A WSN pipeline monitoring system was used to detect and localized leakage and blockage in oilfield pipelines [119]. Guo et al. used features from environmental sensors such as wind speed and direction, humidity, and temperature to develop a real-time and large area wireless monitoring system for gas leakage [120].

3.2.2. Internet of Things (IoT)-Robotics

Khan et al. describe a new Internet of Things (IoT)-based system to make data collection from connected objects, as simple, secure, robust, reliable, and quick that could be applied to any of the three sectors of the industry [121]. Priyadarshy et al. reviewed in detail the IoT applications in wearable watches, smart helmets, and smart glasses [122]. These devices were used by oil field engineers in offshore fields for real-time assistance, safety, and communication with the control tool for navigation and enhanced collaboration.

Kim et al. proposed an autonomous sensor-based system named sensor-based pipeline autonomous monitoring and maintenance system (SPAMMS) that combines robot agent-based technologies with sensing technologies for achieving active and corrective monitoring and maintenance of the pipelines [123]. The sensor technology could also be applied to remote terrain such as an underwater system. Felemban et al. surveyed methods for anomalous events in the oil and gas industry, such as detection of pipeline leakage detection with emphasis on software-based methods [124].

Some examples of such technologies include digitization of oil fields, real-time optimization of drilling operations, the use of nanotechnology, WSN to aid gauging, reservoir

modeling, and diagnostics [125]. Other examples include real-time data collected by sensors are used to ensure better control and optimization of crude production, robots for drilling, inspection, and damage control to enhance efficiency and personal safety, WSN that monitors and improves production, as well as to detect and prevent issues with regards to health and safety.

3.2.3. Machine Learning Algorithms

There are several reports in the literature demonstrating the contribution of several types of ML methods in the three main sectors of the oil and gas industry. Successful ML algorithms that have been effectively applied in the oil and gas industry include SVM, artificial neural networks (ANNs), and DL which contributed to provide a safer environment for the workers in this industry. There are several reports of machine learning algorithms used in the exploration of oil and gas [126], and drilling [127], reservoir engineering [128], production operations [129], in the oil and gas industry.

The following are some examples of the application of robots with ML algorithms used instead of humans for many tasks that could be risky for the workers and which could facilitate monitoring of leakage, corrosion, or any other damage from remote facilities. Smart robots could intervene to remote areas to assess soil composition during the oil excavation stage [130]. RF and Landsat 8 OLI imagery algorithms were able to map land oil spills [131] efficiently. Jin et al. used LS-SVM to detect leak levels on a gas pipeline based on the acoustic wave method with high accuracy [132]. Robots are used in offshore fields for drilling, inspection, and erosion control to enhance efficiency and personal safety. Mashreq has developed another autonomous robot that has been used for pipelines and other equipment inspections [133].

3.2.4. Summary

As a result, setting overall goals and delegating decision-making to autonomous systems is one of the best things companies can do in such adverse conditions to improve the safety and health of the workers. For example, the introduction of smart robots in drilling and inspection of the various processes and equipment found in the harsh and hazardous environment of the oil and gas industry has improved the safety and health of their workers. These robots reduce worker exposure to extreme temperature, pressure, and humidity. In addition, they are sent into confined spaces, thus reducing exposure to physical and environmental hazards found in these spaces. Moreover, ergonomic-related injuries such as lifting heavy items, bending, working in awkward postures, and repetitive tasks have decreased significantly due to the application of smart robots in these workplaces. Also, WSN technology has allowed workers to remotely monitor operations in hazardous, and inaccessible environments, which prevent them from being exposed to such environments.

3.3. Mining

AI and ML algorithms have essential roles to play in the mining industry by increasing the efficiency of mineral exploration and improving workers' safety and health. Like the oil and gas industry, the mining industry puts the health and safety of miners in jeopardy due to the remote and harsh mining environmental conditions. According to the NIOSH, the fatality rate in the mining industry was reported as 10.4 per 100,000 employees in 2018 [134]. Mining operations could be divided into two stages, exploration and extraction. Mining starts by exploring mineral deposits by collecting data from various remote sites. The next step in the process is drilling and extracting the minerals. The exploration and extraction stages of mining are performed in dangerous and hazardous conditions. Workers tend to be in environments with tight working space, poor lighting, inadequate air supply, and under unstable roofs. In addition, these environments tend to accumulate hazardous waste, poisonous gases, metal and non-metal dust particles, toxic substances, and radioactive materials. These factors tend to make mining operations dangerous and a significant source

of adverse health outcomes for workers [135]. AI and ML algorithms can be applied to develop autonomous drills that can locate the potential sites identified in the prospecting stage and perform drilling activities [136].

Most of the reviewed papers focused on structural and environmental mine conditions could be used to analyze the main routes that contain hazardous situations and eliminate them by decreasing or completely removing workers from those conditions [136] (Table 6). Also, ML techniques such as decision tree, RF, and NN can predict the outcome of mining injuries and days away from work using an injury dataset provided by the Mine Safety and Health Administration [137]. AI technologies supporting the safety and health of mineworkers can be organized in two broad categories, sensors and wearable devices and are explored further in this section.

3.3.1. Sensors

Deployed sensors can be split into three types: worker-based sensors, environmental sensors, and autonomous robots. One of the first worker-based sensor systems was developed by Johnson who used global positioning systems (GPS) to monitor workers' locations and movements [138]. More recently, Baek et al. utilized blue-tooth-based motion and speed sensors, and communication sensors modules to ensure a connection with a worker in remote locations [139]. In addition, sensors used in the medical field to measure physiological features such as body temperature, heart rate, blood pressure could be utilized to monitor the health of the workers inside mines [140–142].

Environmental sensors are used to collect data on the conditions surrounding the worker, including humidity, noise, toxic gases, temperature, light, and dust [143]. One crucial system is an autonomous remote monitoring framework of wireless toxic gas sensors that can monitor the levels of toxic gases, and provide warnings to protect the health and safety of the mineworkers [79]. Another example is using sensors to monitor humidity levels to combat bacterial growth and prevent worker exposure to harmful bacteria [143]. Lastly, acoustic and ultrasonic optical fiber sensors can be used to monitor the noise level [144–146].

Mobile autonomous robots and IoT technology play an important role in the occupational safety and health of mineworkers as they provide real-time information about the status of the mine and mine workers and allow the mine workers to avoid hazardous areas [147]. Sinha et al. reported the use of IoT based on ZigBee techniques to actively monitor underground mineworkers and provide immediate assistance during an emergency [148]. As hundreds of mine workers are shown to be involved in machinery-related injuries routinely, the IoT would provide a highly valuable intelligent machine monitoring system [149] that could be effectively used in detrimental working conditions. Mishra et al. developed and established a Zigbee-based WSN and extended it to IoT with an IP-enabled gateway [150]. Lastly, Autonomous Support Systems could reduce the need for human involvement in perilous mining operations such as roof support [151].

3.3.2. Wearable Devices

Wearable devices using different types of sensors can be used in a wide variety of conditions such as to track motion and location, measure extreme environments, and record physiological characteristics of workers, etc. These features could collectively be incorporated to develop an efficient ML algorithm that could detect hazardous situations more promptly to improve health and safety conditions in the mines. There are many examples of wearable smart devices that integrate information from the environment, motion levels, location and activity, and exposure to hazardous materials. The common devices are helmets, watches, cameras, and activity trackers, which are all useful to improve the overall health and safety of mineworkers.

Table 6. Mining AI/OSH algorithm, sensor and actuator research organized by the REDECA framework. Major technologies described by each paper is mentioned and linked to the relevant papers [134–158]. Summary of each paper is found in Appendix C.

REDECA Component	AI Algorithms (ML)	Sensors	Actuators	Environment (Type of Hazard)
Prob. R2			Robot: [147] IoT: [147]	General: [147]
Detect R1→R2		Motion: [139,153] Accelerometer: [139,145] Gyroscope: [145] Magnetometer: [145] GPS: [139] Humidity: [143,150] Sound: [143,145,146] Temperature: [143,145,150] Toxic gases: [143–145,150,152,154] Dust: [143,145] Heart Rate: [145] Infrared: [145] Camera: [145,153] Smoke: [145] Silica: [146]	Smartphone: [145] Smartwatch: [145] Smart helmet: [145,152–154]	General: [139,145] Fall: [153] Bacteria: [143] Hearing: [143,146] Toxic gases: [143,144,150,152,154] Temperature: [143,150] Silica: [146] Humidity: [150]
Int. R1→R2		Motion: [139,153] Accelerometer: [139] GPS: [139] Camera: [153]	IoT: [149] Smart helmet: [153]	General: [139] Machinery: [149] Fall: [153]
Int. R2→R1		Accelerometer: [145] Gyroscope: [145] Magnetometer: [145] Heart Rate: [145] Infrared: [145] Camera: [145] Sound: [145] Smoke: [145] Gas: [145] Temperature: [145] Dust: [145]	Smartphone: [145] Smartwatch: [145]	General: [145]
Prob. R3		Accelerometer: [145] Gyroscope: [145] Magnetometer: [145] Heart Rate: [145] Infrared: [145] Camera: [145] Sound: [145] Smoke: [145] Gas: [145] Temperature: [145] Dust: [145,155]	Smartphone: [145] Smartwatch: [145] Smart helmet: [155]	General: [145] Fall: [151] Silica: [155]
Detect R2→R3				
Int. R2→R3				
Prob. Rec.	ANN: [137] DT: [137] RF: [137]			General: [137]
Int. R3				

Helmets and Respirators

Helmets with wireless sensors are vital for the safety of the workers in the mining industry [151]. Several commercial companies have developed smart helmets with sensors to monitor the worker and their environments, such as Smart Helmet clip and Angel helmet. Deloitte and Expert mining solutions have acquired the Smart Helmet Clip wearable device with sensors that enable situational awareness including worker's location and vital signs and the presence of dangerous gasses in the environment [152]. Angel helmet contains detecting systems of motion, impacts, active and passive location, and the position of the workers, besides other effective communication systems [153].

Hazarika developed a safety helmet for coal mine workers, which is equipped with methane and carbon monoxide gas sensor [154]. This sensor detects changes in the gas concentrations, and the data is transmitted to the control room wirelessly. It will alert the workers of unsafe methane or carbon-monoxide gas concentration thus efficiently preventing incidents. In addition, wearable respiratory dust monitors could protect workers from exposure to hazardous substances found in mines such as crystalline silica [146].

Helmet-Cam, which is a device to assess the amount of dust around the workers in the mine, has been tested at mineral mines [155]. This technology has several components which are held together as a system through a safety vest. The components consist of a real-time data-logging, a respirable dust monitor which is attached to the worker's belt or backpack, a video monitor, and a video camera which is attached to the helmet. The captured video and dust data then transfers and analyzes to a software to measure the concentration of respirable silica dust in the air.

Mardonova et al. have developed an integrated system to improve the health, safety, and efficiency of the mineworkers [156]. Mardonova's an expandable smart device combining a safety vest, eyewear, helmet, and watch. The system uses a mobile software system that coordinates the information captured from the individual sensor.

Watches

Smartwatches integrate the functionality of a regular watch with added features such as motion detection, global positioning system (GPS) navigation systems, and fitness/health tracking features [157].

Parate et al. described a smartwatch that can measure smoking activities via sensors that detect specific hand gestures such as smoking and separate them from many irrelevant hand gestures [158]. Being able to delineate between normal and abnormal body movements is essential in allowing the ML algorithm to understand the status of the worker when they need help or assistance.

Smart Eyewear and Cameras

Smart eyewear with display screens is able to send alerts and notifications of workers who are in remote locations [156]. Delabrida et al. describe a wearable device made of a head-up display (HUD) assembled with Google Cardboard API and sensors that can measure the distance to an object and can take measurement of the wearers' environment [6].

3.3.3. Summary

As a result, ML algorithms, sensors, autonomous technologies, and wearable devices, are being developed to address the crucial needs of the mining industry while monitoring the occupational safety and health handoff of the mine.

3.4. Transportation

Transportation networks are vital to the economy and societal development. Driver fatigue-related traffic accidents are one of the main factors affecting the safety of workers in the transportation industry [159,160]. The US National Highway Traffic Safety Administration estimates that in 2017, 91,000 police-reported crashes involved drowsy drivers (https://www.nhtsa.gov/risky-driving/drowsy-driving (accessed on 8 August 2019)).

Operating a car involves a coordinated set of actions that require situational awareness and prompt decisions, and impairment of awareness is linked to increased risk of crashes [161]. The majority of transportation related papers focused on fatigue related issues (Table 7).

Table 7. Transportation AI/OSH algorithm, sensor and actuator research organized by the REDECA framework. Major technologies described by each paper is mentioned and linked to the relevant papers [159–210]. Summary of each paper is found in Appendix D.

REDECA Component	AI Algorithms (ML)	Sensors	Actuators	Environment (Type of Hazard)
Prob. R2	GMM: [203] Helly model: [203] ANN: [207]	Infrared: [170] Camera: [170,207] EMG: [180] Pressure: [203] Vehicular: [207]		Fatigue: [170,180,203,207]
Detect R1→R2	SVM: [173–175,188,209] CNN: [183,190–192] Bayesian NN: [178,182,202,208] Digital Signal Processing: [181] Fuzzy NN: [186,187] DL: [189] Binary Decision Classifier: [200,201] ANN: [207] NN: [210]	Infrared: [170,193,210] Camera: [170,186–193, 200,205,206,208,210] ECG: [173,181] PPG: [174,208,209] EOG: [175,181] EEG: [178,181,183] Vehicular: [201,205–207,209,210] Accelerometer: [209] Gyroscope: [209]	Alarm: [191,208] Smartwatch: [209]	Fatigue: [170,173–175,178,181–183,186–193,200–202,205–210] Distraction: [193]
Int. R1→R2	CNN: [191] Bayesian NN: [208] SVM: [209]	Camera: [191,208] PPG: [208,209] Accelerometer: [209] Gyroscope: [209] Vehicular: [209]	Alarm: [191,208] Smartwatch: [209]	Fatigue: [191,208,209]
Int. R2→R1				
Prob. R3	SVM: [168,173]	ECG: [173] PPG: [174] Infrared: [193] Camera: [193]		Fatigue: [168,173,174,193] Distraction: [193]
Detect R2→R3				
Int. R2→R3				
Prob. Rec.				
Int. R3				

Fatigue is a physiological state of mind and body expressed by several signs and has different intensities [162]. Examples of signs of fatigue include yawning [163], slow reaction time [164], eyelid shutting [165], and loose steering grip [160]. One of the standards that all fatigue algorithms are contrasted against is the Karolinska Sleepiness Scale (KSS) [166–168]. The KSS is one of the earliest tools used to measure fatigue levels using a self-administered questionnaire [167]. The KSS is considered the gold standard in measuring fatigue, though it is important to note that it is a subjective reporting method that is not real-time and suffers from recall and reporting biases that might be needed to prevent crashes.

Fatigue could be classified into active, passive, and sleep-related fatigue [169]. There is a connection between fatigue signs such as drivers' blink duration and driving performance [170–172]. It would be too complex to explicitly code every situation to generate predictive crash models using the usual statistical methods. As a result, machine learning algorithms would be more efficient in detecting and predicting driver fatigue by using

information from drivers' characteristics, vehicle characteristics, or both. Driver fatigue detection algorithms can be categorized based on the data collected by the sensors. These algorithms fit into four broad categories: biological, facial, vehicular, and hybrid algorithms.

3.4.1. Biological Algorithms

Biological algorithms use real-time data collected from the heart, brain, and muscular activity as indicators of the onset of fatigue [167]. Changes in the heart rate (HR) and heart variability (HRV) from electrocardiograms (ECG) non-invasive sensors embedded in steering wheels could be used to detect driver's fatigue [173]. Changes in photo platysma gram (PPG) readings could also be used to identify fatigue. Li et al. used a PPG sensor on the steering wheel of the vehicle to measure HRV and the SVM algorithm to categorize drivers into fatigued and alert states with a 95% accuracy compared to the gold standard KSS and PERCLOS [174]. Another biological measurement is electro-oculography (EoG), which is the measurement of the cornea-retinal potential difference between the back and the front of the eye, Zhu et al. used an unsupervised machine learning algorithm to detect fatigue [174]. EoG data was obtained from 22 participants with electrodes around their eyes, and response error was shown to increase with fatigue. Since a sensor near the eye could distract the driver, Zhang et al. developed a sensor on the forehead instead [175]. Electroencephalography (EEG) could similarly be used to assess the onset of fatigue in the brain. The EEG signal is divided into five waves which are associated with different levels of drowsiness [176–178]:

- Gamma (30–42 Hz)
- Beta (13–30 Hz): a measure of alertness and early sleep stage.
- Alpha (8–13 Hz): associated with relaxed status
- Theta (4–8 Hz): associated with deep sleep
- Delta (0.5–4 Hz): related to the early stage of sleep

The sensor could also be used to collect information regarding the level of muscle activity from the surface of the skin using a surface electromyogram (sEMG) [179]. Balasubramanian et al. used sEMG to measure muscle activity changes in the shoulder, neck, back, and wrist found that the power in 15–30 Hz frequency increased with fatigue [180]. Although these changes have a high correlation with fatigue, obtaining EEG and sEMG are both intrusive methods that have limitations in their applicability.

Multiple biological features could be used to improve the performance of the fatigue detection method. Sun et al. used recruited 30 participants to use wearable ECG and EEG sensors and had the EoG sensors fixed on the vehicle ceiling to test his fatigue-detection method [181].

Sun et al. observed that the following features were associated with fatigue: (1) increased blink duration and frequency; (2) decreased power density of alpha and beta waves; (3) decreased LF/HF; (4) increased SDNN; increased RMSSD, LF and HF.

Chai et al. categorized fatigue by developing a feed-forward Bayesian neural network [182]. Their classification system used independent components by entropy rate bound minimization analysis (ERBM-ICA) for the source separation. Also, the features were extracted through an autoregressive (AR) method. At the end, the Bayesian neural network was developed to classify fatigue state versus alert state. The model was evaluated through sensitivity, specificity, and accuracy metrics which are of 89.7%, 86.8%, and 88.2% respectively. In another study, a CNN model was developed to detect fatigue from the EEG signals by Yang [183].

3.4.2. Facial Algorithms

Facial expressions, such as eye, mouth, and head movements are the most visible signs of fatigue, and several commercial companies have developed fatigue detection systems relying on drivers features such as yawning, blink duration, and frequency, percent of the time the eyes are closed (PERCLOS), head movement [184]. Applied Science Laboratories

(ASL) designed an eye-tracking system using a computer vision techniques system to measure eye movement association with fatigue [185].

In another study, blinking frequency, eye-closed duration, mean of eye-opened level, and yawing frequency were used as the physical features. Moreover, the percentage of non-steering, the standard deviation of steering-angle, frequency of abnormal land deviation, and standard deviation of vehicle speed were used as the vehicle features [186]. Sigari et al. demonstrated that the face tracking method using a fuzzy classifier (fatigue levels: low, normal, and high) was not optimal and complex when testing it on 5 participants in a real driving environment [187].

Mandal (developed a vision-based fatigue detection system for bus drivers by monitoring and testing on 23 bus drivers in a real driving condition [188]. The system consisted of various modules of head-shoulder detection, face detection, eye detection, eye openness estimation, fusion, PERCLOS estimation.

Mouth movement data were also used to predict fatigue. Alioua et al. developed a non-intrusive fatigue detection system by monitoring yawning features with face extraction-based SVM and a mouth detection approach based on circular Hough transform (CHT) [189]. This system was able to detect fatigue with a 98% accuracy when more features were included, but fatigue was simulated, and the number of participants was not reported.

A different way to approach this problem is to allow deep learning algorithms to learn the features. Dwivedi et al. developed a DL algorithm to select the visual elements for fatigue classification [190].

In another study, the drowsiness of the drivers was monitored through eye movement of the driver, CNN was developed as the ML algorithm to do the prediction of if the driver is drowsy or not, and if he is able to drive safely or not, and the sound alarm was produced when the driver was drowsy [191]. Also, a complex network (CN)-based broad learning was developed to detect fatigue from the EEG signals [192].

Many commercial companies have developed facial algorithms to detect fatigue. Smart Eye AB has designed Anti Sleep, a system that uses 3D head position, head orientation, gaze direction, and eyelid closures to detect driver fatigue [193]. The OPTALERT developed by Sleep Diagnostics Pvt, uses wireless glasses to record eyelid and pupil activity which were used as an early warning to inform drivers about fatigue [194]. Driver Fatigue Monitor System MR688, developed by Care Drive alerts the drivers in which detection of features of fatigue or distraction is done by infrared image sensors that record the pupil and head movement [195]. Op Guard is a real-time fatigue and distraction detection system developed by Guard Vent using sensors to measure eye, head, and face movements, and driver's behavior. It sends immediate notification of fatigue to the driver by remote personnel monitoring the drivers' performance [196].

3.4.3. Vehicular Algorithms

Vehicle and steering wheel movement patterns can also be used to detect fatigue. Toyota has developed the Toyota Sense P fatigue-detection system by collecting information about the vehicle's surroundings, lane deviation, and detection of pedestrians [197]. Nissan Maxima tracks the driver's steering patterns, and if it detects any unusual deviation from the designed model, a warning signal is generated to alert the driver [198]. Volkswagen also offers a similar lane tracking system, pedal use, and erratic steering wheel movements to judge driver fatigue levels [199].

Fatigue reduces influences the driver's performance that could be captured from driving features such as steering wheel angle, lane deviation, load center position (LCP), and posture changes.

Measuring steering angle could be used to identify driver fatigue. McDonald et al. developed a fatigue-detection method using features such as lane departures from steering wheel angle data (from modified observer rating of drowsiness) and a RF algorithm. Using

72 participants, the RF algorithm had higher accuracy and ROC than PERCLOS and had a comparable positive predictive value [200].

Li et al. used approximate entropy (ApEn) features which were collected under real driving condition from the sensors mounted on the steering lever to monitor the level of driver fatigue and the drowsiness of the drivers [201]. The data included 14.68 h of driving on a Chinese highway, and the model yielded an accuracy of 78.01%. Li et al. illustrate that ApEn features are useful, but further development is needed to improve accuracy.

Yang et al. recruited 12 subjects to measure a type of different sleep levels (partial versus no sleep sleep-deprivation) test under a simulated driving environment [202]. Several stimulus-response tasks as well as routine driving tasks were performed to analyze the performance differences of drivers under various sleep-deprivation levels. They also demonstrated that sleep deprivation affected rule-based than skill-based cognitive functions where sleep-deprived drivers had power response to unexpected disturbances degraded but were able to continue the routine driving tasks such as lane tracking, vehicle following, and lane changing. Another feature used in fatigue detection is the LPC measured by pressure sensors placed in the seats. Furugori et al. showed that in a vehicle of 12 subjects, the LPC from body pressure sensors was at the beginning distributed throughout the seat, but as time progressed, the pressure started to concentrate more or less at one point toward the back of the seat [203].

Wakita et al. developed a GMM and the Helly models to identify driver fatigue. Multiple features such as vehicle velocity, brake pedal, accelerator pedal, and distance from car in-front were utilized to feed to the models [204]. The GMM model yielded better results compared to the Helly model in terms of accuracy metric which were 81% on a simulator and 73% on a real vehicle.

3.4.4. Hybrid Sensors

Integrating driver data features and vehicular features to detect fatigue could drastically increase the accuracy of fatigue detection methods compared to a single feature (from either the driver or the vehicle) approaches. Cheng et al. proposed a technique that incorporates both driver characteristics as well as vehicle characteristics such as eyelid closure, maximum close duration, and percentage of non-steering percentages, percentages of on-center driving, the standard deviation of lane position [205]. A data fusion framework was developed to model the data from the driver and the vehicle. To measure the feature-level fusion, Fisher's linear discriminant was used. Also, the Dempster Shafer evidence theory was used in the decision level fusion process. In this study, the vehicle dependent, and the driver dependent measures, were 81.9% and 86.9% accurate respectively. However, the fusion of both measures were more accurate which was 90.7%.

Sun et al. developed a self-adaptive dynamic recognition model. The features were collected from several sources. Also, the sequential levels of fusion were built at both feature and the decision levels [206].

Naurois et al. developed a detection and prediction model using several physiological and behavioral features, recorded driving behavior, driving time, and participant information [207]. These features were then fed to the ANN model to detect fatigue. The best result was obtained once physical features, driving time, and participant information were employed.

Combinations of biological, and vehicular features have been shown to improve the accuracy of the predictive algorithm [208–210]. A mobile-based support vector machine (M-SVM) was able to classify the driver state with a 95.8% accuracy. Samiee et al. combined features such as eye status, lateral position, SWA, ECG, EEG, and sEMG from 12 subjects to have a prediction system with 94.63% accuracy [210].

In another work, a dynamic probability assignment (BPA) was introduced to the decision-level fusion. In this approach, the weight of each feature changes dynamically, and the combination of the previous fatigue state and the current step in the decision-level fusion are used to improve the result of the fatigue driving detection. Using the fusion

of all fatigue features offers an accuracy of 92.1% (an improvement of 90.8% for vehicle features and 91.6% for facial features) and using only the most useful features offers an accuracy of 93.8% [205].

As a result, due to the complexity of coding every situation to generate predictive crash models using the usual statistical methods, driver fatigue detection algorithms have been developed by using information from drivers' characteristics, vehicle characteristics, or both to detect and predict driver fatigue more efficiently.

3.5. Construction

The construction industry is described as a loosely coupled system with several issues in a typical project [211]. One of these issues is the safety and health of workers at a construction site. According to OSHA data, out of 4779 worker fatalities in private industry in 2018, 1008 or 21.1% were in construction, and among construction fatalities, the leading cause of fatality was falls [212]. Not surprisingly, the focus of most of the AI/OSH papers was on detecting and predicting falls in construction sites (Table 8). Several types of sensors are used to collect data, and a variety of machine learning algorithms are used to analyze and detect falls that are explored further in this section.

Table 8. Construction AI/OSH algorithm, sensor and actuator research organized by the REDECA framework. Major technologies described by each paper is mentioned and linked to the relevant papers [211–256]. Summary of each paper is found in Appendix E.

REDECA Component	AI Algorithms (ML)	Sensors	Actuators	Environment (Type of Hazard)
Prob. R2	SVM: [254]	Pressure: [254] Motion: [256]		Fall: [254,256]
Detect R1→R2	ANN: [253] KNN: [255]	Accelerometer: [253] Audio: [255]		General Safety: [255] Fall: [215,253]
Int. R1→R2			BIM: [215–221]	General Safety: [216] Falls: [215,217–221]
Int. R2→R1	KNN: [255]	Audio: [255]		General Safety: [255]
Prob. R3	ANN: [253]	Accelerometer: [253]		Fall: [253]
Detect R2→R3	ANN: [225,248,253] KNN: [225,231,255] RBF: [225] PPCA: [225] LDA: [225] High level fuzzy: [226] Petri net: [226] GMM: [226] HMM: [245,246] SVM: [227–229,241,248] Decision tree: [230,232–235,244,251] Computer Vision: [238] Naïve Bayes: [242] Pattern matching: [243] Markov Chain: [247]	Accelerometer: [225–230,234,238,251] Gyroscope: [231–233] Barometer: [232,233] Electromyography: [235,236] Camera: [238] Vibration: [241–244] Audio: [242–255] Pressure: [245] Ambient: [246–248]		Fall: [225–236,238,241–248,251] General Safety: [255]
Int. R2→R3				
Prob. Rec.				
Int. R3	KNN: [255]	Audio: [255]		General Safety: [255]

3.5.1. Fall Detection Sensors

Fall detection starts with the gathering of data from sensors. It is essential to have a precise measurement of a fall event to develop an efficient fall-detection algorithm. Falls are unexpected, rare, and diverse events. A fall is defined as "an event which results in a person coming to rest unintendedly on the ground or other lower level, not as a result of a major intrinsic event (such as stroke) or overwhelming hazard" [213,214]. There are no typical methods for fall detection in terms of type of sensors, features to extract, and specific ML algorithms to achieve better results. Fall detection has been detected through building information modeling (BIM) technology in several studies [215–222]. Other reports of fall detection methods in the literature could be divided into three categories: wearable devices, ambiance sensor-based, and camera-based [214,223]. Detection of fall helps to get first responders at the scene quickly and potentially reduce the negative health outcomes related to the fall.

Wearable Devices

Advances in sensor technology have led to the development of non-intrusive small, low-cost sensors that could be integrated into devices such as watches or phones, that can monitor workers in real-time. The number of wearable sensors and their market size has risen significantly and is anticipated to be around 3 billion wearable sensors by the year 2025 (Figure 6) [224]. One main reason that the market is achieving prominence is because of the rising number of health and fitness monitoring applications globally such as the health of the workers in the workplaces.

The most popular features extracted from these sensors are the magnitude of the accelerometer called the signal magnitude vector (SMV) [225–235], the angular magnitude of the gyroscope [232,233], and electromyography [236]. Robust fall detection methods were developed based on acceleration features with sensors placed in the right position in the body [237,238].

Camera-Based

A camera-based sensor is non-intrusive equipment for monitoring the user's environment and behavior by measuring the ratio of the width to the height of an image. Low-cost cameras can detect changes in body movement [238–241] shape, posture, and head movement.

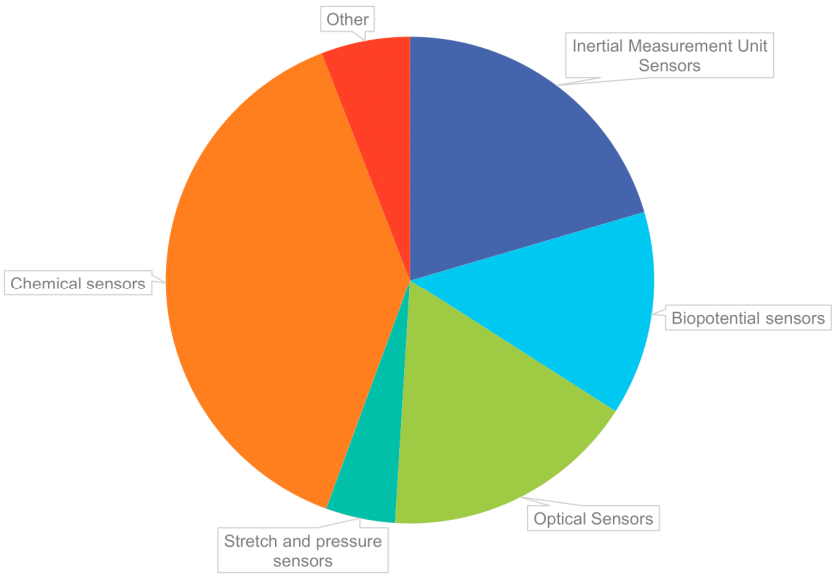


Figure 6. 2020 revenue from wearable sensors, the graph is provided by the market research report 'Wearable Sensors 2021–2031' IDTeachEx [239]. Copyright © 2021 IDTechEx Research. Some rights reserved.

Ambiance Sensors

An ambient device collects information about the changes in the environment surrounding the individual. An ambient sensor such as vibration patterns [242,243], pressure sensors [244,245], detect changes in infrared patterns [246], an electric field [247] which can be used for accurate measurements of various mobility and gait parameters used critically in fall-detection systems [248]. An acoustic sensor makes use of a microphone sensor to capture the movements of the users where Mel Frequency Cepstral Coefficient (MFCC) features are extracted to be analyzed and detect the falls.

3.6. Developing Fall-Detection Algorithms

In almost all of the current research efforts to develop a fall-detection model, the following steps are used: data collection from different sensors, extracting the relevant features from the data, developing the classification models and prediction stage, and finally, evaluating the fall-detection system [31]. Selecting the relevant features improves the accuracy of the prediction method by reducing the size of the noise in the dataset [249]. The developed ML algorithm and the types of sensors that are used can affect the accuracy values significantly. Mubashir et al. found vision-based devices are more robust for detecting falls [250]. Yu et al. advocated for generic fall detection algorithms and the fusion of different sensors such as wearable and vision sensors to provide more accurate fall detection models [223].

Ojetola et al. were able to discriminate between falls and other similar activities by developing a decision tree model, which resulted in a precision value of 81% and a recall value of 92% [251]. Noury et al. [252] and Yu et al. [223] summarized the systems, algorithms, and sensors used for the automatic early detection of the fall and illustrated the difficulty in comparing the performances of the different methods due to the lack of a common framework [252]. The unsupervised learning methods in the research failed to identify the first fall as it was not observed, and the supervised methods were likely to misidentify regular movements as falls [252].

Detection of near-miss fall is also essential as it could evolve into fall incidents in construction sites [253]. Zhang et al. demonstrated the use of smartphones to capture near-miss falls and identify them with an ANN algorithm yielding a precision of 90.02%, recall of 90.93%, and F_1 score of 90.42%.

In case of an injury incident on a construction site where the location of workers is needed for rescue efforts, Liu et al. developed position estimation algorithms based on the strength of the radio signals received from multiple wireless access points inside buildings [11].

In addition, machine learning algorithms could be used to detect and predict falls from scaffolding structures. Sakhakarmi et al. designed a method of classifying scaffolding failure cases and reliably predicting safety conditions based on strain data sets obtained from scaffolding columns [254].

Lee et al. developed a sound recognition system. This technology was able to send immediate notification and alarm to the workers when an incident took place. Also, it was able to provide information regarding safety measures that workers should take in the case of unsafe situations before they start their work activities. The sound features were then fed to a ML algorithm to detect the falls [255].

ML algorithms developed by Yang et al. were able to predict potential fall incidents using data of workers' abnormal gait patterns in a construction site [256]. They found the following four gait parameters (i.e., stride time, stride distance, average velocity, and maximum foot clearance) were better at distinguishing hazardous environments.

As a result, various wearable devices, camera based and ambiance sensors, as well as ML algorithms have been developed to detect the falls.

4. Discussion

The application of AI in the realm of several industries has been described as the Fourth Industrial Revolution [257]. Innovations in artificial intelligence through the use of sensors, robots, ML algorithms have been shown to increase productivity and could potentially improve the safety and health of workers in the workplace. Since the application of AI in workplaces has increased over the past few years, it is very crucial to have a thorough understanding of AI methods, and the effects of these methods on the workers and workplaces as well. To aid in this understanding, this paper developed a the REDECA framework to categorize and highlight the applications of AI in OSH. This novel approach is a natural by-product of the literature developed. It was created by carefully reviewing the literature and developing large categories where the papers in the literature fell. The available OSH AI literature was compiled in tables by industry and by AI system element to identify the key strengths, weaknesses, and opportunities. Tables 4–8 categorizes the available literature by which element of the AI system each publication's intervention focused by the targeted AI approach in the REDECA (Figure 4) framework. This categorization clearly and efficiently highlights the strengths, opportunities, and weaknesses of using AI in OSH.

In brief, the construction industry and evaluating driver fatigue in the transportation industry had many AI algorithms identified in the peer-reviewed literature. These algorithms spanned across most elements of the AI REDECA. Conversely, in agriculture, mining, and oil and gas industries there were very few AI algorithms used. Similarly, we see the agriculture and mining industries have many actuators, when other industries did not. In all industries there were many papers published describing the use of sensors and environment descriptors. The ability to be able to quickly view where there are gaps in the literature across the AI system is strength of using this framework. Another strength of the program is to be able to identify which part of the REDECA is missing AI involvement.

By separating the papers in the published literature into their targeted approach to protecting workers using the AI REDECA it becomes clear that most AI interventions target probabilities, detection, and interventions when a worker is in R1. In general, there is a lack of developed and published material describing AI systems aimed at detecting when someone goes from being exposed to a risk environment (R2) to being injured or put in risk state 3. This then precludes one from establishing how long it will take to return to healthy. There is also an opportunity to develop AI models targeting interventions to keep workers from moving to R3 and interventions to minimize the damage from being in R3 and improve recovery time. When protecting workers, it is important to focus efforts on the early stages of intervention with the goal of never having a worker in R3. Unfortunately, this is not always possible and thus the opportunity uncovered by using this framework is to develop AI systems targeted at reducing the probability and increasing the interventions of workers in R3 of the AI REDECA (Figure 4). These elements are crucial to minimize harm in the event of a workplace incidents.

This paper is not a systematic review of the AI literature. Our paper is the first survey of the reach of existing applications of AI in OSH and documents several examples of how AI can enhance the effectiveness of OSH interventions to protect workers in diverse work sectors. The authors acknowledge the limitations of the current paper and recommend several areas for further exploration:

(1) First and foremost, a systematic review of scientific journals, industry reports and other practice journals may provide insights into more applications of AI in OSH beyond the scope of this survey. Additionally, qualitative approaches may be needed to fully understand the dynamics of AI-OSH teams in the field that have not been captured in this survey.

(2) Our survey did not find any educational papers about AI curriculum or training in OSH. A recent paper specifically highlights the need for OSH professionals, practitioners, researchers, employers, and workers should develop a better understanding of worker health, safety and well-being applications of AI [258]. A comprehensive

scan of existing AI curricula in academia and training and skills needs among OSH professionals in industry may provide a better understanding of future AI capacity needs for OSH researchers and practitioners. For example, a significant increase in the availability of funding for AI applications in healthcare over the past ten years has led to a shift in the number of students and healthcare professionals with access to AI training and the capacity to implement AI applications.

(3) Currently there is no dedicated funding source for AI research or practice in OSH. The fourth industrial revolution (also known and Industry 4.0) is here and the NIOSH Future of Work Initiative was launched in 2019 to identify novel research solutions, practical approaches, and stakeholder opportunities to collectively address the future of work [259,260]. AI, including deep leaning, neural networks and machine learning, are priority topics and subtopics listed in the guiding framework for NIOSH research and practice-based activities as part of this initiative [259]. We need to advocate for resources to fund research and training of OSH professionals in governmental agencies (NIOSH), academic institutions and industries to fully leverage the capacity of AI to protect the health, safety and well-being of workers.

(4) AI will continue to play a very significant role in the design of future workplaces, work health and worker well-being. It is anticipated that massive innovation in industries driven by AI could potentially lead to the creation of new sectors for growth and jobs, and eliminate several existing jobs. Recently the European Commission proposed new rules and actions aiming to "turn Europe into the global hub for trustworthy Artificial Intelligence (AI)" [260]. The goal is to "coordinate a plan with Member States to ensure the safety and fundamental rights of people and businesses, while strengthening AI uptake, investment and innovation across the EU" [260]. This aspect of AI was not the focus of this paper but the authors recognize the potential of AI use on occupational health equity (biased outcomes). OSH researchers and practitioners need to advocate for a long-term strategy in partnership with government, AI experts and industry for protecting the health, safety and well-being of all workers.

5. Conclusions

AI was founded in 1955 as an academic discipline with the idea that a machine can be endowed with tools that can be made precisely to simulate human intelligence. AI will be ubiquitous in the workplace across all industries and can be used to detect, evaluate and predict hazardous events and environments to improve the health and safety of the workers. Application of the REDECA framework has highlighted AI/OSH strengths and opportunities for advances in sensors, robotics, and machine learning algorithms to greatly improve working conditions in the agriculture, oil and gas, mining, transportation and construction sectors. As AI applications across other industries continues to grow, there is a need for collaboration among OSH and industry partners to more systematically explore the benefits and challenges of AI applications in OSH to protect worker health, safety and well-being.

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Appendix A

Table A1. Reports of AI Applications in the Agricultural Industry.

Study	AI Applications		Tasks	OSH Relevance or Outcome
	Sensor/ Robot	Algorithm/ Technology		
[43]	Robotics	NA	Introduction of robotics for land preparation	Reducing the manual work, Prevention of musculoskeletal disorders (MSDs) which is caused over time by repetitive works
[55]	Robotics	NA	Melon detection autonomous	Reducing the manual work while detecting the melon faster
[81]	LiDAR sensors	NA	Tracking robot position from the workers	Reducing possible injuries of the workers due to the HRI
[87]	Robot sprayer	NA	Semiautomatic teleoperation of HRI system	Reducing possible injuries due to the HRI, Reducing the manual work, Preventing diseases due to the exposure to the toxic pesticides
[90]	HRI	NA	Detection of fatigue, workload, and awareness for the human operator	Preventing possible injuries due to fatigue and over workload
[91]	Agricultural robot sprayer	NA	Situation awareness for operator and robot	Reducing possible injuries due to the HRI, Reducing the manual work, Preventing diseases due to the exposure to the toxic pesticides
[94]	NA	DL, simulation	Simulate steering a tractor with almost the same accuracy as the manual steering by analyzing EMG	Reducing manual work, preventing MSDs due to the repetitive steering
[96–98]	Triaxial sensors	NA	Monitoring the level of exposure of the workers to vibration and repetitive activities.	Prevention of MSDs which is caused over time by repetitive works

Appendix B

Table A2. Reports of AI Applications in the Oil and Gas Industry.

Study	AI Applications		Tasks	OSH Relevance or Outcome
	Sensor/ Robot	Algorithm/Technology		
[100]	Temperature and gas sensors	WSN technology using At mega 2560 controller	Oil well monitoring and control	Prevention of the workers from exposure to high-pressure line and equipment, extreme temperature environment, hazardous chemical, explosion, and fires
[101]	NA	ZigBee technology	Remote Monitoring and Control of the pipelines	Prevention of the workers from exposure to hazardous chemical, explosion, and fires

Table A2. *Cont.*

Study	AI Applications		Tasks	OSH Relevance or Outcome
	Sensor/ Robot	Algorithm/Technology		
[102]	Gas safety system for oil drilling sites	WSN technology	Monitoring the oil drilling sites	Prevention of the workers from exposure to ergonomic related injuries such as lifting heavy items, bending, working in awkward postures, and repetitive tasks
[103]	Pressure, Temperature, Acoustic, Vibration sensors	Simulation-based on MATLAB and C++	An efficient oil and gas pipeline monitoring systems	Prevention of the workers from exposure to extreme temperature, high-pressure line and equipment, and ergonomic related injuries due to the repetitive exposure to vibrations
[104]	Flow sensors	WSN technology and game theoretic approach	Pipeline monitoring	Prevention of the workers from exposure to high-pressure line and equipment, hazardous chemical, explosion and fires
[105]	Pressure and temperature sensors	Simulation-based Microcontroller, Zigbee	Monitoring of oil and gas pipelines	Prevention of the workers from exposure to high-pressure line and equipment, hazardous chemical, extreme temperature environment, explosion, and fires
[106]	Pressure, Temperature, sensors	WSN technology	Monitoring of oil and gas pipelines	Prevention of the workers from exposure to high-pressure line and equipment, hazardous chemical, extreme temperature environment, explosion, and fires
[107]	Pressure transducers	SVM, KNN, GMM algorithms	Leakage detection and size estimation	Prevention of the workers from exposure to high-pressure line and equipment, hazardous chemical, extreme temperature environment, explosion, and fires
[108]	Ultrasonic transducers, flow sensors, Transit-Time Ultrasonic Flow Meter(TTUF), Doppler Ultrasonic Flowmeter(DUF)	WSN technology	Detection of leaking in long pipelines	Prevention of the workers from exposure to hazardous chemical, explosion, and fires
[109]	Pressure transducers	SVM, KNN, and GMM algorithms	Leakage detection	Prevention of the workers from exposure to high-pressure line and equipment, hazardous chemical, explosion, and fires
[110]	Magnetic induction-based, pressure and Acoustic sensors	WSN technology	Monitoring underground pipeline	Prevention of the workers from exposure to the high-pressure line and equipment, and hearing injuries
[111]	Pressure, Temperature, Acoustic sensors	WSN technology	Monitoring Underwater pipelines	Prevention of the workers from exposure to extreme temperature, high-pressure line and equipment, and hearing injuries
[112]	NA	graded network, GPRS, Anko-TC series, OMNet++	Remote monitoring terrestrial petroleum pipeline cathodic protection system	Prevention of the workers from exposure to hazardous chemical, explosion, and fires

Table A2. *Cont.*

Study	AI Applications		Tasks	OSH Relevance or Outcome
	Sensor/ Robot	Algorithm/Technology		
[113]	Acoustic sensor	SVM, Wavelet Transform technology	Hierarchical leak detection and localization method in natural gas pipeline monitoring	Prevention of the workers from hearing injuries
[115]	Pressure, Temperature, Acoustic, Vibration sensors	WSN technology	Autonomously monitor and detect any defects in the different downstream operations	Prevention of the workers from exposure to extreme temperature, high-pressure line and equipment, and ergonomic related injuries due to the repetitive exposure to vibrations
[116]	Sensor nodes on the machine, Vibration, and stator current	WSN technology	Autonomously monitor and detect any defects in the operations	Prevention of the workers from ergonomic related injuries due to the repetitive exposure to vibrations
[118]	Propane sensors	WSN technology, Localization algorithms	A gas leak detection and localization with a detection rate of 91%	Prevention of the workers from exposure to hazardous chemical, explosion, and fires
[119]	Pressure, Temperature, Acoustic flow rate sensors	WSN technology	Using pipeline monitoring system to detect and localized leakage and blockage in oilfield pipelines	Prevention of the workers from exposure to extreme temperature, high-pressure line and equipment, and hearing injuries
[120]	Gas, wind, temperature, and humidity sensors	WSN technology	features from environmental sensors such as wind speed used to develop a real-time and large area wireless monitoring system for gas leakage	Prevention of the workers from exposure to high-pressure line and equipment, hazardous chemical, explosion and fires, extreme temperature and humidity environments
[120]	NA	IoT	Data collection	Prevention of the workers from exposure to extreme environments, fall sites
[122]	Different sensors in wearable watches, smart helmets, and smart glasses	IoT	Used by oil field engineers in offshore fields for real-time assistance, safety, and communication with the control room for navigation and enhanced collaboration	Prevention of the workers from exposure to extreme temperature, high-pressure line, and equipment, hazardous chemical, explosion and fires, vehicle accidents, falls, working the confined space, and ergonomic related injuries such lifting heavy items, bending, working in awkward postures
[123]	Sensor-based Pipeline Autonomous Monitoring and Maintenance System (SPAMMS)	WSN technology	Active and corrective monitoring and maintenance of the pipelines	Preventing the workers from exposure to hazardous chemical, explosion, and fires
[124]	Pressure, temperature, acoustic, vibration sensors	Radio-frequency identification (RFID	Detect anomalous events such as pipeline leakage detection	Prevention of the workers from exposure to extreme temperature, high-pressure line and equipment, and ergonomic related injuries due to the repetitive exposure to vibrations

Table A2. *Cont.*

Study	AI Applications		Tasks	OSH Relevance or Outcome
	Sensor/ Robot	Algorithm/Technology		
[125]	Autonomous Systems Wireless Sensor Networks	WSN technology	Digitization of oil fieldsreal-time optimization of drilling operationsthe use of nanotechnologyto aid gauging, reservoir modeling, and diagnostics	Prevention of the workers from exposure to extreme environments, vehicle accidents, falls, working the confined space, ergonomically related injuries such lifting heavy items, bending, working in awkward postures
[126]	Smart robots	AVA classification as an unsupervised ML algorithm	Exploration of oil and gas autonomously	Prevention of the workers from exposure to extreme environments falls
[131]	NA	RF and Landsat 8 OLI imagery algorithms	Map land oil spills	Prevention of the workers from exposure to hazardous chemical, explosion, and fires
[132]	Pressure, Temperature, Acoustic, Vibration sensors	LS-SVM machine learning algorithm, acoustic wave method	Detect leak levels on a gas pipeline	Prevention of the workers from exposure to high-pressure line and equipment, extreme temperature environment, hazardous chemical, explosion, and fires
[133]	Autonomous robot	NA	Inspection of pipeline and other equipment	Prevention of the workers from exposure to extreme environments, vehicle accidents, falls, working the confined space, ergonomic related injuries such as lifting heavy items, bending, working in awkward postures

Appendix C

Table A3. Reports of AI Applications in the Mining Industry.

Study	AI Applications		Tasks	OSH Relevance or Outcome
	Sensor/ Robot	Algorithm/ Technology		
[137]	NA	Decision tree, RF, NN	Predicting mining accident and days away from work	Preventing from accidents in the mining industry by predicting it
[139]	GPS	NA	Monitoring locations and movements	Preventing from fall injury by measuring the gait stability, estimating the fall risk, preventing from entering the workers to the hazardous environments by identifying the location of a workers and warning
[139]	Motion and speed sensors, Communication sensors	NA	Monitor the movement of the workers in remote locations and communicate with them	Preventing from a fall injury, ensuring the safety of the workers by staying connected and communicating with them while they are in the mine
[143]	Environmental sensors	NA	Collecting data from surrounding of the workers	Preventing the workers from harmful bacteria due to high level of humidity, high temperature, hearing damage, and toxic gases in the mine

Table A3. *Cont.*

Study	AI Applications		Tasks	OSH Relevance or Outcome
	Sensor/ Robot	Algorithm/ Technology		
[144]	Toxic gases sensors	NA	Monitoring the level of the toxic gases	Protection of the workers from exposure to the toxic and inflammable gases and prevention of fire explosion in the mine for their safety
[146]	Acoustic sensors, and wearable dust sensors	NA	Monitoring the noise level and monitoring the level of exposure to crystalline silica	Preventing hearing damage and hearing loss of the workers due to the high level of noise in the mine and prevention of respiratory diseases due to the exposure to crystalline silica over time
[147]	IoT and smart robots	NA	Monitoring the real-time information of the mine and mineworkers	Exploring inaccessible areas underground which hazardous situations occur with unpredictable risks that are too severe for human activity
[152]	Smart Helmet Clip wearable sensor	NA	Monitoring the surrounding of the workers to identify the presence of the dangerous gasses	Prevention of the exposure of the workers from toxic and inflammable gases, fire, and explosion in the mine for the safety of the workers
[153]	Angel helmet	NA	Monitoring location and positioning of the workers	Preventing from fall injury by measuring the gait stability, estimating the fall risk, preventing from entering the workers to the hazardous environments by identifying the location of a workers and warning
[154]	Safety helmet with CH4 and CO gas sensors	NA	Monitoring the level of the CH4 and CO gases	Protection of the workers from exposure to the CH4 and CO which are toxic and inflammable in the mine for their safety
[155]	Helmet-Cam	NA	Monitoring the concentration of silica dust	Prevention of respiratory diseases due to the exposure to crystalline silica over time
[156]	Smart devices combining a safety vest, eyewear, helmet, and watch	NA	Monitoring the health and safety of workers in different aspects and monitoring activity of the workers to prevent fall injury	Preventing the workers from head and body injuries through wearing smart eyewear, safety vest, and helmet, preventing the workers from high temperature, hearing damage, and toxic gases in the mine through the smartwatch, and preventing from fall injury of the worker at the mine
[157]	Smartwatch	NA	Monitoring the motion and health of the workers	Preventing from fall injury by measuring the gait stability, estimating the fall risk, preventing from entering the workers to the hazardous environments by identifying the location of a workers and warning
[158]	Smartwatch	NA	Distinguishing the normal from the abnormal posture of the workers	Prevention of the fall injures and reducing risks for MSDs which is caused over time by repeating the abnormal posture of the workers in the mine

Appendix D

Table A4. Reports of AI Applications in the Transportation Industry.

Study	AI Application		Task
	Sensor/ Robot	Algorithm/Technology	
[173]	non-invasive sensors embedded in steering wheels	SVM	Fatigue detection through analyzing ECG features
[174]	PPG sensor on the steering wheel	SVM	Fatigue detection through analyzing PPG features
[175]	Computer vision Sensors on the forehead	SVM	Fatigue detection by analyzing the EoG features
[176]	EEG sensors	Bayesian neural network	Assessment of mental workload, detection of fatigue and drowsiness by analyzing EEG features
[179]	sEMG	Power in band	Fatigue detection by analyzing the sEMG features
[181]	ECG, EEG, EoG	Digital signal processing	Fatigue detection by analyzing the ECG, EEG, EoG features
[184]	Computer vision	Various ML models	Fatigue detection by analyzing the mouth, eye, head movements, and facial expressions as features
[186]	Computer vision	Various ML models	Fatigue detection by analyzing the face tracking method
[188]	Computer vision	SVM	Fatigue detection by analyzing the mouth movement features
[189]	Computer vision	DL	Fatigue detection by analyzing the mouth movement features
[199]	Computer vision	RF	Detecting fatigue through analyzing steering wheel angles
[200]	Computer vision	Binary decision classifier	Detection of fatigue through analyzing the steering wheel angles as features
[203]	Driving simulator	GMM and the Helly model	Fatigue detection by analyzing vehicle velocity, brake pedal, accelerator pedal, and distance from car in-front as features
[204]	Multiple onboard sensors	Linear discriminant	Fatigue detection through analyzing both driver characteristics and vehicle characteristics
[205]	Computer vision, vehicle movement sensors	two-stage data fusion framework	Fatigue detection by analyzing driver and vehicle characteristics
[206]	Computer vision, vehicle movement sensors	ANN	Fatigue detection by analyzing the physiological and behavioral features of the driver
[207]	Computer vision, vehicle movement sensors	M-SVM	Fatigue detection by analyzing the combinations of biological, and vehicular features

OSH relevance or outcome in all cases is 'preventing accident due to fatigue'.

Appendix E

Table A5. Reports of AI Applications in Wearable Devices in Construction.

Study	AI Application	
	Sensor/Robot	Algorithm/Technology
[224]	Accelerometer	Comparator system
[226]	Accelerometer	High level fuzzy, Petri net, GMM
[228]	Accelerometer	SVM
[229]	Accelerometer	Decision tree
[231]	Accelerometer, gyroscope	k-NN
[232]	Accelerometer, gyroscope, barometric altimeter	Decision tree
[233]	Accelerometer, barometric pressure, Gyroscope	Decision tree
[234]	Accelerometer, cardio tachometer	Decision tree
[235]	Electromyography	Decision tree
[240]	Smartphone	Decision tree
[241]	Vibration	SVM
[242]	Vibration, microphone	Naïve Bayes
[243]	Special Piezo pressure transducer	Pattern matching
[244]	Special Piezo pressure transducer	Decision tree
[245]	Special Piezo pressure transducer	HMM

OSH relevance or outcome in all cases is 'detection and prevention of fall'. Tasks in all cases are 'Detecting fall through ML algorithm by analyzing the data which collected through sensors'.

References

1. Perrault, R.; Shoham, Y.; Brynjolfsson, E.; Clark, J.; Etchemendy, J.; Grosz, B.; Lyons, T.; Manyika, J.; Mishra, S.; Niebles, J.C. *The AI Index 2019 Annual Report*; AI Index Steering Committee, Human-Centered AI Institute; Stanford University: Stanford, CA, USA, 2019.
2. Howard, J. Artificial intelligence: Implications for the future of work. *Am. J. Ind. Med.* **2019**, *62*, 917–926. [CrossRef] [PubMed]
3. Turing, A.M. Lecture to the London Mathematical Society on 20 February 1947. *MD Comput.* **1995**, *12*, 390–397. [PubMed]
4. Andresen, S.L. John McCarthy: Father of AI. *IEEE Intell. Syst.* **2002**, *17*, 84–85. [CrossRef]
5. Akbar, S.A.; Chattopadhyay, S.; Elfiky, N.M.; Kak, A. A novel benchmark RGBD dataset for dormant apple trees and its application to automatic pruning. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops, Las Vegas, NV, USA, 27–30 June 2016; pp. 81–88. [CrossRef]
6. Delabrida, S.E.; Angelo, T.D.; Oliveira, R.A.R.; Loureiro, A.A.F. Towards a Wearable Device for Monitoring Ecological Environments. In Proceedings of the 2015 Brazilian Symposium on Computing Systems Engineering (SBESC), Foz do Iguaçu, PR, Brazil, 3–6 November 2015; pp. 148–153. [CrossRef]
7. Ding, J.; Wang, J.; Yuan, N.; Pan, Q. The monitoring system of leakage accidents in crude oil pipeline based on ZigBee technology. In Proceedings of the 2011 Second International Conference on Mechanic Automation and Control Engineering, Inner Mongolia, China, 15–17 July 2011; pp. 1774–1777. [CrossRef]
8. Shukla, A.; Karki, H. Application of robotics in offshore oil and gas industry—A review Part II. *Robot. Auton. Syst.* **2016**, *75*, 508–524. [CrossRef]
9. Belforte, G.; Gay, P.; Aimonino, D.R. Robotics for improving quality, safety and productivity in intensive agriculture: Challenges and opportunities. In *Industrial Robotics: Programming, Simulation and Application*; Low, K.H., Ed.; IntechOpen: London, UK, 2006. [CrossRef]
10. Buczak, A.L.; Wang, H.H.; Darabi, H.; Jafari, M.A. Genetic algorithm convergence study for sensor network optimization. *Inf. Sci.* **2001**, *133*, 267–282. [CrossRef]
11. Liu, H.; Darabi, H.; Banerjee, P. A new rapid sensor deployment approach for first responders. *Int. J. Intell. Control Syst.* **2005**, *10*, 131–142. [CrossRef]
12. Pishgar, M.; Karim, F.; Majumdar, S.; Darabi, H. Pathological voice classification using mel-cepstrum vectors and support vector machine. In Proceedings of the 2018 IEEE International Conference on Big Data, Seattle, WA, USA, 10–13 December 2018. [CrossRef]
13. Barboza, F.; Kimura, H.; Altman, E. Machine learning models and bankruptcy prediction. *Expert Syst. Appl.* **2017**, *83*, 405–417. [CrossRef]
14. Mann, M.; Smith, M. Automated facial recognition technology: Recent developments and approaches to oversight. *UNSWLJ* **2017**, *40*, 121.
15. Davenport, T.; Guha, A.; Grewal, D.; Bressgott, T. How artificial intelligence will change the future of marketing. *J. Acad. Mark. Sci.* **2020**, *48*, 24–42. [CrossRef]

16. Kumar, N.; Gupta, R.; Gupta, S. Whole Slide Imaging (WSI) in Pathology: Current Perspectives and Future Directions. *J. Digit. Imaging* **2020**. [CrossRef]
17. Rhoads, D.D. Computer vision and artificial intelligence are emerging diagnostic tools for the clinical microbiologist. *J. Clin. Microbiol.* **2020**, *58*. [CrossRef]
18. Correll, R. What Is Occupational Health and Safety? Available online: https://www.verywellhealth.com/what-is-occupational-health-and-safety-4159865 (accessed on 3 June 2020).
19. NIOSH. Available online: https://www.cdc.gov/niosh/topics/robotics/default.html (accessed on 1 October 2020).
20. Moore, P.V. OSH and the Future of Work: Benefits and Risks of Artificial Intelligence Tools in Workplaces. In Proceedings of the International Conference on Human-Computer Interaction, Orlando, FL, USA, 26–31 July 2019; pp. 292–315. [CrossRef]
21. Bringsjord, S.A.G.; Sundar, N. Artificial Intelligence. In *Stanford Encyclopedia of Philosophy*; Zalta, E.N., Ed.; Stanford University: Stanford, CA, USA, 2020.
22. Clearing the Confusion: AI vs Machine Learning vs Deep Learning Differences. Available online: https://towardsdatascience.com/clearing-the-confusion-ai-vs-machine-learning-vs-deep-learning-differences-fce69b21d5eb (accessed on 2 October 2020).
23. Hastie, T.; Tibshirani, R.; Friedman, J. *The Elements of Statistical Learning*, 2nd ed.; Springer: New York, NY, USA, 2009.
24. Delahoz, Y.S.; Labrador, M.A. Survey on fall detection and fall prevention using wearable and external sensors. *Sensors* **2014**, *14*, 19806–19842. [CrossRef]
25. Hinton, G.E.; Sejnowski, T.J.; Poggio, T.A. *Unsupervised Learning: Foundations of Neural Computation*; MIT Press: Cambridge, MA, USA, 1999.
26. Zhu, X.; Goldberg, A.B. Introduction to semi-supervised learning. In *Synthesis Lectures on Artificial Intelligence and Machine Learning*; Morgan & Claypool: San Rafael, CA, USA, 2009; Volume 3, pp. 1–130. [CrossRef]
27. Szepesvári, C. Algorithms for reinforcement learning. In *Synthesis Lectures on Artificial Intelligence and Machine Learning*; Morgan & Claypool: San Rafael, CA, USA, 2010; Volume 4, pp. 1–103. [CrossRef]
28. Reinforcement Learning. Available online: https://www.geeksforgeeks.org/what-is-reinforcement-learning/ (accessed on 4 September 2020).
29. Cockburn, I.M.; Henderson, R.; Stern, S. *The Impact of Artificial Intelligence on Innovation*; National Bureau of Economic Research: Cambridge, MA, USA, 2018. [CrossRef]
30. Sikander, G.; Anwar, S. Driver fatigue detection systems: A review. *IEEE Trans. Intell. Transp. Syst.* **2018**, *20*, 2339–2352. [CrossRef]
31. Vallabh, P.; Malekian, R. Fall detection monitoring systems: A comprehensive review. *J. Ambient. Intell. Humaniz. Comput.* **2018**, *9*, 1809–1833. [CrossRef]
32. Olden, J.D.; Lawler, J.J.; Poff, N.L. Machine Learning Methods Without Tears: A Primer for Ecologists. *Q. Rev. Biol.* **2008**, *83*, 171–193. [CrossRef]
33. Winkler-Schwartz, A.; Marwa, I.; Bajunaid, K.; Mullah, M.; Alotaibi, F.E.; Bugdadi, A.; Sawaya, R.; Sabbagh, A.J.; Del Maestro, R. A Comparison of Visual Rating Scales and Simulated Virtual Reality Metrics in Neurosurgical Training: A Generalizability Theory Study. *World Neurosurg.* **2019**, *127*, e230–e235. [CrossRef]
34. Johnson, A.E.W.; Pollard, T.J.; Shen, L.; Lehman, L.H.; Feng, M.; Ghassemi, M.; Moody, B.; Szolovits, P.; Celi, L.A.; Mark, R.G. MIMIC-III, a freely accessible critical care database. *Sci. Data* **2016**, *3*, 160035. [CrossRef]
35. Instituto Colombiano para la Evaluación de la Educación—ICFES. Available online: http://www.icfes.gov.co/ (accessed on 4 April 2020).
36. Kletti, J. *Manufacturing Execution Systems—MES*; Springer: New York, NY, USA, 2010.
37. Kaggle Datasets. Available online: https://www.kaggle.com/datasets (accessed on 5 September 2020).
38. Reason, J. The Contribution of Latent Human Failures to the Breakdown of Complex Systems. *Philos. Trans. R. Soc. Lond. Ser. B* **1990**, *327*, 475–484. [CrossRef]
39. U.S. Bureau of Labor Statistics. Available online: https://www.bls.gov/charts/census-of-fatal-occupational-injuries/number-and-rate-of-fatal-work-injuries-by-industry.htm (accessed on 9 February 2020).
40. Issa, S.F.; Patrick, K.; Thomson, S.; Rein, B. Estimating the Number of Agricultural Fatal Injuries Prevented by Agricultural Engineering Developments in the United States. *Safety* **2019**, *5*, 63. [CrossRef]
41. Moorehead, S.J.; Wellington, C.K.; Paulino, H.; Reid, J.F. R-gator: An unmanned utility vehicle. In Proceedings of the Unmanned Systems Technology XII, Orlando, FL, USA, 6–9 April 2010; p. 769215. [CrossRef]
42. Gogarty, B.; Robinson, I. Unmanned vehicles: A (rebooted) history, background and current state of the art. *J. Law Inf. Sci.* **2011**, *21*, 1. [CrossRef]
43. Sistler, F. Robotics and intelligent machines in agriculture. *IEEE J. Robot. Autom.* **1987**, *3*, 3–6. [CrossRef]
44. Yanco, H.A.; Drury, J.L. A taxonomy for human-robot interaction. In Proceedings of the AAAI Fall Symposium on Human-Robot Interaction, North Falmouth, MA, USA, 15–17 November 2002; pp. 111–119. [CrossRef]
45. Lee, W.; Cho, H.; Hyeong, S.; Chung, W. Practical Modeling of GNSS for Autonomous Vehicles in Urban Environments. *Sensors* **2019**, *19*, 4236. [CrossRef]
46. Marras, W.S.; Lavender, S.A.; Leurgans, S.E.; Rajulu, S.L.; Allread, S.W.G.; Fathallah, F.A.; Ferguson, S.A. The role of dynamic three-dimensional trunk motion in occupationally-related. *Spine* **1993**, *18*, 617–628. [CrossRef]
47. Fathallah, F.A. Musculoskeletal disorders in labor-intensive agriculture. *Appl. Ergon.* **2010**, *41*, 738–743. [CrossRef]

48. Damalas, C.A.; Eleftherohorinos, I.G. Pesticide exposure, safety issues, and risk assessment indicators. *Int. J. Environ. Res. Public Health* **2011**, *8*, 1402–1419. [CrossRef]
49. Issa, S.F.; Cheng, Y.-H.; Field, W. Summary of Agricultural Confined-Space Related Cases: 1964–2013. *J. Agric. Saf. Health* **2016**, *22*, 33–45. [CrossRef]
50. Beaver, R.L.; Field, W.E. Summary of Documented Fatalities in Livestock Manure Storage and Handling Facilities-1975–2004. *J. Agromed.* **2007**, *12*, 3–23. [CrossRef] [PubMed]
51. Cheng, Y.-H.; Field, W.E. Summary of Auger-Related Entanglement Incidents Occurring Inside Agricultural Confined Spaces. *J. Agric. Saf. Health* **2016**, *22*, 91–106. [CrossRef] [PubMed]
52. Baker, L.D.; Field, W.E.S. *Manure Storage Safety*; (ASAE EP470.1); American Society of Agricultural and Biological Engineers: St. Joseph, MI, USA, 2011.
53. Vasconez, J.P.; Kantor, G.A.; Fernando, B.; Cheein, A.A. Human-robot interaction in agriculture: A survey and current challenges. *Biosyst. Eng.* **2019**, *179*, 35–48. [CrossRef]
54. Robert, K.; Elisabeth, Q.; Josef, B. Analysis of occupational accidents with agricultural machinery in the period 2008–2010 in Austria. *Saf. Sci.* **2015**, *72*, 319–328. [CrossRef]
55. Bechar, A.; Vigneault, C. Agricultural robots for field operations: Concepts and components. *Biosyst. Eng.* **2016**, *149*, 94–111. [CrossRef]
56. Van Henten, E.J.; Bac, C.; Hemming, J.; Edan, Y. Robotics in protected cultivation. *IFAC Proc. Vol.* **2013**, *46*, 170–177. [CrossRef]
57. Yaghoubi, S.; Akbarzadeh, N.A.; Bazargani, S.S.; Bazargani, S.S.; Bamizan, M.; Asl, M.I. Autonomous robots for agricultural tasks and farm assignment and future trends in agro robots. *Int. J. Mech. Mechatron. Eng.* **2013**, *13*, 1–6.
58. Moreno, F.-A.; Cielniak, G.; Duckett, T. Evaluation of laser range-finder mapping for agricultural spraying vehicles. In Proceedings of the Conference Towards Autonomous Robotic Systems, Oxford, UK, 28–30 August 2013; pp. 210–221. [CrossRef]
59. Adamides, G.; Katsanos, C.; Parmet, Y.; Christou, G.; Xenos, M.; Hadzilacos, T.; Edan, Y. HRI usability evaluation of interaction modes for a teleoperated agricultural robotic sprayer. *Appl. Ergon.* **2017**, *62*, 237–246. [CrossRef]
60. Oberti, R.; Marchi, M.; Tirelli, P.; Calcante, A.; Iriti, M.; Tona, E.; Hočevar, M.; Baur, J.; Pfaff, J.; Schütz, C. Selective spraying of grapevines for disease control using a modular agricultural robot. *Biosyst. Eng.* **2016**, *146*, 203–215. [CrossRef]
61. Rengifo, H.F.C.; Preciado, J.A.C. Hardware and software architecture for Plexil-based, simulation supported, robot automation. In Proceedings of the 2016 IEEE Colombian Conference on Robotics and Automation (CCRA), Bogota, Colombia, 29–30 September 2016; pp. 1–6. [CrossRef]
62. Hassan, M.U.; Ullah, M.; Iqbal, J. Towards autonomy in agriculture: Design and prototyping of a robotic vehicle with seed selector. In Proceedings of the 2016 2nd International Conference on Robotics and Artificial Intelligence (ICRAI), Rawalpindi, Pakistan, 1–2 November 2016; pp. 37–44. [CrossRef]
63. Slaughter, D.; Giles, D.; Downey, D. Autonomous robotic weed control systems: A review. *Comput. Electron. Agric.* **2008**, *61*, 63–78. [CrossRef]
64. Corollaro, M.L.; Aprea, E.; Endrizzi, I.; Betta, E.; Demattè, M.L.; Charles, M.; Bergamaschi, M.; Costa, F.; Biasioli, F.; Corelli Grappadelli, L.; et al. A combined sensory-instrumental tool for apple quality evaluation. *Postharvest Biol. Technol.* **2014**, *96*, 135–144. [CrossRef]
65. Donis-González, I.R.; Guyer, D.E.; Pease, A.; Fulbright, D.W. Relation of computerized tomography Hounsfield unit measurements and internal components of fresh chestnuts (*Castanea* spp.). *Postharvest Biol. Technol.* **2012**, *64*, 74–82. [CrossRef]
66. Lunadei, L.; Diezma, B.; Lleó, L.; Ruiz-Garcia, L.; Cantalapiedra, S.; Ruiz-Altisent, M. Monitoring of fresh-cut spinach leaves through a multispectral vision system. *Postharvest Biol. Technol.* **2012**, *63*, 74–84. [CrossRef]
67. Munera, S.; Besada, C.; Blasco, J.; Cubero, S.; Salvador, A.; Talens, P.; Aleixos, N. Astringency assessment of persimmon by hyperspectral imaging. *Postharvest Biol. Technol.* **2017**, *125*, 35–41. [CrossRef]
68. Pace, B.; Cefola, M.; Renna, F.; Attolico, G. Relationship between visual appearance and browning as evaluated by image analysis and chemical traits in fresh-cut nectarines. *Postharvest Biol. Technol.* **2011**, *61*, 178–183. [CrossRef]
69. Van Dael, M.; Verboven, P.; Dhaene, J.; Van Hoorebeke, L.; Sijbers, J.; Nicolai, B. Multisensor X-ray inspection of internal defects in horticultural products. *Postharvest Biol. Technol.* **2017**, *128*, 33–43. [CrossRef]
70. Bac, C.W.; van Henten, E.J.; Hemming, J.; Edan, Y. Harvesting robots for high-value crops: State-of-the-art review and challenges ahead. *J. Field Robot.* **2014**, *31*, 888–911. [CrossRef]
71. De-An, Z.; Jidong, L.; Wei, J.; Ying, Z.; Yu, C. Design and control of an apple harvesting robot. *Biosyst. Eng.* **2011**, *110*, 112–122. [CrossRef]
72. Nuske, S.; Achar, S.; Bates, T.; Narasimhan, S.; Singh, S. Yield estimation in vineyards by visual grape detection. In Proceedings of the 2011 IEEE/RSJ International Conference on Intelligent Robots and Systems, San Francisco, CA, USA, 25–30 September 2011; pp. 2352–2358. [CrossRef]
73. Sa, I.; Lehnert, C.; English, A.; McCool, C.; Dayoub, F.; Upcroft, B.; Perez, T. Peduncle detection of sweet pepper for autonomous crop harvesting—Combined Color and 3-D Information. *IEEE Robot. Autom. Lett.* **2017**, *2*, 765–772. [CrossRef]
74. Vitzrabin, E.; Edan, Y. Changing task objectives for improved sweet pepper detection for robotic harvesting. *IEEE Robot. Autom. Lett.* **2016**, *1*, 578–584. [CrossRef]
75. Cullen, R.H.; Smarr, C.-A.; Serrano-Baquero, D.; McBride, S.E.; Beer, J.M.; Rogers, W.A. The smooth (tractor) operator: Insights of knowledge engineering. *Appl. Ergon.* **2012**, *43*, 1122–1130. [CrossRef]

76. Lashgari, M.; Imanmehr, A.; Tavakoli, H. Fusion of acoustic sensing and deep learning techniques for apple mealiness detection. *J. Food Sci. Technol.* **2020**, *57*, 2233–2240. [CrossRef]
77. Diels, E.; Odenthal, T.; Keresztes, J.; Vanmaercke, S.; Verboven, P.; Nicolaï, B.; Saeys, W.; Ramon, H.; Smeets, B. Development of a visco-elastoplastic contact force model and its parameter determination for apples. *Postharvest Biol. Technol.* **2016**, *120*, 157–166. [CrossRef]
78. Kondo, N.; Monta, M.; Fujiura, T. Fruit harvesting robots in Japan. *Adv. Space Res.* **1996**, *18*, 181–184. [CrossRef]
79. Tkach, I.; Bechar, A.; Edan, Y. Switching between collaboration levels in a human–robot target recognition system. *IEEE Trans. Syst. Man Cybern. Part C (Appl. Rev.)* **2011**, *41*, 955–967. [CrossRef]
80. Freitas, G.; Zhang, J.; Hamner, B.; Bergerman, M.; Kantor, G. A low-cost, practical localization system for agricultural vehicles. In Proceedings of the International Conference on Intelligent Robotics and Applications, Montreal, QC, Canada, 3–5 October 2012; pp. 365–375. [CrossRef]
81. Popescu, D.; Stoican, F.; Stamatescu, G.; Ichim, L.; Dragana, C. Advanced UAV-WSN System for Intelligent Monitoring in Precision Agriculture. *Sensors* **2020**, *20*, 817. [CrossRef]
82. Sheridan, T.B. Human-Robot Interaction: Status and Challenges. *Hum. Factors* **2016**, *58*, 525–532. [CrossRef]
83. Al-Ali, Z.M.; Abdullah, M.M.; Asadalla, N.B.; Gholoum, M. A comparative study of remote sensing classification methods for monitoring and assessing desert vegetation using a UAV-based multispectral sensor. *Environ. Monit. Assess.* **2020**, *192*, 389. [CrossRef]
84. Alexandridis, T.K.; Tamouridou, A.A.; Pantazi, X.E.; Lagopodi, A.L.; Kashefi, J.; Ovakoglou, G.; Polychronos, V.; Moshou, D. Novelty Detection Classifiers in Weed Mapping: Silybum marianum Detection on UAV Multispectral Images. *Sensors* **2017**, *17*, 2007. [CrossRef]
85. Basso, M.; Stocchero, D.; Ventura Bayan Henriques, R.; Vian, A.L.; Bredemeier, C.; Konzen, A.A.; Pignaton de Freitas, E. Proposal for an Embedded System Architecture Using a GNDVI Algorithm to Support UAV-Based Agrochemical Spraying. *Sensors* **2019**, *19*, 5397. [CrossRef]
86. Adamides, G.; Christou, G.; Katsanos, C.; Xenos, M.; Hadzilacos, T. Usability Guidelines for the Design of Robot Teleoperation: A Taxonomy. *IEEE Trans. Hum. Mach. Syst.* **2015**, *45*, 256–262. [CrossRef]
87. Adamides, G.; Katsanos, C.; Constantinou, I.; Christou, G.; Xenos, M.; Hadzilacos, T.; Edan, Y. Design and development of a semi-autonomous agricultural vineyard sprayer: Human–robot interaction aspects. *J. Field Robot.* **2017**, *34*, 1407–1426. [CrossRef]
88. Berenstein, R.; Edan, Y. Human-robot collaborative site-specific sprayer. *J. Field Robot.* **2017**, *34*, 1519–1530. [CrossRef]
89. Cantelli, L.; Bonaccorso, F.; Longo, D.; Melita, C.D.; Schillaci, G.; Muscato, G. A Small Versatile Electrical Robot for Autonomous Spraying in Agriculture. *AgriEngineering* **2019**, *1*, 29. [CrossRef]
90. Adamides, G.; Katsanos, C.; Christou, G.; Xenos, M.; Papadavid, G.; Hadzilacos, T. User Interface Considerations for Telerobotics: The Case of an Agricultural Robot Sprayer. In Proceedings of the Second International Conference on Remote Sensing and Geoinformation of the Environment, Paphos, Cyprus, 7–10 April 2014; Volume 9229. [CrossRef]
91. Reina, G.; Milella, A.; Rouveure, R.; Nielsen, M.; Worst, R.; Blas, M.R. Ambient awareness for agricultural robotic vehicles. *Biosyst. Eng.* **2016**, *146*, 114–132. [CrossRef]
92. Berenstein, R.; Edan, Y. Human-robot cooperative precision spraying: Collaboration levels and optimization function. *IFAC Proc. Vol.* **2012**, *45*, 799–804. [CrossRef]
93. Gomez-Gil, J.; San-Jose-Gonzalez, I.; Nicolas-Alonso, L.F.; Alonso-Garcia, S. Steering a tractor by means of an EMG-based human-machine interface. *Sensors* **2011**, *11*, 7110–7126. [CrossRef] [PubMed]
94. Szczepaniak, J.; Tanas, W.; Pawlowski, T.; Kromulski, J. Modelling of agricultural combination driver behaviour from the aspect of safety of movement. *Ann. Agric. Environ. Med.* **2014**, *21*. [CrossRef] [PubMed]
95. Zanatta, M.; Amaral, F.G.; Vidor, G. The role of whole-body vibration in back pain: A cross-sectional study with agricultural pilots. *Int. J. Ind. Ergon.* **2019**, *74*, 102872. [CrossRef]
96. Kociolek, A.M.; Lang, A.E.; Trask, C.M.; Vasiljev, R.M.; Milosavljevic, S. Exploring head and neck vibration exposure from quad bike use in agriculture. *Int. J. Ind. Ergon.* **2018**, *66*, 63–69. [CrossRef]
97. Calvo, A.; Romano, E.; Preti, C.; Schillaci, G.; Deboli, R. Upper limb disorders and hand-arm vibration risks with hand-held olive beaters. *Int. J. Ind. Ergon.* **2018**, *65*, 36–45. [CrossRef]
98. Arguenon, V.; Bergues-Lagarde, A.; Rosenberger, C.; Bro, P.; Smari, W. Multi-agent based prototyping of agriculture robots. In Proceedings of the International Symposium on Collaborative Technologies and Systems (CTS'06), Las Vegas, NV, USA, 14–17 May 2006; pp. 282–288. [CrossRef]
99. Aalsalem, M.Y.; Khan, W.Z.; Gharibi, W.; Khan, M.K.; Arshad, Q. Wireless Sensor Networks in oil and gas industry: Recent advances, taxonomy, requirements, and open challenges. *J. Netw. Comput. Appl.* **2018**, *113*, 87–97. [CrossRef]
100. Barani, R.; Lakshmi, V.J. Oil well monitoring and control based on wireless sensor networks using Atmega 2560 controller. *Int. J. Comput. Sci. Commun. Netw.* **2013**, *3*, 341.
101. Ibrahim, A. Using ZigBee for Wireless Remote Monitoring and Control. *J. Energy* **2015**, *2*, 189–197. [CrossRef]
102. Aliyu, F.; Al-Shaboti, M.; Garba, Y.; Sheltami, T.; Barnawi, A.; Morsy, M.A. Hydrogen sulfide (h2s) gas safety system for oil drilling sites using wireless sensor network. *Procedia Comput. Sci.* **2015**, *63*, 499–504. [CrossRef]

103. Yu, H.; Guo, M. An efficient oil and gas pipeline monitoring systems based on wireless sensor networks. In Proceedings of the 2012 International Conference on Information Security and Intelligent Control, Yunlin, Taiwan, 14–16 August 2012; pp. 178–181. [CrossRef]
104. Islam, M.S.; Nix, R.; Kantarcioglu, M. A game theoretic approach for adversarial pipeline monitoring using Wireless Sensor Networks. In Proceedings of the 2012 IEEE 13th International Conference on Information Reuse & Integration (IRI), Las Vegas, NV, USA, 8–10 August 2012; pp. 37–44. [CrossRef]
105. Saeed, H.; Ali, S.; Rashid, S.; Qaisar, S.; Felemban, E. Reliable monitoring of oil and gas pipelines using wireless sensor network (WSN)—REMONG. In Proceedings of the 2014 9th International Conference on System of Systems Engineering (SOSE), Adelaide, Australia, 9–13 June 2014; pp. 230–235. [CrossRef]
106. Ali, S.; Ashraf, A.; Qaisar, S.B.; Afridi, M.K.; Saeed, H.; Rashid, S.; Felemban, E.A.; Sheikh, A.A. SimpliMote: A wireless sensor network monitoring platform for oil and gas pipelines. *IEEE Syst. J.* **2016**, *12*, 778–789. [CrossRef]
107. Rashid, S.; Akram, U.; Qaisar, S.; Khan, S.A.; Felemban, E. Wireless sensor network for distributed event detection based on machine learning. In Proceedings of the 2014 IEEE International Conference on Internet of Things (iThings), and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom), Taipei, Taiwan, 1–3 September 2014; pp. 540–545. [CrossRef]
108. Santos, A.; Younis, M. A sensor network for non-intrusive and efficient leak detection in long pipelines. In Proceedings of the 2011 IFIP Wireless Days (WD), Niagara Falls, ON, Canada, 10–12 October 2011; pp. 1–6. [CrossRef]
109. Rashid, S.; Akram, U.; Khan, S.A. WML: Wireless sensor network based machine learning for leakage detection and size estimation. *Procedia Comput. Sci.* **2015**, *63*, 171–176. [CrossRef]
110. Sun, Z.; Wang, P.; Vuran, M.C.; Al-Rodhaan, M.A.; Al-Dhelaan, A.M.; Akyildiz, I.F. MISE-PIPE: Magnetic induction-based wireless sensor networks for underground pipeline monitoring. *Ad Hoc Netw.* **2011**, *9*, 218–227. [CrossRef]
111. Al-Jaroodi, J.; Zhang, L.; Jawhar, I.; Mohamed, N. Monitoring Underwater Pipelines Using Sensor Networks. In Proceedings of the 2010 IEEE 12th International Conference on High Performance Computing and Communications (HPCC), Melbourne, VIC, Australia, 1–3 September 2010. [CrossRef]
112. Liu, P.; Huang, Z.; Duan, S.; Wang, Z.; He, J. Optimization for remote monitoring terrestrial petroleum pipeline cathode protection system using graded network. *Int. J. Smart Home* **2015**, *9*, 51–64. [CrossRef]
113. Wan, J.; Yu, Y.; Wu, Y.; Feng, R.; Yu, N. Hierarchical leak detection and localization method in natural gas pipeline monitoring sensor networks. *Sensors* **2012**, *12*, 189–214. [CrossRef]
114. Basu, S.; Pramanik, S.; Dey, S.; Panigrahi, G.; Jana, D.K. Fire monitoring in coal mines using wireless underground sensor network and interval type-2 fuzzy logic controller. *Int. J. Coal Sci. Technol.* **2019**, *6*, 274–285. [CrossRef]
115. Imran, M.; Alnuem, M.A.; Alsalih, W.; Younis, M. A novel wireless sensor and actor network framework for autonomous monitoring and maintenance of lifeline infrastructures. In Proceedings of the 2012 IEEE International Conference on Communications (ICC), Ottawa, ON, Canada, 10–15 June 2012; pp. 6484–6488. [CrossRef]
116. Hou, L.; Bergmann, N.W. Novel industrial wireless sensor networks for machine condition monitoring and fault diagnosis. *IEEE Trans. Instrum. Meas.* **2012**, *61*, 2787–2798. [CrossRef]
117. Jung, J.; Song, B. The possibility of wireless sensor networks for industrial pipe rack safety monitoring. In Proceedings of the 2014 47th Hawaii International Conference on System Sciences, Waikoloa, HI, USA, 6–9 January 2014; pp. 5129–5134. [CrossRef]
118. Chraim, F.; Erol, Y.B.; Pister, K. Wireless gas leak detection and localization. *IEEE Trans. Ind. Inform.* **2015**, *12*, 768–779. [CrossRef]
119. Yoon, S.; Ye, W.; Heidemann, J.; Littlefield, B.; Shahabi, C. SWATS: Wireless sensor networks for steamflood and waterflood pipeline monitoring. *IEEE Netw.* **2011**, *25*, 50–56. [CrossRef]
120. Guo, X.; Wang, Y.; Wei, X. Design of wsn-based environment monitoring system on repair of gas leakage. In Proceedings of the The 27th Chinese Control and Decision Conference (2015 CCDC), Qingdao, China, 23–25 May 2015; pp. 3340–3344. [CrossRef]
121. Khan, W.Z.; Aalsalem, M.Y.; Khan, M.K.; Hossain, M.S.; Atiquzzaman, M. A reliable Internet of Things based architecture for oil and gas industry. In Proceedings of the 2017 19th International Conference on Advanced Communication Technology (ICACT), Pyeongchang, Korea, 19–22 February 2017; pp. 705–710. [CrossRef]
122. Priyadarshy, S. IoT revolution in oil and gas industry. In *Internet of Things and Data Analytics Handbook*; Wiley Telecom: New York, NY, USA, 2017; pp. 513–520. [CrossRef]
123. Kim, J.; Sharma, G.; Boudriga, N.; Iyengar, S.S. SPAMMS: A sensor-based pipeline autonomous monitoring and maintenance system. In Proceedings of the 2010 Second International Conference on COMmunication Systems and NETworks (COMSNETS 2010), Bangalore, India, 5–9 January 2010; pp. 1–10. [CrossRef]
124. Felemban, E.; Sheikh, A.A. RFID for oil and gas industry: Applications and challenges. *Int. J. Eng. Innov. Technol.* **2013**, *3*. [CrossRef]
125. Fjellheim, R.; Landre, E.; Nilssen, R.; Steine, T.; Transeth, A. *Autonomous Systems: Opportunities and Challenges for the Oil and Gas. Industry*; Norwegian Society of Automatic Control: Kristiansand, Norway, 2013. [CrossRef]
126. Bougher, B.; Herrmann, F. AVA classification as an unsupervised machine-learning problem. In Proceedings of the 2016 SEG International Exposition and Annual Meeting, Dallas, TX, USA, 16–21 October 2016. [CrossRef]
127. Noshi, C.; Noynaert, S.; Schubert, J. Casing Failure Using Machine Learning Algorithms: Five Case Studies. In Proceedings of the SPE Thermal Well Integrity and Design Symposium, Banff, AB, Canada, 27–29 November 2018. [CrossRef]

128. Putcha, V.B.; Ertekin, T. A Hybrid Integrated Compositional Reservoir Simulator Coupling Machine Learning and Hard Computing Protocols. In Proceedings of the SPE Kingdom of Saudi Arabia Annual Technical Symposium and Exhibition, Dammam, Saudi Arabia, 23–26 April 2018. [CrossRef]
129. Kellog, R.P.; Chessum, W.; Kwong, R. Machine Learning Application for Wellbore Damage Removal in the Wilmington Field. In Proceedings of the SPE Western Regional Meeting, Garden Grove, CA, USA, 22–26 April 2018. [CrossRef]
130. Bhattacharya, B.; Solomatine, D.P. Machine learning in soil classification. *Neural Netw.* **2006**, *19*, 186–195. [CrossRef]
131. Ozigis, M.S.; Kaduk, J.D.; Jarvis, C.H. Mapping terrestrial oil spill impact using machine learning random forest and Landsat 8 OLI imagery: A case site within the Niger Delta region of Nigeria. *Environ. Sci. Pollut. Res. Int.* **2019**, *26*, 3621–3635. [CrossRef] [PubMed]
132. Jin, H.; Zhang, L.; Liang, W.; Ding, Q. Integrated leakage detection and localization model for gas pipelines based on the acoustic wave method. *J. Loss Prev. Process. Ind.* **2014**, *27*, 74–88. [CrossRef]
133. Mashreq. Disrupting Oil & Gas. Available online: https://www.meed.com/wp-content/uploads/2019/02/Mashreq-Energy-Report-Vol-2.pdf (accessed on 15 June 2019).
134. Number and Rate of Occupational Mining Fatalities by Year, 1983–2019. Available online: https://wwwn.cdc.gov/NIOSH-Mining/MMWC/Fatality/NumberAndRate (accessed on 8 July 2020).
135. Saleh, J.H.; Cummings, A.M. Safety in the mining industry and the unfinished legacy of mining accidents: Safety levers and defense-in-depth for addressing mining hazards. *Saf. Sci.* **2011**, *49*, 764–777. [CrossRef]
136. Hyder, Z.; Siau, K.; Nah, F. Artificial Intelligence, Machine Learning, and Autonomous Technologies in Mining Industry. *J. Database Manag.* **2019**, *30*, 67–79. [CrossRef]
137. Yedla, A.; Kakhki, F.D.; Jannesari, A. Predictive Modeling for Occupational Safety Outcomes and Days Away from Work Analysis in Mining Operations. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7054. [CrossRef]
138. Johnson, L. GPS in mining. *Mining Magazine*, 7 August 1998; 387–389.
139. Baek, J.; Choi, Y.; Lee, C.; Suh, J.; Lee, S. BBUNS: Bluetooth Beacon-Based Underground Navigation System to Support Mine Haulage Operations. *Minerals* **2017**, *7*, 228. [CrossRef]
140. Wang, J. Electrochemical biosensors: Towards point-of-care cancer diagnostics. *Biosens. Bioelectron.* **2006**, *21*, 1887–1892. [CrossRef] [PubMed]
141. Monošík, R.; Stred'anský, M.; Šturdík, E. Biosensors—Classification, characterization and new trends. *Acta Chim. Slovaca* **2012**, *5*, 109–120. [CrossRef]
142. Wang, H.; Peng, D.; Wang, W.; Sharif, H.; Chen, H.; Khoynezhad, A. Resource-aware secure ECG healthcare monitoring through body sensor networks. *IEEE Wirel. Commun.* **2010**, *17*, 12–19. [CrossRef]
143. Jones, K.W. Environmental Sensors. In *Sensors: Micro- and Nanosensor Technology-Trends in Sensor Markets*; Meixner, H., Jones, R., Eds.; Wiley-VCH: Weinheim, Germany, 1995; pp. 451–489.
144. Osunmakinde, I.O. Towards safety from toxic gases in underground mines using wireless sensor networks and ambient intelligence. *Int. J. Distrib. Sens. Netw.* **2013**, *9*, 159273. [CrossRef]
145. Adjiski, V.; Despodov, Z.; Mirakovski, D.; Serafimovski, D. System Architecture to Bring Smart Personal Protective Equipment Wearables and Sensors to Transform Safety at Work in the Underground Mining Industry. *Rud. Geološko Naft. Zb.* **2019**, *34*, 37–44. [CrossRef]
146. Verma, D.K.; Rajhans, G.S.; Malik, O.P.; des Tombe, K. Respirable dust and respirable silica exposure in Ontario gold mines. *J. Occup. Environ. Hyg.* **2014**, *11*, 111–116. [CrossRef]
147. Gunther, D.-I.F.; Mischo, H.; Lösch, R.; Grehl, S.; Güth, F. Increased Safety in Deep Mining with IoT and Autonomous Robots. In *Mining Goes Digital*; CRC Press: Boca Raton, FL, USA, 2019.
148. Sinha, K.; Paul, P. An Underground Mine Safety of Personnel's Using IoT. In *Nanoelectronics, Circuits and Communication Systems*; Springer: Berlin/Heidelberg, Germany, 2019; pp. 77–88. [CrossRef]
149. McNinch, M.; Parks, D.; Jacksha, R.; Miller, A. Leveraging IIoT to Improve Machine Safety in the Mining Industry. *Min. Metall. Explor.* **2019**, *36*, 675–681. [CrossRef]
150. Mishra, P.; Kumar, S.; Kumar, M.; Kumar, J. IoT based multimode sensing platform for underground coal mines. *Wirel. Pers. Commun.* **2019**, *108*, 1227–1242. [CrossRef]
151. Ghasemi, E.; Ataei, M.; Shahriar, K.; Sereshki, F.; Jalali, S.E.; Ramazanzadeh, A. Assessment of roof fall risk during retreat mining in room and pillar coal mines. *Int. J. Rock Mech. Min. Sci.* **2012**, *54*, 80–89. [CrossRef]
152. Vandrico Smartglass. Available online: http://www.motionmetrics.com/press/motion-metrics-partners-with-vandrico-to-develop-smartglass-application-for-mining/ (accessed on 7 September 2019).
153. Angelhelmet. Available online: http://www.angelhelmet.com/index_eng.html (accessed on 5 June 2020).
154. Hazarika, P. Implementation of smart safety helmet for coal mine workers. In Proceedings of the 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), Delhi, India, 4–6 July 2016; pp. 1–3.
155. Haas, E.J.; Cecala, A.B.; Hoebbel, C.L. Using Dust Assessment Technology to Leverage Mine Site Manager-Worker Communication and Health Behavior: A Longitudinal Case Study. *J. Progress. Res. Soc. Sci.* **2016**, *3*, 154–167.
156. Mardonova, M.; Choi, Y. Review of Wearable Device Technology and Its Applications to the Mining Industry. *Energies* **2018**, *11*, 547. [CrossRef]

157. Khoa, T. Wearable Smart Technologies: New Era of Technology. Master's Thesis, Lapland University of Applied Sciences, Lapland, Finland, 2015.
158. Parate, A.; Ganesan, D. Detecting Eating and Smoking Behaviors Using Smartwatches. In *Mobile Health*; Springer: Berlin/Heidelberg, Germany, 2017; pp. 175–201.
159. Klauer, S.G.; Dingus, T.A.; Neale, V.L.; Sudweeks, J.D.; Ramsey, D.J. *The Impact of Driver Inattention on Near-Crash/Crash Risk: An. Analysis Using the 100-Car Naturalistic Driving Study Data*; The Virginia Tech Transportation Institute: Blacksburg, VA, USA, 2006.
160. Stevenson, M.R.; Elkington, J.; Sharwood, L.; Meuleners, L.; Ivers, R.; Boufous, S.; Williamson, A.; Haworth, N.; Quinlan, M.; Grunstein, R. The role of sleepiness, sleep disorders, and the work environment on heavy-vehicle crashes in 2 Australian states. *Am. J. Epidemiol.* **2014**, *179*, 594–601. [CrossRef]
161. Endsley, M.R. Toward a theory of situation awareness in dynamic systems. *Hum. Factors* **1995**, *37*, 32–64. [CrossRef]
162. May, J.F.; Baldwin, C.L. Driver fatigue: The importance of identifying causal factors of fatigue when considering detection and countermeasure technologies. *Transp. Res. Part F Traffic Psychol. Behav.* **2009**, *12*, 218–224. [CrossRef]
163. Kamieńska-Żyła, M.; Prync-Skotniczny, K. Subjective fatigue symptoms among computer systems operators in Poland. *Appl. Ergon.* **1996**, *27*, 217–220. [CrossRef]
164. Kosinski, R.J. A literature review on reaction time. *Clemson Univ.* **2012**, *10*, 337–344.
165. Schleicher, R.; Galley, N.; Briest, S.; Galley, L. Blinks and saccades as indicators of fatigue in sleepiness warnings: Looking tired? *Ergonomics* **2008**, *51*, 982–1010. [CrossRef]
166. Bekiaris, E.; Amditis, A.; Wevers, K. Advanced driver monitoring-the awake project. In Proceedings of the 8th World Congress on ITS, Sydney, Australia, 30 September–4 October 2001.
167. Kaida, K.; Takahashi, M.; Åkerstedt, T.; Nakata, A.; Otsuka, Y.; Haratani, T.; Fukasawa, K. Validation of the Karolinska sleepiness scale against performance and EEG variables. *Clin. Neurophysiol.* **2006**, *117*, 1574–1581. [CrossRef]
168. Hu, S.; Zheng, G. Driver drowsiness detection with eyelid related parameters by Support Vector Machine. *Expert Syst. Appl.* **2009**, *36*, 7651–7658. [CrossRef]
169. Zielinski, M.R.; Systrom, D.M.; Rose, N.R. Fatigue, Sleep, and Autoimmune and Related Disorders. *Front. Immunol.* **2019**, *10*, 1827. [CrossRef]
170. Körber, M.; Cingel, A.; Zimmermann, M.; Bengler, K. Vigilance decrement and passive fatigue caused by monotony in automated driving. *Procedia Manuf.* **2015**, *3*, 2403–2409. [CrossRef]
171. Thiffault, P.; Bergeron, J. Monotony of road environment and driver fatigue: A simulator study. *Accid. Anal. Prev.* **2003**, *35*, 381–391. [CrossRef]
172. Bougard, C.; Espié, S.; Larnaudie, B.; Moussay, S.; Davenne, D. Effects of time of day and sleep deprivation on motorcycle-driving performance. *PLoS ONE* **2012**, *7*. [CrossRef]
173. Jung, S.-J.; Shin, H.-S.; Chung, W.-Y. Driver fatigue and drowsiness monitoring system with embedded electrocardiogram sensor on steering wheel. *IET Intell. Transp. Syst.* **2014**, *8*, 43–50. [CrossRef]
174. Li, G.; Chung, W.-Y. Detection of Driver Drowsiness Using Wavelet Analysis of Heart Rate Variability and a Support Vector Machine Classifier. *Sensors* **2013**, *13*, 16494–16511. [CrossRef]
175. Zhang, X.; Gao, X.; Zhu, J.; Zheng, W.; Lu, B. A novel approach to driving fatigue detection using forehead EOG. In Proceedings of the 2015 7th International IEEE/EMBS Conference on Neural Engineering (NER), Montpellier, France, 22–24 April 2015; pp. 707–710. [CrossRef]
176. Britton, J.W.; Frey, L.C.; Hopp, J.L.; Korb, P.; Koubeissi, M.Z.; Lievens, W.E.; Pestana-Knight, E.M.; St. Louis, E.K. *Electroencephalography (EEG): An Introductory Text. and Atlas of Normal and Abnormal Findings in Adults, Children, and Infants*; American Epilepsy Society: Chicago, IL, USA, 2016.
177. Borghini, G.; Vecchiato, G.; Toppi, J.; Astolfi, L.; Maglione, A.; Isabella, R.; Caltagirone, C.; Kong, W.; Wei, D.; Zhou, Z.; et al. Assessment of mental fatigue during car driving by using high resolution EEG activity and neurophysiologic indices. In Proceedings of the 2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, San Diego, CA, USA, 28 August–1 September 2012; pp. 6442–6445. [CrossRef]
178. Borghini, G.; Astolfi, L.; Vecchiato, G.; Mattia, D.; Babiloni, F. Measuring neurophysiological signals in aircraft pilots and car drivers for the assessment of mental workload, fatigue and drowsiness. *Neurosci. Biobehav. Rev.* **2014**, *44*, 58–75. [CrossRef]
179. De Luca, C.J. Myoelectrical manifestations of localized muscular fatigue in humans. *Crit. Rev. Biomed. Eng.* **1984**, *11*, 251–279.
180. Balasubramanian, V.; Adalarasu, K. EMG-based analysis of change in muscle activity during simulated driving. *J. Bodyw. Mov. Ther.* **2007**, *11*, 151–158. [CrossRef]
181. Sun, Y.; Yu, X. An innovative nonintrusive driver assistance system for vital signal monitoring. *IEEE J. Biomed. Health Inform.* **2014**, *18*, 1932–1939. [CrossRef]
182. Chai, R.; Naik, G.R.; Nguyen, T.N.; Ling, S.H.; Tran, Y.; Craig, A.; Nguyen, H.T. Driver Fatigue Classification With Independent Component by Entropy Rate Bound Minimization Analysis in an EEG-Based System. *IEEE J. Biomed. Health Inform.* **2017**, *21*, 715–724. [CrossRef]
183. Yang, Y.; Gao, Z.; Li, Y.; Cai, Q.; Marwan, N.; Kurths, J. A Complex Network-Based Broad Learning System for Detecting Driver Fatigue From EEG Signals. *IEEE Trans. Syst. Man Cybern. Syst.* **2019**. [CrossRef]
184. Gengler, A. Are you on Track? Money 2007. p. 114. Available online: https://money.cnn.com/magazines/moneymag/moneymag_archive/2007/01/01/8397408/index.htm (accessed on 7 March 2020).

185. Morimoto, C.H.; Koons, D.; Amir, A.; Flickner, M. Pupil detection and tracking using multiple light sources. *Image Vis. Comput.* **2000**, *18*, 331–335. [CrossRef]
186. Wang, Q.; Yang, J.; Ren, M.; Zheng, Y. Driver Fatigue Detection: A Survey. In Proceedings of the 6th World Congress on Intelligent Control and Automation, Dalian, China, 21–23 June 2006; IEEE: Piscataway, NJ, USA, 2006; Volume 15, pp. 8587–8591. [CrossRef]
187. Sigari, M.-H.; Fathy, M.; Soryani, M. A Driver Face Monitoring System for Fatigue and Distraction Detection. *Int. J. Veh. Technol.* **2013**, *2013*, 263983. [CrossRef]
188. Mandal, B.; Li, L.; Wang, G.S.; Lin, J. Towards Detection of Bus Driver Fatigue Based on Robust Visual Analysis of Eye State. *IEEE Trans. Intell. Transp. Syst.* **2017**, *18*, 545–557. [CrossRef]
189. Alioua, N.; Amine, A.; Rziza, M. Driver's Fatigue Detection Based on Yawning Extraction. *Int. J. Veh. Technol.* **2014**, *2014*, 678786. [CrossRef]
190. Dwivedi, K.; Biswaranjan, K.; Sethi, A. Drowsy driver detection using representation learning. In Proceedings of the 2014 IEEE International Advance Computing Conference (IACC), Gurgaon, New Delhi, India, 21–22 February 2014; pp. 995–999. [CrossRef]
191. Nikolskaia, K.; Bessonov, V.; Starkov, A.; Minbaleev, A. Prototype of Driver Fatigue Detection System Using Convolutional Neural Network. In Proceedings of the 2019 International Conference Quality Management, Transport and Information Security, Information Technologies (IT&QM&IS), Sochi, Russia, 23–27 September 2019; pp. 82–86. [CrossRef]
192. Gu, W.H.; Zhu, Y.; Chen, X.D.; He, L.F.; Zheng, B.B. Hierarchical CNN-based real-time fatigue detection system by visual-based technologies using MSP model. *IET Image Process.* **2018**, *12*, 2319–2329. [CrossRef]
193. Bretzner, L.; Krantz, M. Towards low-cost systems for measuring visual cues of driver fatigue and inattention in automotive applications. In Proceedings of the IEEE International Conference on Vehicular Electronics and Safety, Xi'an, Shaan'xi, China, 14–16 October 2005; pp. 161–164.
194. Optalert. Available online: https://www.optalert.com/optalert-drowsiness-attentiveness-monitoring/ (accessed on 9 June 2020).
195. Care Drive. Available online: http://www.care-drive.com/product/driver-fatigue-monitor-mr688/ (accessed on 9 June 2020).
196. Guardvant. Available online: https://www.mining-technology.com/contractors/health-and-safety/guardvant/ (accessed on 12 May 2020).
197. Toyota. Available online: https://www.toyota.com/content/ebrochure/CFA_TSS_P.pdf (accessed on 7 March 2020).
198. Nissan. Available online: https://www.nissan.co.uk/corporate-sales/intelligent-mobility/safety-shield.html (accessed on 11 March 2020).
199. Volkswagen. Available online: https://www.volkswagen.co.uk/technology/car-safety/driver-alert-system (accessed on 12 March 2020).
200. McDonald, A.D.; Schwarz, C.; Lee, J.D.; Brown, T.L. Real-Time Detection of Drowsiness Related Lane Departures Using Steering Wheel Angle. *Proc. Hum. Factors Ergon. Soc. Annu. Meet.* **2012**, *56*, 2201–2205. [CrossRef]
201. Li, Z.; Li, S.E.; Li, R.; Cheng, B.; Shi, J. Online Detection of Driver Fatigue Using Steering Wheel Angles for Real Driving Conditions. *Sensors* **2017**, *17*, 495. [CrossRef]
202. Yang, J.H.; Mao, Z.; Tijerina, L.; Pilutti, T.; Coughlin, J.F.; Feron, E. Detection of Driver Fatigue Caused by Sleep Deprivation. *IEEE Trans. Syst. Man Cybern. Part A Syst. Hum.* **2009**, *39*, 694–705. [CrossRef]
203. Furugori, S.; Yoshizawa, N.; Iname, C.; Miura, Y. Estimation of driver fatigue by pressure distribution on seat in long term driving. *Rev. Automot. Eng.* **2005**, *26*, 53–58.
204. Wakita, T.; Ozawa, K.; Miyajima, C.; Igarashi, K.; Itou, K.; Takeda, K.; Itakura, F. Driver identification using driving behavior signals. *IEICE Trans. Inf. Syst.* **2005**, *89*, 1188–1194. [CrossRef]
205. Cheng, B.; Zhang, W.; Lin, Y.; Feng, R.; Zhang, X. Driver drowsiness detection based on multisource information. *Hum. Factors Ergon. Manuf. Serv. Ind.* **2012**, *22*, 450–467. [CrossRef]
206. Sun, W.; Zhang, X.; Peeta, S.; He, X.; Li, Y.; Zhu, S. A Self-Adaptive Dynamic Recognition Model for Fatigue Driving Based on Multi-Source Information and Two Levels of Fusion. *Sensors* **2015**, *15*, 24191–24213. [CrossRef]
207. Jacobé de Naurois, C.; Bourdin, C.; Stratulat, A.; Diaz, E.; Vercher, J.-L. Detection and prediction of driver drowsiness using artificial neural network models. *Accid. Anal. Prev.* **2019**, *126*, 95–104. [CrossRef]
208. Lee, B.; Chung, W. Driver Alertness Monitoring Using Fusion of Facial Features and Bio-Signals. *IEEE Sens. J.* **2012**, *12*, 2416–2422. [CrossRef]
209. Lee, B.; Lee, B.; Chung, W. Smartwatch-based driver alertness monitoring with wearable motion and physiological sensor. In Proceedings of the 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Milan, Italy, 25–29 August 2015; pp. 6126–6129. [CrossRef]
210. Samiee, S.; Azadi, S.; Kazemi, R.; Nahvi, A.; Eichberger, A. Data Fusion to Develop a Driver Drowsiness Detection System with Robustness to Signal Loss. *Sensors* **2014**, *14*, 17832–17847. [CrossRef]
211. Dubois, A.; Gadde, L.-E. The construction industry as a loosely coupled system: Implications for productivity and innovation. *Constr. Manag. Econ.* **2002**, *20*, 621–631. [CrossRef]
212. OSHA. Available online: https://www.osha.gov/data/commonstats (accessed on 1 February 2021).
213. Igual, R.; Medrano, C.; Plaza, I. Challenges, issues and trends in fall detection systems. *Biomed. Eng. Online* **2013**, *12*, 66. [CrossRef]
214. Khan, S.S.; Hoey, J. Review of fall detection techniques: A data availability perspective. *Med. Eng. Phys.* **2017**, *39*, 12–22. [CrossRef]

215. Zhang, S.; Teizer, J.; Lee, J.-K.; Eastman, C.M.; Venugopal, M. Building Information Modeling (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules. *Autom. Constr.* **2013**, *29*, 183–195. [CrossRef]
216. Hossain, M.M.; Ahmed, S. Developing an automated safety checking system using BIM: A case study in the Bangladeshi construction industry. *Int. J. Constr. Manag.* **2019**, 1–19. [CrossRef]
217. Khan, N.; Ali, A.K.; Skibniewski, M.J.; Lee, D.Y.; Park, C. Excavation Safety Modeling Approach Using BIM and VPL. *Adv. Civ. Eng.* **2019**, *2019*, 1515808. [CrossRef]
218. Qi, J.; Issa Raja, R.A.; Olbina, S.; Hinze, J. Use of Building Information Modeling in Design to Prevent Construction Worker Falls. *J. Comput. Civ. Eng.* **2014**, *28*, A4014008. [CrossRef]
219. Melzner, J.; Zhang, S.; Teizer, J.; Bargstädt, H.-J. A case study on automated safety compliance checking to assist fall protection design and planning in building information models. *Constr. Manag. Econ.* **2013**, *31*, 661–674. [CrossRef]
220. Zhang, S.; Sulankivi, K.; Kiviniemi, M.; Romo, I.; Eastman, C.M.; Teizer, J. BIM-based fall hazard identification and prevention in construction safety planning. *Saf. Sci.* **2015**, *72*, 31–45. [CrossRef]
221. Abed, H.R.; Hatem, W.A.; Jasim, N.A. Adopting BIM Technology in Fall Prevention Plans. *Civ. Eng. J.* **2019**, *5*, 2270–2281. [CrossRef]
222. Fargnoli, M.; Lombardi, M. Preliminary Human Safety Assessment (PHSA) for the Improvement of the Behavioral Aspects of Safety Climate in the Construction Industry. *Buildings* **2019**, *9*, 69. [CrossRef]
223. Yu, X. Approaches and principles of fall detection for elderly and patient. In Proceedings of the HealthCom 2008-10th International Conference on E-health Networking, Applications and Services, Singapore, 7–9 July 2008; pp. 42–47. [CrossRef]
224. Shuai, G.; Martinez-Feria, R.A.; Zhang, J.; Li, S.; Price, R.; Basso, B. Capturing Maize Stand Heterogeneity Across Yield-Stability Zones Using Unmanned Aerial Vehicles (UAV). *Sensors* **2019**, *19*, 4446. [CrossRef]
225. Gibson, R.M.; Amira, A.; Ramzan, N.; Casaseca-de-la-Higuera, P.; Pervez, Z. Multiple comparator classifier framework for accelerometer-based fall detection and diagnostic. *Appl. Soft Comput.* **2016**, *39*, 94–103. [CrossRef]
226. Shen, V.R.; Lai, H.-Y.; Lai, A.-F. The implementation of a smartphone-based fall detection system using a high-level fuzzy Petri net. *Appl. Soft Comput.* **2015**, *26*, 390–400. [CrossRef]
227. Pannurat, N.; Thiemjarus, S.; Nantajeewarawat, E. A hybrid temporal reasoning framework for fall monitoring. *IEEE Sens. J.* **2017**, *17*, 1749–1759. [CrossRef]
228. Karantonis, D.M.; Narayanan, M.R.; Mathie, M.; Lovell, N.H.; Celler, B.G. Implementation of a real-time human movement classifier using a triaxial accelerometer for ambulatory monitoring. *IEEE Trans. Inf. Technol. Biomed.* **2006**, *10*, 156–167. [CrossRef]
229. Zhang, T.; Wang, J.; Xu, L.; Liu, P. Fall detection by wearable sensor and one-class SVM algorithm. In *Intelligent Computing in Signal Processing and Pattern Recognition*; Springer: Berlin/Heidelberg, Germany, 2006; pp. 858–863.
230. Anania, G.; Tognetti, A.; Carbonaro, N.; Tesconi, M.; Cutolo, F.; Zupone, G.; De Rossi, D. Development of a novel algorithm for human fall detection using wearable sensors. In Proceedings of the SENSORS, 2008 IEEE, Lecce, Italy, 26–29 October 2008; pp. 1336–1339. [CrossRef]
231. Lai, C.-F.; Chang, S.-Y.; Chao, H.-C.; Huang, Y.-M. Detection of cognitive injured body region using multiple triaxial accelerometers for elderly falling. *IEEE Sens. J.* **2010**, *11*, 763–770. [CrossRef]
232. Jian, H.; Chen, H. A portable fall detection and alerting system based on k-NN algorithm and remote medicine. *China Commun.* **2015**, *12*, 23–31. [CrossRef]
233. Sabatini, A.M.; Ligorio, G.; Mannini, A.; Genovese, V.; Pinna, L. Prior-to-and post-impact fall detection using inertial and barometric altimeter measurements. *IEEE Trans. Neural Syst. Rehabil. Eng.* **2015**, *24*, 774–783. [CrossRef]
234. Bianchi, F.; Redmond, S.J.; Narayanan, M.R.; Cerutti, S.; Lovell, N.H. Barometric pressure and triaxial accelerometry-based falls event detection. *IEEE Trans. Neural Syst. Rehabil. Eng.* **2010**, *18*, 619–627. [CrossRef]
235. Wang, J.; Zhang, Z.; Li, B.; Lee, S.; Sherratt, R.S. An enhanced fall detection system for elderly person monitoring using consumer home networks. *IEEE Trans. Consum. Electron.* **2014**, *60*, 23–29. [CrossRef]
236. Leone, A.; Rescio, G.; Caroppo, A.; Siciliano, P. A wearable EMG-based system pre-fall detector. *Procedia Eng.* **2015**, *120*, 455–458. [CrossRef]
237. Perry, J.T.; Kellog, S.; Vaidya, S.M.; Youn, J.-H.; Ali, H.; Sharif, H. Survey and evaluation of real-time fall detection approaches. In Proceedings of the 2009 6th International Symposium on High Capacity Optical Networks and Enabling Technologies (HONET), Alexandria, Egypt, 28–30 December 2009; pp. 158–164. [CrossRef]
238. Ozcan, K.; Velipasalar, S. Wearable camera-and accelerometer-based fall detection on portable devices. *IEEE Embed. Syst. Lett.* **2015**, *8*, 6–9. [CrossRef]
239. Hayward, J.; Chansin, D.G. Wearable Sensors 2021–2031: Market Forecasts, Technologies, Players. Available online: https://www.idtechex.com/en/research-report/wearable-sensors-2021-2031/780 (accessed on 18 June 2021).
240. Kumari, P.; Mathew, L.; Syal, P. Increasing trend of wearables and multimodal interface for human activity monitoring: A review. *Biosens. Bioelectron.* **2017**, *90*, 298–307. [CrossRef]
241. Ozcan, K.; Velipasalar, S.; Varshney, P.K. Autonomous fall detection with wearable cameras by using relative entropy distance measure. *IEEE Trans. Hum. Mach. Syst.* **2016**, *47*, 31–39. [CrossRef]
242. Yazar, A.; Keskin, F.; Töreyin, B.U.; Çetin, A.E. Fall detection using single-tree complex wavelet transform. *Pattern Recognit. Lett.* **2013**, *34*, 1945–1952. [CrossRef]

243. Zigel, Y.; Litvak, D.; Gannot, I. A method for automatic fall detection of elderly people using floor vibrations and sound—Proof of concept on human mimicking doll falls. *IEEE Trans. Biomed. Eng.* **2009**, *56*, 2858–2867. [CrossRef] [PubMed]
244. Alwan, M.; Rajendran, P.J.; Kell, S.; Mack, D.; Dalal, S.; Wolfe, M.; Felder, R. A smart and passive floor-vibration based fall detector for elderly. In Proceedings of the 2006 2nd International Conference on Information & Communication Technologies, Damascus, Syria, 24–28 April 2006; pp. 1003–1007. [CrossRef]
245. Chaccour, K.; Darazi, R.; el Hassans, A.H.; Andres, E. Smart carpet using differential piezoresistive pressure sensors for elderly fall detection. In Proceedings of the 2015 IEEE 11th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), Abu Dhabi, United Arab Emirates, 19–21 October 2015; pp. 225–229. [CrossRef]
246. Popescu, M.; Hotrabhavananda, B.; Moore, M.; Skubic, M. VAMPIR-an automatic fall detection system using a vertical PIR sensor array. In Proceedings of the 2012 6th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops, San Diego, CA, USA, 21–24 May 2012; pp. 163–166. [CrossRef]
247. Rimminen, H.; Lindström, J.; Linnavuo, M.; Sepponen, R. Detection of falls among the elderly by a floor sensor using the electric near field. *IEEE Trans. Inf. Technol. Biomed.* **2010**, *14*, 1475–1476. [CrossRef]
248. Van de Ven, P.; O'Brien, H.; Nelson, J.; Clifford, A. Unobtrusive monitoring and identification of fall accidents. *Med. Eng. Phys.* **2015**, *37*, 499–504. [CrossRef] [PubMed]
249. Daher, M.; Diab, A.; El Najjar, M.E.B.; Khalil, M.A.; Charpillet, F. Elder tracking and fall detection system using smart tiles. *IEEE Sens. J.* **2016**, *17*, 469–479. [CrossRef]
250. Mubashir, M.; Shao, L.; Seed, L. A survey on fall detection: Principles and approaches. *Neurocomputing* **2013**, *100*, 144–152. [CrossRef]
251. Ojetola, O.; Gaura, E.I.; Brusey, J. Fall detection with wearable sensors–safe (Smart Fall Detection). In Proceedings of the 2011 Seventh International Conference on Intelligent Environments, Nottingham, UK, 25–28 July 2011; pp. 318–321. [CrossRef]
252. Noury, N.; Fleury, A.; Rumeau, P.; Bourke, A.; Laighin, G.; Rialle, V.; Lundy, J. Fall detection—Principles and methods. In Proceedings of the 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Lyon, France, 22–26 August 2007; pp. 1663–1666. [CrossRef]
253. Zhang, M.; Cao, T.; Zhao, X. Using Smartphones to Detect and Identify Construction Workers' Near-Miss Falls Based on ANN. *J. Constr. Eng. Manag.* **2019**, *145*, 04018120. [CrossRef]
254. Sakhakarmi, S.; Park, J.; Cho, C. Enhanced machine learning classification accuracy for scaffolding safety using increased features. *J. Constr. Eng. Manag.* **2019**, *145*, 04018133. [CrossRef]
255. Lee, Y.-C.; Shariatfar, M.; Rashidi, A.; Lee, H.W. Evidence-driven sound detection for prenotification and identification of construction safety hazards and accidents. *Autom. Constr.* **2020**, *113*, 103127. [CrossRef]
256. Yang, K.; Ahn, C.R.; Kim, H. Validating ambulatory gait assessment technique for hazard sensing in construction environments. *Autom. Constr.* **2019**, *98*, 302–309. [CrossRef]
257. Schwab, K. *The Fourth Industrial Revolution*; Currency: Redfern, NSW, Australia, 2017.
258. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the Future of Work to Safeguard the Safety, Health, and Well-being of the Workforce: A Perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
259. Future of Work. Available online: https://www.cdc.gov/niosh/topics/future-of-work/default (accessed on 9 June 2020).
260. Shaping Europe's Digital Future. Available online: https://digital-strategy.ec.europa.eu/en (accessed on 17 May 2021).

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Thriving from Work: Conceptualization and Measurement

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Abstract: Work is a major contributor to our health and well-being. Workers' thriving is directly influenced by their job design, work environment and organization. The purpose of this report is to describe the qualitative methods used to develop the candidate items for a novel measure of Thriving from Work through a multi-step iterative process including: a literature review, workshop, interviews with experts, and cognitive testing of the candidate items. Through this process, we defined Thriving from Work as the state of positive mental, physical, and social functioning in which workers' experiences of their work and working conditions enable them to thrive in their overall lives, contributing to their ability to achieve their full potential in their work, home, and community. Thriving from Work was conceptualized into 37 attributes across seven dimensions: psychological, emotional, social, work–life integration, basic needs, experience of work, and health. We ultimately identified, developed and/or modified 87 candidate questionnaire items mapped to these attributes that performed well in cognitive testing in demographically and occupationally diverse workers. The Thriving from Work Questionnaire will be subjected to psychometric testing and item reduction in future studies. Individual items demonstrated face validity and good cognitive response properties and may be used independently from the questionnaire.

Keywords: total worker health; healthy work design and well-being; flourishing; questionnaire design; survey design; cognitive interviewing; measurement of well-being; thriving; worker well-being; worker thriving

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1. Introduction

Work is a central human life function, with workers, on average, spending over one-third of their waking hours performing work-related activities [1]. Work plays a major role in shaping health and well-being; thus, employment is a well-recognized social determinant of health and a leading health indicator for the United States' Healthy People 2030 initiative [2,3]. Exposures to specific conditions of work—physical, organizational, and psychosocial—not only contribute to injury and increase the risk of ill-health and mental distress but may also be instrumental in fostering well-being [4]. Many people work long hours, experience work overload, have excessive emotional and cognitive job demands, and are exposed to hazardous and stressful working conditions [5]. With current technologies and in response to the COVID-19 pandemic, the lines between work and non-work commitments are blurring. Burnout [6–12] and substance use, such as alcohol dependence and opioid misuse [13–15], are on the increase in many industries.

All of these circumstances are likely to have detrimental impacts on health and well-being. Positive working conditions have been associated with fostering worker well-being, such as supervisor support and leadership behaviors [16,17]; coworker support [18]; decision latitude, job and schedule control and autonomy [19–21]; positive organizational culture [22]; opportunities for advancement [23]; and fair pay [23].

Traditionally, occupational health and safety research has focused primarily on understanding the causes of disease and on developing strategies for limiting or mitigating risk. An expanded focus on the potential beneficial influence of work on health and well-being can provide a complementary expansion to the traditional occupational health and safety paradigm [24]. The World Health Organization's definition of Health as *"a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"* [25], is supportive of considering both the health risks and health benefits of work.

The National Institute for Occupational Safety and Health (NIOSH) and other leading international health agencies have recognized that work can have a profound positive influence on health and well-being [26–29]. Nevertheless, this important area of research remains largely understudied. One reason for this is the lack of reliable and valid instruments that can be used in various populations to measure worker well-being in the context of the conditions of work.

Thriving contributes to an individuals' vitality, personal and professional growth, and life satisfaction [30–34]. Brown et al. defined *thriving as "the state of positive functioning at its fullest range—mentally, physically, and socially*." [30] (p. 256). Spreitzer et al. conceptualized a narrower view of thriving than Brown et al., centered only on vitality and learning [33,35,36]. Based on this narrower conceptualization of thriving, Porath et al. developed the 'Thriving at Work Scale' which focused only on these two dimensions [37], without recognition of the bidirectional nature that work and life outside work have on each other. Although this instrument has strong theoretical underpinnings, it has been critiqued based on its limited focus and interpretation; and others, such as Brown et al. [30], have recommended that a broader instrument of thriving from work is needed.

A method to assess worker's thriving is needed in the occupational health field for several reasons. A standard measure of thriving from work would allow comparisons across worker populations and across studies of the same population, and could be used to evaluate the effect of interventions on a common scale. Our goal is to design an instrument that can be used for both research and practice with diverse applications: (a) as an outcome measure of workers' thriving, and dimensions of workers' thriving, (b) as a vehicle for periodic surveillance across a diversely employed worker population or within a single employing organization, (c) as an organizational diagnostic tool to identify priority areas for interventions to improve worker well-being, and (d) as a means to measure or monitor intervention, policy, or program effectiveness. Thriving from work is an important, complex, worker well-being construct, that draws from both the positive psychology and occupational health literatures and encapsulates how the experience of work, and its conditions, shape a worker's functioning and life satisfaction—not only at work but also in a worker's life outside of work.

While the importance of developing worker well-being metrics is receiving increasing attention, there is limited literature on the topic of thriving from work; and efforts to measure both worker well-being and thriving from work are scarce. Other instruments that measure worker well-being have been developed; however, these instruments also have limitations. NIOSH's Worker Well-being Questionnaire (WellBQ) was designed as a battery of questions mapped to a framework to examine the multiple facets of well-being, primarily to identify areas for intervention to improve worker well-being or for surveillance of these different facets [38]. However, it does not provide a single unidimensional measure of worker well-being. Some instruments have focused exclusively on the affective component of well-being, that is, how employees feel about various aspects of their work [39]. Questionnaires such as 'Work-related Well-being Index' [40] and 'Work Well-being Questionnaire' [41], focus mainly on subjective impressions of work, with only a narrow focus

on the workers' experiences of work, e.g., social well-being; and, Zheng et al.'s employee well-being scale focuses on broader aspects such as life well-being and psychological well-being not related to work [42]. Due to these limitations, researchers often use proxies to measure work-related well-being such as job satisfaction, worker engagement, and mental health status [43–45]. The Thriving from Work Questionnaire aims to overcome these limitations by capturing how work and its specific conditions and policies shape the extent to which workers thrive from their work. Through our conceptualization of thriving from work, we recognize that thriving is the result of a bidirectional relationship between an individual and the environments (including work) in which they function.

This paper is important for several reasons. Well-designed instruments are the foundation of many of the variables we measure in our research and practice. Researchers, practitioners and policy-makers need to be confident in the validity of the instruments they use. Boateng et al. in their paper, "best practices for developing and validating scales for health, social and behavioral research" advocate for scale developers to be transparent in reporting their development methods to facilitate the advancement and understanding of the outcome measures we use [46]. Morgado et al. in their systematic review of scale development practices stated that item generation is possibly the most important step of the scale development process, as identification and early testing of these items for face validity is important to ensure the construct is adequately being captured and measured appropriately [47]. Failing to adequality define the conceptual domain of a construct can lead to various problems as a result of poor construct definition [47–49]. Thus, the purpose of this paper is to describe the conceptualization and preliminary stages of development of a novel measure of "Thriving from Work".

2. Materials and Methods

We conducted formative research to develop candidate items for the *Thriving from Work Questionnaire* with the following aims:

- to define "thriving from work"
- to identify attributes that could be mapped onto key dimensions of thriving from work
- to develop a comprehensive list of cognitively tested items for later psychometric evaluation and ultimately use in occupational health and safety [OHS] research and practice.

We used an evidence-based multi-step process consisting of several steps: (a) review of the literature on work-related well-being and thriving, and identification of existing measures and related constructs, (b) review of candidate questions resulting from the literature review by the investigator team, (c) workshop to obtain input on a preliminary draft of the questionnaire, and conceptualization and definition of thriving from work, (d) content expert interviews and in-depth review of questionnaire, and, (e) four rounds of cognitive testing with a sample of workers from various sectors and with different demographic characteristics.

2.1. Workshop

In December 2019, the Harvard T.H. Chan School of Public Health Center for Work, Health, and Well-being (the Center) sponsored an interactive 90-minute workshop attended by 33 Center members and affiliates from diverse disciplines including epidemiology, biostatistics, occupational and environmental health, law, economics, medicine, psychology, sociology, business, and public health. The main objective of the workshop was to obtain input on a preliminary draft of a questionnaire, and conceptualization and definition of thriving from work, informed by a prior review of the literature. Participants attended in person or by videoconference. In advance of the workshop, we distributed a draft definition and discussion of the concept of thriving from work, based on an initial literature review, as well as candidate items under consideration for use in the Thriving from Work Questionnaire. During the workshop, we obtained feedback and discussed challenges that the investigative team were facing in the development of the questionnaire.

2.2. Content Expert Interviews and Review

The study, as originally designed included an in-person modified Delphi process to be conducted in 2020, intended to reach a reasonable level of consensus in the content of the Thriving from Work Questionnaire. The plans for an in-person meeting were revised due to the COVID-19 pandemic. Instead, eighteen content experts from different disciplines and backgrounds were invited to participate individually in a one-time in-person video-conference interview using Voice over Internet Protocol (VoIP) mediated technology (Zoom Video Communications, San Jose, CA, USA). Interviews occurred between May and July 2020: fifteen were conducted jointly by lead investigators (GRW and SP) and three were conducted by one investigator (SP). VOiP is considered acceptable as a replicable method for in-person interviews, as it allows for real-time interaction involving sound, video and even written text using the chat function (this included relevant documents or publications being shared by the experts during the interview) [50]. Interviews were audio-recorded and transcribed using automated features. Interview transcripts were reviewed and summarized after each interview was completed. The lead investigators reviewed and discussed the key findings from each interview and adjusted the questionnaire after each interview, taking into consideration the totality of the previously obtained advice, information, and opinions. Thus, each expert reviewed a potentially different version of the questionnaire. In some instances, the investigators provided questions and options regarding potential items and attributes based on findings from a previous interview's findings.

The last four interviews provided little new information and were primarily confirmatory in their nature; interviews were stopped at a point where saturation naturally occurred during the data collection.

Experts often suggested a specific attribute of Thriving from Work that they perceived as being very important that they felt had not yet been incorporated into the instrument they reviewed. In these instances, the investigators would first attempt to identify an item from an existing published peer-reviewed questionnaire. If an acceptable item could not be found, the investigator team developed or modified an item and presented both the attribute and item in subsequent expert interviews. Both positive and negative items were identified for some attributes because directionality was considered important by the experts and the investigator team. After the initial round of expert interviews were completed, each expert was asked to participate in a second review of the questionnaire that had been modified based on the initial interviews. The second review was completed electronically via email in late September 2020.

2.3. Cognitive Testing with Workers

We conducted a total of four rounds of cognitive testing to ensure that items included on the questionnaire were understood consistently, as intended by the investigators, and to identify and remedy any problems [49]. Following the workshop but prior to the expert review, we conducted a first round of cognitive testing with a convenience sample of six workers. We then tested a revised list of candidate items, that also included items added through the expert panel, through an additional three rounds of cognitive testing with a convenience sample consisting of a total of 20 workers (6–8 participants per round). To the extent possible, workers were purposively recruited from different industries, job levels, education levels, work arrangements, genders, races and ethnicities, and age groups.

We used the think-aloud method with retrospective probing to ask additional clarifying questions on comprehension, information retrieval, judgment/estimation, and selection of response category [48,49]. The interview had two main parts: general questions focused on topics of interest related to the questionnaire, and specific questions regarding items in the questionnaire. General questions focused on the worker's perception of the meaning of thriving from work, differences between "work" and "job", questionnaire instructions, response categories and layout. Specific questions asked workers about their interpretation of specific words that the researchers thought might be problematic (for example, "what does realize my full potential" mean to you?"). For some items, the workers were asked,

"how would you ask this in your own words" to assess alignment between question intent and understanding. We also asked participants to give examples of some of the more general items, for example "what does the word 'resources' mean to you in the statement—I can easily access the resources to do my job well." We also asked participants to indicate how well each item resonated in relation to their own sense of thriving.

Interviews were conducted either using VOiP, or by phone for workers who were not familiar with or did not have access to video-conference facilities. Interviews were audio-recorded only, and comments regarding each item were summarized and discussed by the investigator team. Substantive changes were made to items between each round.

3. Results

3.1. Defining Thriving from Work

Our initial investigation from the literature, workshop and expert interviews resulted in our adopting the following definition of Thriving from Work:

> *"Thriving from work" is defined as the state of positive mental, physical, and social functioning in which workers' experiences of their work and working conditions enable them to thrive in their overall lives, contributing to their ability to achieve their full potential in their work, home, and community.*

This definition recognizes that thriving reflects a multidimensional relationship between an individual worker and the environments (including the work environment) in which the individual functions. An individual's thriving may be increased or diminished because of specific working conditions, or workplace policies and practices. The experiences of a worker at home or in their community is likely to reflect specific working conditions, but the worker's contribution to their workplace and their perception of the conditions and policies they face at work may also reflect, in part, the other kinds of social, physical, and economic conditions they experience outside of the workplace. For example, workplace schedule predictability and access to leave with short notice may be important in controlling the stresses resulting from being a caregiver. Conversely, the responsibilities and stresses of being a caregiver may influence an individual's engagement in their work.

3.2. Conceptualizing Thriving from Work

Based on an extensive literature review, a draft definition and conceptualization of Thriving from Work was presented at the Center's workshop. We initially conceptualized Thriving from Work into seven dimensions (Table 1, Column 1) and 13 attributes (Table 1, Column 2). Then, based on the findings from the workshop and the expert review, we added fourteen attributes (Table 1, Column 3). This resulted in a total of 37 attributes mapped to the seven dimensions.

Additional items were generated as a result of both the workshop and expert review process. Source items were either identified through known published reliable and valid instruments, [51–60] or were developed by the investigator team if not known items could be identified.

3.3. Findings from the Cognitive Testing

Four rounds of cognitive testing with a total of 26 workers were conducted (Table 2).

Cognitive testing respondents were provided with the following instructions for the questionnaire: "The following items relate to how you perceive the work you do day-to-day. If you have more than one job, please consider your current job that is most IMPORTANT to you when responding. Please think about this same job when you are answering all of the questions. Indicate how often, if at all, you have generally felt that way about your work over the last month. Select one response for each item." This introduction was easily understood, and no changes were made.

Every candidate item on the questionnaire was rated on a Likert scale: Always, Almost Always, Usually, Sometimes, Rarely, or Never. 'Not Applicable' was also provided as a response option. The 'Almost Always' response was added after the second round of

cognitive testing following consistent feedback from participants suggesting the need for this category. All other categories were unchanged from the first round of cognitive testing.

Changes to the candidate items were made based on input from multiple respondents and after discussion among the investigators. Modifications were made through each round of the cognitive testing as indicated in Appendix A (Table A1). Some items were dropped because they were too difficult to answer or were identified as redundant. During this process, additional items were added in response to the expert interviews and the results from earlier rounds of cognitive testing. Specific attention was made to the interpretation of items and concepts regarding "work" versus "job" to ensure participants were interpreting items in a similar way. Throughout the cognitive testing process, we found several items to have ambiguous terminology resulting in an unintended restrictive interpretation of an item, frequent responses outside our thriving from work framework, or phrasing that was too complex to be answered within the response categories. Of note, many items that had been taken from previously validated scales needed to be modified for our instrument, first to capture our conceptualization of "thriving from work" and, second, based on our cognitive testing results. The cognitive testing process resulted in a final list of 87 candidate items for the Thriving from Work Questionnaire (Table 3).

Table 1. Thriving from Work: Dimensions and Attributes.

Dimensions of Thriving from Work	Initial Attributes Drafted from the Literature Review	Attributes Added Through the Workshop and Expert Review
Psychological well-being from work	Meaning & Purpose Growth & development	Values align with company
Emotional well-being from work	Job satisfaction Happiness Engagement	Enthusiasm Contribution to life satisfaction
Social well-being from Work	Supportive relationships Valued Belonging Respect Contributions to others	Fair treatment Worker voice Recognition
Work–life integration	Work–life balance Commuting	Work-Family Job creep
Basic needs for Thriving from Work	Job security Pay	Benefits Opportunities for promotion
Job design and experience of work	Autonomy Schedule control Job demands Physical work environment Adequate resources Skills & knowledge	Work intensity
Health, and Physical and Mental Well-being from Work	Physical Safety Psychological Safety Energy	Stress Injury Exhaustion

Table 2. Details of Cognitive Testing Participants (n = 26).

		Mean (SD; Range)
Age (Years)		36.2 (10.6; 24 to 69)
		% (*n*)
Gender	Male	62% (16)
	Female	38% (10)
Race/Ethnicity	White	46% (12)
	Asian	27% (7)
	Hispanic/Latinx	15% (4)
	Black	8% (2)
	Native American	(1)
Main language spoken at home	English	85% (22)
	Other	15% (4)
Education Level	Completed Grade 12/High school	15% (4)
	Some college or technical school	23% (6)
	College degree	42% (11)
	Graduate/Master's degree	20% (5)
Main Occupation	Hospitality/Food service	19% (5)
	Construction	12% (3)
	Education	12% (3)
	Healthcare	12% (3)
	Transportation	12% (3)
	Military/security	8% (2)
	Professional Services (e.g., human resources, media relations)	8% (2)
	Agriculture/farming	(1)
	Entertainment	(1)
	Retail	(1)
	Manufacturing	(1)
	Information Technology	(1)
	Technical/Scientific	(1)
Number of jobs/employers	One	88% (23)
	Two or more	12% (3)
Employment status	Full time, salaried	54% (14)
	Full time, shift work with overtime	8% (2)
	Part time/hourly	23% (6)
	Contract	8% (2)
	App-based	(1)
	Work without pay (e.g., family farm)	(1)

Table 3. Thriving from Work Questionnaire: Final Candidate Questions.

Dimension	Item
Psychological Well-being from Work	My work gives me a sense of purpose.
	My work adds meaning to my life.
	My work makes a meaningful contribution to society.
	My work allows me to develop new knowledge and skills.
	My job allows me to achieve my full potential.
	At work, I have the opportunity to do what I do best every day.
	The things I am asked to do at work are consistent with my personal values.
	I get asked to do things at work that I don't feel comfortable doing.
Emotional Well-being from Work	I feel engaged by my work.
	At work, my mind is focused on my job.
	I am satisfied with my job.
	I am satisfied with the kind of work I do.
	The kind of work I do makes me happy.
	My job makes me happy.
	My work adds to my overall life satisfaction.
	I love my job.
	I am enthusiastic about my work.
	My job is pointless (has no useful purpose).
	My job is boring.

Table 3. *Cont.*

Dimension	Item
Social Well-being from Work	I receive recognition at work for my accomplishments I feel supported by the people I work with. I feel supported by my coworkers. I feel supported by my managers/supervisors. I receive useful and timely feedback at work from my managers/supervisors. I feel valued by the people I work with. I feel valued by my coworkers. I feel valued by my managers/supervisors. I feel valued by other people I interact with at work, such as customers, clients, students, patients (any other people who are NOT your supervisors or coworkers). My work is valued by others. My work is valued by my coworkers. My work is valued by my managers/supervisors. My work is valued by other people I interact with at work, such as customers, clients, students, patients (any other people who are NOT your supervisors or coworkers). At work, I feel like I belong. I am comfortable being myself at work. I am treated with respect at work. I am treated with respect by my coworkers. I am treated with respect by my managers/supervisors I am treated with respect by other people I interact with at work, such as customers, clients, students, patients (any other people who are NOT your supervisors or coworkers). I am treated fairly at work. I am treated fairly by my coworkers. I am treated fairly by my managers/supervisors. I am treated fairly by other people I interact with at work, such as customers, clients, students, patients (any other people who are NOT your supervisors or coworkers). I am bullied, harassed, or humiliated at work. My work allows me to contribute to the happiness and well-being of others. I can voice concerns or make suggestions at work without getting into trouble. At work, my opinions matter. No one cares about my opinions at work.
Work–life Integration	I can easily manage my job as well as attend to my needs and the needs of my family. I can achieve a healthy balance between my work and my life outside of work. I worry about things at work when I am not working. My family and friends value the work I do. Travelling to and from work is stressful for me. Travelling to and from work is easy and stress-free. I feel safe getting to and from work.
Basic Needs for Thriving from Work	I feel my job is secure. I am grateful for my job. I am paid fairly for the job I do. My pay meets my needs and the needs of my family. I am not paid enough money to make ends meet. I am satisfied with the employee benefits provided through my work, such as access to health insurance, life insurance, a pension or retirement savings plan. I am satisfied with the amount of paid vacation days I get. I am satisfied with the amount of paid leave I can take to care for myself or family members. I have good opportunities for promotion.

Table 3. *Cont.*

Dimension	Item
Job Design and Experience of Work	I can easily manage the demands of my job. I have more work to do than I can complete during paid work hours. I am happy with how much input I have in decisions that affect my work. I have control over how my daily work is done. I can solve problems at work without having to ask for permission. I am happy with how much control I have over my work schedule. I can schedule a day off or take vacation when I want or need to. I can take unpaid leave if I need to. I have enough time, within my normal working hours, to get my job done. I have adequate control over the pace of my work. My physical work environment (workspace, light, temperature) is set up in a way that helps me do my job well. Noise at work interferes with my ability to get the job done. I have the skills and knowledge I need to do my job well. I have access to the resources I need to do my job well. I know enough about what is going on in my company/organization to do my job well.
Health, and Physical and Mental Well-being from Work	I feel physically safe at work. I feel psychologically safe at work. After I leave work, I have enough energy to do the things I want or need to do. I am too tired after work to enjoy things. I feel excessive levels of stress at work. I worry that I will get hurt at work. I find work emotionally exhausting. I find work physically exhausting. My work contributes in a positive way to my well-being.

4. Discussion

The construct, "Thriving from Work", is a useful, integrated indicator of worker well-being. We describe the process we followed to develop the candidate items for an instrument to measure Thriving from Work, intended to assess the conditions and experiences at work and out-of-work factors that interact with one another and collectively influence a worker's well-being.

In the context of questionnaire development, response error due to respondent's poor interpretability of the items, responses, and instructions, can be addressed through methods such as substantive content expert review and cognitive testing [61]. The candidate items yielded through this research have established good face validity and cognitive response properties as single items through rigorous review by substantive content experts and cognitive testing with workers, respectively. Although our intention is to conduct item reduction and psychometric evaluation on the instrument through future studies, researchers can use individual items from the current questionnaire and interpret them directly.

Positive health outcomes that result from workplace policies, practices, and exposures are often overlooked in the OHS scientific literature that focuses more commonly on identifying risks of injury or ill-health. Current challenges, such as the COVID-19 pandemic, have called attention to the importance of embracing a well-being framework as workers return to work and continue to struggle with the mental and physical sequalae of the pandemic [62–64]. NIOSH, as well as other international organizations, have emphasized the value of incorporating a positive well-being focus.

NIOSH recently published a framework of worker well-being [24], and an integrated assessment of worker well-being (WellBQ) [38], based on a substantive literature review and expert panel. The panel concluded that worker well-being is a multi-dimensional, dynamic, and integrative concept. They defined worker well-being as the "experience of positive perceptions, and the presence of constructive conditions at work and beyond that enables workers to thrive and achieve their full potential" [24] (p. 592). This definition

captures well-being as a continuum, with thriving considered as the highest level of well-being. Our conceptualization and instrument complement the NIOSH WellBQ. Both have a focus on the relationship of working policies, practices, and conditions as well as conditions outside of work that are influenced by and influence the work experience, and recognize well-being as a comprehensive, multi-dimensional integrated measure.

The Thriving from Work Questionnaire is intended to serve multiple purposes across research, policy, and practice. Next steps in the development of the Thriving from Work Questionnaire include item reduction and psychometric evaluation of the instrument across samples of diverse workers, as well as design of a scoring and benchmarking system. We have designed a series of studies to validate our questionnaire, and systematically reduce the number of items, in an online sample of U.S. workers, as well as in various industry-specific samples. Although this process will lead to a briefer instrument, it is important to note that the 87 questions identified through this research provide a battery of cognitively tested items that are ready for current use (Table 3).

Of note, although we used an international expert panel, the questionnaire was cognitively tested with U.S. workers and therefore items may not be as useful without modification in countries outside of the U.S. where labor, economic and social security systems differ. In these settings, additional cognitive testing with workers is recommended. Additionally, we modified our original methods due to the COVID-19 pandemic. For example, we had planned to conduct the expert panel as an in-person one-day workshop and instead converted to videoconference interviews. The value of having experts discuss the topics and the questionnaire as a group might have yielded different findings; however, the benefit of conducting interviews virtually meant we could expand to an international panel. Additionally, while there have been reported concerns regarding the technological issues that may be faced conducting interviews by video conference [50], we did not experience any such problems.

5. Conclusions

The importance of work-related well-being, and thriving from work, as critical worker outcomes are supported by both evidence and practice. Therefore, evidence-based practical, reliable, and validated measures are needed to measure these positive health outcomes. This research will serve as the foundation for the Thriving from Work Questionnaire which is being developed to meet this need. Through our formative research, our goal was to develop a battery of cognitively tested candidate items that will have broad utility across workers from different occupations and industries. The questionnaire will have application for assessing the consequences of workplace modifications and interventions, including those specifically designed to improve worker well-being. We were able to demonstrate that the candidate items for the Thriving from Work Questionnaire effectively assessed the defined attributes of Thriving from Work based on our definition and conceptualization across seven broad dimensions. Items were established as having good face validity and cognitive response properties; researchers and practitioners may consider the individual questionnaire items in their own survey research. Future research will focus on item reduction and psychometric evaluation of the questionnaire.

Thriving from Work is an important positive health and well-being construct, that measures the extent an individual thrives because of their working conditions and experience of work, not only at work but also in their life beyond work. Future research is needed to identify how work can have positive health and well-being impacts to create thriving workforces and workplaces, in which workers thrive not only at work but in their lives outside of work. As future work continues to change and evolve, future research should also focus on examining how workers' thriving–its definition and conceptualization–may also be evolving.

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Appendix A

Table A1. Findings from the cognitive testing of Thriving from Work Questionnaire candidate items.

Attribute	Round 1	Round 2	Round 3	Round 4
Psychological Well-Being from Work				
Purpose	My work gives me a sense of purpose.	*No change.*	*No change*	*No change.*
Meaning	My work gives meaning to my life.	*No change.*	My work adds meaning to my life. [c]	*No change*
				My work makes a meaningful contribution to society. [b]

Table A1. *Cont.*

Attribute	Round 1	Round 2	Round 3	Round 4
Growth and Development	My work allows me to develop new knowledge and skills.	*No change.*	*No change.*	*No change.*
	My work supports my interests.	*No change.*	*No change.*	*DROPPED* [b]
		I feel that my job allows me to realize my full potential. [a]	My job allows me to realize my full potential. [b]	My job allows me to achieve my full Potential. [b]
				At work, I have the opportunity to do what I do best every day. [b]
Values Align with Company			The things I am asked to do at work are consistent with my personal values. [a]	*No change.*
			I get asked to do things at work that I don't feel comfortable doing.	*No change.*
Emotional Well-being from Work				
Engagement	I am engaged in my work.	*No change.*	I feel engaged by my work. [b]	*No change.*
				At work, my mind is focused on my job. [b]
Job Satisfaction	Overall, I am satisfied with my job.	*No change.*	*No change.*	I am satisfied with my job. [b]
	Overall, I am satisfied with the work I am doing.	*No change.*	Overall, I am satisfied with the work I do. [b]	I am satisfied with the kind of work I do. [b]
Happiness	My work makes me happy.	My work makes me happy. [d]	*No change.*	The kind of work I do makes me happy. [b]
		My job makes me happy. [d]	*No change.*	*No change.*
	I look forward to going to work each day.	DROPPED [c]		
Contribution to Life Satisfaction			My work makes a positive contribution to my overall life satisfaction. [a]	My work adds to my overall life satisfaction. [b]
Enthusiasm			I love my job. [a,b,d]	*No change.*
			I am enthusiastic about my work. [a]	*No change.*
			My job is pointless (has no useful purpose). [d]	*No change.*
			My job is boring. [d]	*No change.*

Table A1. *Cont.*

Attribute	Round 1	Round 2	Round 3	Round 4
Social Well-being from Work				
Supportive Work Relationships				I feel supported by the people I work with.
	I have a supportive relationship with my coworkers.	*No change.*	I feel supported by my coworkers.	*No change.*
	I have a supportive relationship with my supervisor.	I feel supported by my supervisor.	*No change.*	I feel supported by my managers/supervisors.
			I receive useful and timely feedback at work from my supervisors. [a]	I receive useful and timely feedback at work from my managers/supervisors. [b]
			I feel supported by my employer (e.g., workplace policies).[a]	DROPPED [b]
Valued at Work	I am valued at work by my colleagues and supervisors.	*No change.*		I feel valued by the people I work with.
				I feel valued by other people I interact with at work, such as customers, clients, students, patients (any other people who are NOT your supervisors or coworkers).[b]
			I feel valued by my coworkers. [b]	*No change.*
			I feel valued by my supervisors. [b]	*No change.*
				My work is valued by others. [b]
		The work that I do is valued by my colleagues and Supervisors. [a]		*No change.*
			My work is valued by my coworkers. [b]	My work is valued by other people I interact with at work, such as customers, clients, students, patients (any other people who are NOT your supervisors or coworkers).[b]
			My work is valued by my supervisors. [b]	*No change.*
Belonging in the Workplace		I feel like I am an important part of a team or community at my workplace. [a]	I feel like I am part of a community at work. [b]	DROPPED [b]
		I feel like I belong in my workplace. [a]	At work, I feel like I belong. [b]	*No change.*
		I am comfortable being myself at work. [a]	*No change.*	*No change.*

Table A1. *Cont.*

Attribute	Round 1	Round 2	Round 3	Round 4
Respect	I am treated with respect in the workplace.	*No change.*	*No change.*	I am treated with respect at work. [b]
				I am treated with respect by my coworkers. [b]
				I am treated with respect by my managers/supervisors. [b]
				I am treated with respect by other people I interact with at work, such as customers, clients, students, patients (any other people who are NOT your supervisors or coworkers).[b]
Fair Treatment			I am treated fairly at work [a]	I am treated fairly at work. [b]
				I am treated fairly by my coworkers. [b]
				I am treated fairly by my managers/supervisors [b]
				I am treated fairly by other people I interact with at work, such as customers, clients, students, patients (any other people who are NOT your supervisors or coworkers).[b]
				I am bullied, harassed, or humiliated at work [d]
Contributions to Others	My work allows me to contribute to the happiness and wellbeing of others.	*No change.*	*No change.*	*No change.*
Worker Voice		I can voice concerns or make suggestions at work without getting into trouble. [d]	*No change.*	*No change.*
			At work, my opinions matter. [a]	*No change.*
				No one cares about my opinions at work. [b]
Recognition				I receive recognition at work for my Accomplishments. [d]

Table A1. *Cont.*

Attribute	Round 1	Round 2	Round 3	Round 4
Work-Life Integration				
Work-Life Balance	I am satisfied with my work-life balance.	*No change.*	I am able to achieve a healthy balance between my work and my life outside of work. [b]	I can achieve a healthy balance between my work and my life outside of work. [b]
Work-Family	The demands of my work interfere with my family or personal time.	DROPPED [c]		
	The demands of my work make it difficult to fulfil my family or personal responsibilities/duties.	DROPPED [c]		
	I can easily manage my job as well as attend to the needs of myself or my family.	*No change.*	I can easily manage my job as well as attend to my needs and the needs of my family. [b]	*No change.*
				My family and friends value the work I do. [d]
Job Creep			I worry about work problems when I am not working. [d]	I worry about things at work when I am not working. [b]
Commuting	My commute to work in not a problem for me.	My commute to work is a problem for me. [b]	My commute to work is safe, easy and stress-free. [b]	Traveling to and from work is easy and stress-free. [b]
			Travelling to and from work is a problem for me. [b]	Travelling to and from work is stressful for me. [b]
			I feel safe getting to and from work. [b]	*No change.*
Opportunities for Promotion				I have good opportunities for promotion. [b,d]
Basic Needs for Thriving from Work				
Job Security	I feel my job is secure.	*No change.*	*No change.*	*No change.*
				I am grateful for my job.
Pay	I am paid fairly for the job I do.	*No change.*	*No change.*	*No change.*
			I receive adequate pay to meet my needs. [a]	My pay meets my needs and the needs of my family. [b]
				I am not paid enough money to make ends meet. [b]

Table A1. *Cont.*

Attribute	Round 1	Round 2	Round 3	Round 4
Benefits		I am satisfied with the employee benefits (e.g., health insurance, retirement fund, time off, wellness initiatives) that are provided through my work. [a]	*No change.*	I am satisfied with the employee benefits provided through my work, such as access to health insurance, life insurance, a pension or retirement savings plan. [b]
				I am satisfied with the amount of paid vacation days I get. [b]
				I am satisfied with the amount of paid leave I can take to care for myself or family members. [b]
Job Design and Experience of Work				
Job Demands (General)	I can easily manage the demands of my job.	*No change.*	*No change.*	*No change.*
	I spend more time than I would like to complete unpaid work-related activities (e.g., work travel, waiting for my next job, completing work tasks on my own time).	*No change.*	*No change.*	DROPPED [b]
			I have more work to do than I can complete during paid work hours. [d,b]	*No change.*
Autonomy	I am satisfied with how much say I have in decisions that affect my work.	*No change.*	I am happy with how much say I have in decisions that affect my work. [b]	I am happy with how much input I have in decisions that affect my work. [b]
				I have control over how my daily work is done. [d]
			I can solve problems at work without having to ask for permission. [a]	*No change.*
Schedule Control	I am happy with how much control I have over my work schedule.	*No change.*	*No change.*	*No change.*
			I can schedule a day off work when I want or need to. [a,d]	*No change.*
			I can take unpaid leave when I need to. [a,d]	
			I have no control over my work hours. [a,d]	

Table A1. *Cont.*

Attribute	Round 1	Round 2	Round 3	Round 4
Work Intensity			I have enough time, within my normal working hours, to get my job done. [a,d]	*No change.*
			I have no control over the pace of my work. [b,d]	DROPPED [b]
			I have adequate control over the pace of my work. [b,d]	*No change.*
Working Conditions (General)	My working conditions contribute in a positive way to my health and well-being.	*No change.*	*No change.*	My work contributes in a positive way to my health and well-being. [b,d]
Physical Work Environment	The space I work in is conducive to getting my work done.	*No change.*	*No change.*	My physical work environment (workplace, light, temperature) is set up in a way that helps me to get my work done in the best way possible. [b]
			Noise at work interferes with my ability to get the job done. [d]	*No change.*
Skills and Knowledge	I have the skills and knowledge to do my job well.	I have the skills and knowledge I need to do my job well. [b]	*No change.*	*No change.*
Adequate Resources	I can easily access the resources to do my job well.	*No change.*	I have the resources to do my job well. [b]	I have access to the resources I need to do my job well. [b,d,e]
	I know enough about what is going on in my organization to do my job well.	*No change.*	*No change.*	I know enough about what is going on in my company/organization to do my job well. [b]
Health, and Physical and Mental Well-being from Work				
Physical Safety	I feel physically safe at work.	*No change.*	*No change.*	*No change.*
Psychological Safety	I feel psychologically safe at work.	*No change.*	*No change.*	*No change.*
Energy	When I come home from work, I have enough energy to do the things I want or need to do.	After I finish work, I have enough energy to do the things I want or need to do. [b]	After I leave work, I have enough energy to do the things I want or need to do. [b]	*No change.*
			I am too tired after work to enjoy things. [d]	*No change.*
Stress			I feel excessive levels of stress at work. [d]	*No change.*
Injury			I worry that I will get hurt at work. [d]	*No change.*

Table A1. *Cont.*

Attribute	Round 1	Round 2	Round 3	Round 4
Exhaustion			I find work emotionally exhausting. [d]	*No change.*
			I find work physically exhausting. [d]	*No change.*

a- Added through either workshop or expert review. b- Changes made based on findings from cognitive interviews and input from investigator team. c- Item dropped as performed poorly through this round of cognitive testing. d- Additions made by the investigator team based on current evidence and/or investigator expertise. e- After this item was modified it was moved to the "Health, & physical and mental well-being domain".

References

1. U.S. Department of Labor Bureau of Labor Statistics. American Time Use Survey-2017 Results. Available online: https://www.bls.gov/news.release/pdf/atus.pdf (accessed on 15 January 2021).
2. Office of Disease Prevention and Health Promotion. Employment. Available online: https://health.gov/healthypeople/objectives-and-data/social-determinants-health/literature-summaries/employment (accessed on 7 December 2020).
3. Pronk, N.P.; Ochiai, E. Healthy People 2030: Considerations for Workplace Health and Well-being. *ACSM's Health Fit. J.* **2020**, *24*, 65–68. [CrossRef]
4. Sorensen, G.; Dennerlein, J.T.; Peters, S.E.; Sabbath, E.L.; Kelly, E.L.; Wagner, G.R. The future of research on work, safety, health and wellbeing: A guiding conceptual framework. *Soc. Sci. Med.* **2021**, *269*, 113593. [CrossRef]
5. Kelly, E.L.; Moen, P. *Overload: How Good Jobs Went Bad and What We Can Do about It*; Princeton University Press: Oxford, UK, 2020.
6. Reardon, M.; Abrahams, R.; Thyer, L.; Simpson, P. Review article: Prevalence of burnout in paramedics: A systematic review of prevalence studies. *Emerg. Med. Australas.* **2019**, *32*, 182–189. [CrossRef]
7. Verougstraete, D.; Idrissi, S.H. The impact of burn-out on emergency physicians and emergency medicine residents: A systematic review. *Acta Clin. Belg.* **2019**, *75*, 57–79. [CrossRef]
8. Rotenstein, L.S.; Torre, M.; Ramos, M.A.; Rosales, R.C.; Guille, C.; Sen, S.; Mata, D.A. Prevalence of burnout among physicians: A systematic review. *JAMA* **2018**, *320*, 1131–1150. [CrossRef]
9. García-Carmona, M.; Marín, M.D.; Aguayo, R. Burnout syndrome in secondary school teachers: A systematic review and meta-analysis. *Soc. Psychol. Educ.* **2018**, *22*, 189–208. [CrossRef]
10. Stone, K.; Kintziger, K.; Jagger, M.; Horney, J. Public Health Workforce Burnout in the COVID-19 Response in the U.S. *Int. J. Environ. Res. Public Health* **2021**, *18*, 4369. [CrossRef]
11. Woo, T.; Ho, R.; Tang, A.; Tam, W. Global prevalence of burnout symptoms among nurses: A systematic review and meta-analysis. *J. Psychiatr. Res.* **2020**, *123*, 9–20. [CrossRef]
12. Maglalang, D.D.; Sorensen, G.; Hopcia, K.; Hashimoto, D.M.; Katigbak, C.; Pandey, S.; Takeuchi, D.; Sabbath, E.L. Job and family demands and burnout among healthcare workers: The moderating role of workplace flexibility. *SSM Popul. Health* **2021**, *14*, 100802. [CrossRef]
13. Massachusetts Department of Public Health Occupational Health Surveillence Program. Opioid-Related Overdose Deaths in Massachusetts by Industry and Occupation, 2011–2015. Available online: https://www.mass.gov/files/documents/2018/08/07/opioid-industryoccupation.pdf (accessed on 1 July 2019).
14. Roche, A.M.; Chapman, J.; Duraisingam, V.; Phillips, B.; Finnane, J.; Pidd, K. Construction workers' alcohol use, knowledge, perceptions of risk and workplace norms. *Drug Alcohol Rev.* **2020**, *39*, 941–949. [CrossRef]
15. Ompad, D.C.; Gershon, R.R.; Sandh, S.; Acosta, P.; Palamar, J. Construction trade and extraction workers: A population at high risk for drug use in the United States, 2005–2014. *Drug Alcohol Depend.* **2019**, *205*, 107640. [CrossRef]
16. Mohr, C.D.; Hammer, L.B.; Brady, J.M.; Perry, M.L.; Bodner, T. Can supervisor support improve daily employee well-being? Evidence of supervisor training effectiveness in a study of veteran employee emotions. *J. Occup. Organ. Psychol.* **2021**, *94*, 400–426. [CrossRef]
17. Brough, P.; Pears, J. Evaluating the influence of the type of social support on job satisfaction and work related psychological well-being. *Int. J. Organ. Behav.* **2004**, *8*, 472–485.
18. Sloan, M.M. Unfair treatment in the workplace and worker well-being: The role of coworker support in a service work environment. *Work Occup.* **2012**, *39*, 3–34. [CrossRef]
19. Joyce, K.; Pabayo, R.; Critchley, J.; Bambra, C. Flexible working conditions and their effects on employee health and wellbeing. *Cochrane Database Syst. Rev.* **2010**, *2010*, CD008009. [CrossRef]
20. Wheatley, D. Autonomy in Paid Work and Employee Subjective Well-Being. *Work. Occup.* **2017**, *44*, 296–328. [CrossRef]
21. Swanberg, J.E.; McKechnie, S.P.; Ojha, M.U.; James, J.B. Schedule control, supervisor support and work engagement: A winning combination for workers in hourly jobs? *J. Vocat. Behav.* **2011**, *79*, 613–624. [CrossRef]
22. Williams, P.; Kern, M.L.; Waters, L. The Role and Reprocessing of Attitudes in Fostering Employee Work Happiness: An Intervention Study. *Front. Psychol.* **2017**, *8*, 28. [CrossRef] [PubMed]

23. Ton, Z. *The Good Jobs Strategy: How the Smartest Companies Invest in Employees to Lower Costs and Boost Profits*; Houghton Mifflin Harcourt: Boston, MA, USA, 2014.
24. Chari, R.; Chang, C.-C.; Sauter, S.L.; Sayers, E.L.P.; Cerully, J.L.; Schulte, P.; Schill, A.L.; Uscher-Pines, L. Expanding the Paradigm of Occupational Safety and Health. *J. Occup. Environ. Med.* **2018**, *60*, 589–593. [CrossRef] [PubMed]
25. World Health Organization. Preamble to the Constitution of WHO as adopted by the International Health Conference. In Proceedings of the Constitution of the World Health Organization, New York, NY, USA, 19 June–22 July 1946. signed on 22 July 1946 by the representatives of 61 States (Official Records of WHO, no. 2, p. 100) 1948.
26. NIOSH. Total Worker Health. Available online: http://www.cdc.gov/niosh/twh/ (accessed on 19 September 2017).
27. Burton, J. *Healthy Workplaces: A Model for Action: For Employers, Workers, Policy-Makers, and Practitioners*; World Health Organization: Geneva, Switzerland, 2010.
28. Canadian Standards Association Bureau de normalization du Quebec. *CAN/CSA-Z1003-13/BNQ 9700-803/2013–Psychological Health and Safety in the Workplace: Prevention, Promotion, and Guidance to Staged Implementation*; Mental Health Commission of Canada: Ottawa, ON, Canada, 2013.
29. Ministry of Social Affairs and Health. *Policies for the Work Environment and Well-Being at Work Until 2020*; Ministry of Social Affairs and Health: Helsinki, Finland, 2011.
30. Brown, D.; Arnold, R.; Fletcher, D.; Standage, M. Human Thriving. *Eur. Psychol.* **2017**, *22*, 167–179. [CrossRef]
31. Bundick, M.J.; Yeager, D.S.; King, P.E.; Damon, W. Thriving across the Life Span. In *The Handbook of Life-Span Development*; Wiley: Hoboken, NJ, USA, 2010.
32. Kleine, A.; Rudolph, C.W.; Zacher, H. Thriving at work: A meta-analysis. *J. Organ. Behav.* **2019**, *40*, 973–999. [CrossRef]
33. Spreitzer, G.; Sutcliffe, K.; Dutton, J.; Sonenshein, S.; Grant, A.M. A Socially Embedded Model of Thriving at Work. *Organ. Sci.* **2005**, *16*, 537–549. [CrossRef]
34. Su, R.; Tay, L.; Diener, E. The Development and Validation of the Comprehensive Inventory of Thriving (CIT) and the Brief Inventory of Thriving (BIT). *Appl. Psychol. Heal. Well-Being* **2014**, *6*, 251–279. [CrossRef] [PubMed]
35. Spreitzer, G.; Hwang, E.B. How thriving at work matters for creating psychologically healthy workplaces: Current perspectives and implications for the new world of work. In *Creating Psychologically Healthy Workplaces*; Burke, R.J., Richardsen, A.M., Eds.; Edward Elgar Publishing: Northampton, MA, USA, 2019; pp. 293–310.
36. Spreitzer, G.; Porath, C. Creating sustainable performance. *Harv. Bus. Rev.* **2012**, *90*, 92–99. [PubMed]
37. Porath, C.L.; Spreitzer, G.M.; Gibson, C.B.; Garnett, F.G. Thriving at work: Toward its measurement, construct validation, and theoretical refinement. *J. Organ. Behav.* **2011**, *33*, 250–275. [CrossRef]
38. NIOSH. *NIOSH Worker Well-Being Questionnaire (WellBQ)*; U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health: Cincinnati, OH, USA, 2021.
39. Warr, P.B. Decision latitude, job demands, and employee well-being. *Work. Stress* **1990**, *4*, 285–294. [CrossRef]
40. Eaton, J.L.; Mohr, D.; Hodgson, M.J.; McPhaul, K.M. Development and Validation of the Work-Related Well-Being Index. *J. Occup. Environ. Med.* **2018**, *60*, 180–185. [CrossRef] [PubMed]
41. Parker, G.B.; Hyett, M.P. Measurement of Well-Being in the Workplace. *J. Nerv. Ment. Dis.* **2011**, *199*, 394–397. [CrossRef]
42. Zheng, X.; Zhu, W.; Zhao, H.; Zhang, C. Employee well-being in organizations: Theoretical model, scale development, and cross-cultural validation. *J. Organ. Behav.* **2015**, *36*, 621–644. [CrossRef]
43. Brauchli, R.; Peeters, M.C.; Van Steenbergen, E.F.; Wehner, T.; Hämmig, O. The Work-Home Interface: Linking Work-Related Wellbeing and Volunteer Work. *J. Community Appl. Soc. Psychol.* **2017**, *27*, 50–64. [CrossRef]
44. Hämmig, O. Health and well-being at work: The key role of supervisor support. *SSM Popul. Health* **2017**, *3*, 393–402. [CrossRef] [PubMed]
45. Lases, L.S.S.; Arah, O.A.; Busch, O.R.C.; Heineman, M.J.; Lombarts, K. Learning climate positively influences residents' work-related well-being. *Adv. Health Sci. Educ.* **2019**, *24*, 317–330. [CrossRef] [PubMed]
46. Boateng, G.O.; Neilands, T.B.; Frongillo, E.A.; Melgar-Quiñonez, H.R.; Young, S. Best Practices for Developing and Validating Scales for Health, Social, and Behavioral Research: A Primer. *Front. Public Health* **2018**, *6*, 149. [CrossRef] [PubMed]
47. Morgado, F.F.R.; Meireles, J.F.F.; Neves, C.M.; Amaral, A.C.S.; Ferreira, M.E.C. Scale development: Ten main limitations and recommendations to improve future research practices. *Psicol. Reflexão e Crítica* **2018**, *30*, 1–20. [CrossRef] [PubMed]
48. Willis, G.B.; Artino, A.R., Jr. What do our respondents think we're asking? Using cognitive interviewing to improve medical education surveys. *J. Grad. Med Educ.* **2013**, *5*, 353. [CrossRef]
49. Willis, G.B. *Cognitive Interviewing: A Tool for Improving Questionnaire Design*; Sage Publications: New York, NY, USA, 2004.
50. Archibald, M.M.; Ambagtsheer, R.C.; Casey, M.G.; Lawless, M. Using Zoom Videoconferencing for Qualitative Data Collection: Perceptions and Experiences of Researchers and Participants. *Int. J. Qual. Methods* **2019**, *18*, 1609406919874596. [CrossRef]
51. Diener, E.; Wirtz, D.; Tov, W.; Kim-Prieto, C.; Choi, D.-W.; Oishi, S.; Biswas-Diener, R. New Well-being Measures: Short Scales to Assess Flourishing and Positive and Negative Feelings. *Soc. Indic. Res.* **2010**, *97*, 143–156. [CrossRef]
52. Sirgy, M.J.; Efraty, D.; Siegel, P.; Lee, D.-J. A New Measure of Quality of Work Life (QWL) Based on Need Satisfaction and Spillover Theories. *Soc. Indic. Res.* **2001**, *55*, 241–302. [CrossRef]
53. Edmondson, A.C. *The Fearless Organization: Creating Psychological Safety in the Workplace for Learning, Innovation, and Growth*; John Wiley & Sons: Hoboken, NJ, USA, 2018.

54. Easton, S.; Van Laar, D. User Manual for the Work-Related Quality of Life (WRQoL) Scale: A Measure of Quality of Working Life. Available online: http://www.qowl.co.uk/researchers/WRQoL%20ebook%20User%20manual%20v34%2013%20Nov12.pdf (accessed on 1 May 2019).
55. Gallup. Gallup-Sharecare Well-being Index. Available online: http://www.gallup.com/178685/methodology-center.aspx (accessed on 15 November 2020).
56. Karasek, R.A. Control in the workplace and its health-related aspects. In *Job Control and Worker Health*; Sauther, S.L., Hurrell, J.J., Cooper, C.L., Eds.; Wiley: New York, NY, USA, 1989; pp. 129–159.
57. Karasek, R.; Brisson, C.; Kawakami, N.; Houtman, I.; Bongers, P.; Amick, B. The Job Content Questionnaire (JCQ): An instrument for internationally comparative assessments of psychosocial job characteristics. *J. Occup. Health Psychol.* **1998**, *3*, 322–355. [CrossRef]
58. Orsila, R.; Luukkaala, T.; Manka, M.-L.; Nygård, C.-H. A New Approach to Measuring Work-Related Well-Being. *Int. J. Occup. Saf. Ergon.* **2011**, *17*, 341–359. [CrossRef]
59. Weziak-Bialowolska, D.; Bialowolski, P.; Sacco, P.L.; VanderWeele, T.J.; McNeely, E. Well-Being in Life and Well-Being at Work: Which Comes First? Evidence From a Longitudinal Study. *Front. Public Health* **2020**, *8*, 103. [CrossRef] [PubMed]
60. Maslach, C.; Jackson, S.E.; Leiter, M.P.; Schaufeli, W.B.; Schwab, R.L. *Maslach Burnout Inventory*; Consulting Psychologists Press: Palo Alto, CA, USA, 1986; Volume 21.
61. Willis, G. Cognitive Interviewing in Survey Design: State of the Science and Future Directions. In *The Palgrave Handbook of Survey Research*; Vannette, D.L., Krosnick, J.A., Eds.; Springer International Publishing: Cham, Switzerland, 2018; pp. 103–107.
62. Plough, A.L. *Well-Being: Expanding the Definition of Progress: Insights from Practitioners, Researchers, and Innovators from around the Globe*; Oxford University Press: Oxford, UK, 2020.
63. Howe, D.C.; Chauhan, R.S.; Soderberg, A.T.; Ronald Buckley, M. Paradigm shifts caused by the COVID-19 pandemic. *Organ Dyn.* 2020. [CrossRef]
64. Dennerlein, J.T.; Burke, L.; Sabbath, E.L.; Williams, J.A.; Peters, S.E.; Wallace, L.; Karapanos, M.; Sorensen, G. An integrative total worker health framework for keeping workers safe and healthy during the COVID-19 pandemic. *Hum. Factors* **2020**, *62*, 689–696. [CrossRef] [PubMed]

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Applying the Social Vulnerability Index as a Leading Indicator to Protect Fire-Based Emergency Medical Service Responders' Health

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Abstract: During emergencies, areas with higher social vulnerability experience an increased risk for negative health outcomes. However, research has not extrapolated this concept to understand how the workers who respond to these areas may be affected. Researchers from the National Institute for Occupational Safety and Health (NIOSH) merged approximately 160,000 emergency response calls received from three fire departments during the COVID-19 pandemic with the CDC's publicly available Social Vulnerability Index (SVI) to examine the utility of SVI as a leading indicator of occupational health and safety risks. Multiple regressions, binomial logit models, and relative weights analyses were used to answer the research questions. Researchers found that higher social vulnerability on household composition, minority/language, and housing/transportation increase the risk of first responders' exposure to SARS-CoV-2. Higher socioeconomic, household, and minority vulnerability were significantly associated with response calls that required emergency treatment and transport in comparison to fire-related or other calls that are also managed by fire departments. These results have implications for more strategic emergency response planning during the COVID-19 pandemic, as well as improving Total Worker Health® and future of work initiatives at the worker and workplace levels within the fire service industry.

Keywords: coronavirus; emergency management; risk management; social vulnerability index; firefighter; logit regression; occupational stress; relative weights; total worker health; emergency medical services

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1. Introduction

Many fire departments provide not only firefighter but also emergency medical services (EMS). These fire-based EMS responders answer calls that deploy them to locations with limited knowledge and information, putting them at an increased risk for occupational exposure to infectious diseases and other injuries [1]. Consequently, these essential workers have been positioned at a critical intersection of public health, public safety, and healthcare systems [2–4]. To illustrate these intersecting roles, in 2018, just over 64% of fire department calls were for medical emergencies [5]. Another analysis determined that, when combining career and volunteer firefighters in the U.S., these workers respond to an average of one structure fire every other year, where most of their calls are emergency medical and incident responses [6].

Fire-based EMS responders' occupational risks and barriers to proactive safety efforts have become even more apparent during the COVID-19 pandemic. First, these essential workers continued to face substantial occupational exposure while lifting, moving, and carrying patients [7,8]. Although less information is known about infection rates, a survey of a Fire Department in California identified that 48% of fire-based EMS responders had

experienced likely or confirmed contact with patients with COVID-19, while another study concluded that New York City firefighters and EMS responders were 15 times more likely to be infected than the general public [9,10].

There are various reasons that fire-based EMS responders may be more susceptible to SARS-CoV-2 infections including long work shifts that may be 24 h or more, limitations in their ability to practice physical distancing both with their coworkers and during patient interactions, and possible shortages in personal protective equipment (PPE) [11]. Similarly, the CDC [12] indicates that fire-based EMS responders are at an increased risk of exposure based on unique factors, including constantly changing settings, being in an enclosed space during patient transport, needing to make quick decisions with limited information, and caring for a range of patients with different healthcare resources. Due to these varying elements that may contribute to exposure in any given scenario, it is imperative to identify any external factors or combination of factors that may help fire-based EMS responders and fire departments better predict and proactively mitigate occupational risks on the job.

Another barrier to addressing fire-based EMS responders' unique risks both prior to and during the COVID-19 pandemic is the paucity of surveillance data at the national level [7], with systems capturing different data points. Studies have highlighted multiple surveillance systems that capture firefighter deaths, each with different exclusion/inclusion criteria [13,14]. Examples of national surveillance systems within firefighting include those overseen by the National Fire Protection Association (NFPA), the International Association of Fire Fighters, the Bureau of Labor Statistics' Census, and case data from NIOSH's Fire Fighter Fatality Investigation and Prevention Program. There are also individual computer-aided dispatch systems that are unique to a municipality and fire department. These varying systems make it difficult to collect accurate and timely information, much less be able to inform prevention by predicting potential incidents. Researchers concluded that, although fatality information may be consistent, data estimating risks were disparate [14]. Therefore, research examining the utility of existing datasets, including the ability of the data to predict scenarios in which fire-based EMS responders face increased risks of exposure to SARS-CoV-2, is important.

Poplin and colleagues [15] suggest that the diverse hazards experienced in the fire service should be accommodated through an adaptable approach to managing risks. However, the response to addressing fire-based EMS responders' risks to improve worker safety, health, and well-being has been slow in coming for several reasons, even prior to the COVID-19 pandemic. As indicated earlier, fire-based EMS responders have a dynamic, mobile workplace which contributes to additional job stressors, including burnout, fatigue, stress, reduced performance, and negative health outcomes [16–20]. The same outcomes are true for other public safety occupations such as law enforcement [21,22]. This worker population routinely faces unknown risks; however, the COVID-19 pandemic allowed an opportunity to study the prevalence of this common risk factor to improve efforts around emergency planning and response. Research has advocated for the importance of understanding the locations of at-risk groups to help allocate resources for communities efficiently before, during, and after emergencies [23]. However, this information is less often used to support fire-based EMS responders' own decision making during a response.

1.1. Total Worker Health® Approach to Mitigating Fire-Based EMS Responders' Risks

Due to these changing work environments that also come with surveillance challenges, traditional approaches to workplace safety may not be as effective within public safety occupations. Rather, a more holistic approach, such as the use of a Total Worker Health® (TWH) framework, may be beneficial [24]. This paper discusses leading indicators within the realm of NIOSH's TWH® framework [25] to advance future of work initiatives [26] for the fire services. According to Smith and colleagues, fire-based EMS workers are the "embodiment of high-risk workers, facing extreme hazards that pose not only physical risk but psychological and psychosocial risk" [24] p. 194. Occupational connection to TWH® principles were argued prior to the COVID-19 pandemic, to facilitate a focus on

protecting workers facing extreme hazards [27,28]. Now, in response to the pandemic, a TWH® framework and its corresponding elements may be even more applicable to guide workplace solutions to enhance worker health and well-being.

1.1.1. Health Leading Indicators

During the COVID-19 pandemic, the basic principles of risk and emergency management have remained the same, with guidelines serving to help organizations adapt processes and practices to protect workers [29]. However, the pandemic has likely served as an impetus for organizations to integrate and promote additional practices to improve operational readiness and mitigate negative worker outcomes [29–31]. Although this represents a positive shift in priorities, organizations that experience frequent changes to the workplace should continually search for new leading indicators to help prevent and manage emergencies [32]. The CDC has discussed the importance of emergency responders knowing vulnerabilities in communities so they can anticipate needs and provide information to people at the right time [23]. Knowing this information can also help these responders with their own proactive planning to allocate resources and protect themselves.

Leading indicators are proactive, predictive, and preventative measures that provide insight into the future [33,34]. More specifically, health leading indicators refer to "the measures and actions that an organization can take to predict success in worker health outcomes and predict the operation of an organization's health and wellbeing programming" [35], p. 3. Others discuss health leading indicators as insights into public health concerns that can promote behaviors and processes to improve worker health [36–38]. Such ongoing data points may help prevent illness and advance worker health and well-being. The development of CDC's Social Vulnerability Index (SVI), for example, has helped local, state, and federal organizations identify and target vulnerable locations. However, the SVI has not been applied as a leading indicator to inform potential TWH® and well-being approaches within the fire service industry.

1.1.2. SVI as a TWH® Leading Indicator

Research has recognized and documented the impact of social factors on public health. Results have shown that socially vulnerable populations, also referred to as disproportionately affected populations, are more likely to be adversely affected during emergencies [39–46]. To assist in emergency preparedness efforts, reliable surveillance is critical. The Agency for Toxic Substances and Disease Registry (ATSDR) developed the SVI to understand any potential correlations with community outcomes [47]. For example, limited research has used SVI to identify counties that were hot spots for COVID-19, e.g., [48]. The SVI uses 15 social factors from 4 main themes to create a vulnerability score between 0 (least vulnerable) and 1 (most vulnerable). These four themes include (1) socioeconomic status; (2) household composition/disability; (3) minority status/language; and (4) housing type/transportation.

SVI has been used at the state level to customize and localize response efforts. For example, Georgia and North Carolina have both developed state-specific adaptations of the SVI with their health departments [23]. Additionally, fire departments acknowledge the importance of understanding community profiles, including social vulnerability, to accurately assess risks prior to a response. For example, Ohio's Columbus Fire Department, references SVI as an important tool to help officials and responders identify communities that need additional support [49].

Despite the use and connections made between SVI and negative health outcomes for communities and their residents, research has yet to directly focus on the occupational risks for the essential workers who serve these communities. To that end, this study applied SVI as a predictive health leading indicator to mitigate risks for fire-based EMS responders. Emergency preparedness and response has been recognized as an issue impacting all topics within NIOSH's future of work priorities [50]. Understanding the direction of this relationship may have implications for preserving fire-based EMS responders' safety and

health during response activities not only during the COVID-19 pandemic but also for improving TWH® initiatives within the fire services.

1.2. Research Questions

In this study, NIOSH researchers focus on how to effectively use existing data sources to identify hazardous patterns and mitigate worker risks. Specifically, using data received from three fire departments during the COVID-19 pandemic, NIOSH researchers merged and examined the utility of CDC's SVI as a leading indicator to improve future of work initiatives in the fire service industry. Results elucidate ways that current surveillance data can be used and improved, and how the incorporation of a TWH® approach can help identify and implement organizational-level interventions.

Research questions for this study are as follows:

RQ1: Do the four SVI themes predict fire-based EMS responders' potential exposure to SARS-CoV-2 during response calls?

RQ2: Do the four SVI themes predict the types of calls to which fire-based EMS responders are deployed (i.e., EMS, fire, and other)?

Based on the results of these questions, this paper seeks to understand how fire departments and comparable organizations can use SVI to address future of work initiatives within a TWH® framework.

2. Materials and Methods

In May 2019, NIOSH executed several collaborations to advance its public safety research portfolio. Through Research Collaboration Agreements (RCAs), NIOSH supported fire department subscriptions to the International Public Safety Data Institute's (IPSDI) National Fire Operations Reporting System (NFORS). The NFORS application is comprised of two data modules that report details of emergency response calls:

(**1**) Computer-aided dispatch (CAD) module. The CAD extracts fire department operations information that is automated within municipality reporting systems. These data elements include the type of call, duration of call, exposures during the call, and specific resources deployed to the call (e.g., ladder truck, ambulance).

(**2**) Individual exposure module (i.e., career diary). A worker's career diary is manually filled in by a worker after a completed response using either a smart phone or desktop. Within this application, workers input information about potential exposures (e.g., fire, hazmat, chemical, or biological) and personal protective equipment (PPE) worn during the incident (e.g., turnout gear, disposable face shield, or respirator).

2.1. NFORS Data Variables

When the COVID-19 pandemic began, NIOSH leveraged its existing relationship with IPSDI, the administrator of NFORS, to further understand aspects of incident reporting and response during COVID-19. Through the already-established RCAs with fire departments and data use agreements with IPSDI, NIOSH researchers continued to receive emergency call response data in monthly batches that contained call details from three fire departments in Ohio, Massachusetts, and New York. Hundreds of variables are included in these datasets, but the variables used in the current study are debriefed below.

2.1.1. NFORS Self-Reported Potential Exposure to SARS-CoV-2

The Occupational Safety and Health Administration (OSHA) defines a potential occupational exposure as a "reasonably anticipated skin, eye, mucous membrane, or parenteral contact with blood or other potentially infectious materials that may result from the performance of an employee's duties" [51]. Within the NFORS exposure module, such types of biological and chemical exposures are collected. Shortly after the COVID-19 pandemic started, IPSDI added a "Contagious Emergency/COVID-19" exposure response option [52]. The respective CAD systems were also modified to designate COVID-19 call types in CAD dispatch logs as "Contagious Emergency". This addition to the incident

reporting system ensured that departments could easily filter for and track COVID-19 incidents. This addition also allowed NIOSH researchers to appropriately filter and analyze data by exposure type.

2.1.2. NFORS Call Type

The National Fire Incident Reporting System (NFIRS) provides a standardized system that fire departments can use to describe and ultimately code the details of each incident response [53]. Following suit with NFIRS, the IPSDI NFORS application groups these incidents into large categories of "EMS", "Fire", and "Other" based on the incident description and who responded to the call (i.e., fire unit only or fire-based EMS unit). Fire incidents are self-explanatory and can be any indoor or outdoor fire, including a fire alarm. EMS calls vary and can entail a motor vehicle incident, trauma, or health event such as a stroke or heart attack. Finally, service calls, good intent calls, and false alarms are often coded as "Other" call types [53] in the database. Call type was used as a dependent variable in an additional analysis to further understand the use of SVI as a valid leading indicator within the fire services.

2.2. Other Imported Data Variables

2.2.1. Monthly Average of COVID-19 New Cases

Due to the self-reported cases of exposure to SARS-CoV-2, NIOSH researchers also added and controlled for the monthly average of COVID-19 new cases by county. The data were obtained from the New York Times (NYT) public data source hosted on GitHub [54]. Using the NYT data, researchers were able to match each county for which data were received with the averaged new daily cases added.

2.2.2. Social Vulnerability Index

The SVI data are publicly available from the CDC's website, which is not based on clinical or patient data. Data for all SVI themes and subtheme components were downloaded and used for analysis. CDC's SVI values are at the census tract, not the county level. The 2016 data [55] were downloaded from three states based on the response area covered by the participating fire departments. Participating fire departments were from Ohio, Massachusetts, and New York. After downloading the data, researchers matched the NFORS call data by census tract to the CDC's SVI data, which ranks census tracts from 0 to 1, where higher percentile rankings indicate greater social vulnerability. Call data were aggregated to the census tract level to establish the association of social vulnerability with SARS-CoV-2 exposure during emergency response calls. The SVI themes and factors are outlined in Table 1.

Table 1. CDC SVI 2016 themes and subthemes [55].

SVI Theme	SVI Subthemes	Negative Impact
Theme 1: Socioeconomic status (SES)	Percentage of persons below poverty estimate, percentage unemployed estimate, per capita income estimate, and percentage with no high school diploma estimate	Often lack resources needed to comply with emergency preparedness instructions
Theme 2: Household composition/disability	Percentage of people ≥65 and ≤17 years old, percentage with a disability, and percentage of single-parent households	Issues with communication and comprehension of an emergency, subsequent barriers to mobility, and more likely to need financial support
Theme 3: Minority status/language	Percentage in racial/ethnic minority groups and the percentage who speak English less than well	Trouble understanding public health directives, culturally insensitive messaging
Theme 4: Housing/transportation	Percentage multiunit structures, percentage mobile homes, percentage crowding, percentage no vehicle, and percentage group quarters	Live in multi-unit structures or mobile homes in group quarters, lack vehicle

2.3. Sample

From March through September 2020, data from 162,766 incident responses were received from three fire departments. After excluding for missing data, there were 161,948 incident responses. Of the three departments included in this study, 26.7% of the incidents were from one department; 69.7% from the second; and 3.6% from the third. Of these incidents, 99.4%, were considered "urban" in terms of population density and the remaining 0.6% were considered "rural." The lowest number of incidents was reported in April (11.9% of the sample) and the highest number in July (16.0%). Regarding days of the week on which incidents were responded to, calls were evenly dispersed, with the lowest number of incidents reported on Saturday (13.7% of the sample) and the highest number of incidents reported on Monday (14.8%). Within the sample, 63.3% of the calls were coded as EMS; 30.4% as Fire; and 6.3% as Other.

2.4. Analysis

As stated in the research questions, the main interest was determining the association between SVI and potential exposure to SARS-CoV-2 and call type. Consequently, it was important to control for confounding variables to reduce omitted variable bias. To help account for variable selection, researchers controlled for several variables, some of which were discussed in the above section and are highlighted again below:

- COVID-19 new cases: New cases of COVID-19 were controlled for in the analysis because the prevalence of COVID-19 infections in an area might affect the call type (i.e., higher rates of EMS calls) and subsequent potential exposure to SARS-CoV-2.
- Fire department/state: Knowing infection rates could be different by state, based on the time of the study, researchers aimed to capture regional effects (by state/department) by creating fire department dummies for use in the analyses.
- Month: Knowing infection rates could vary over time, researchers aimed to capture seasonal effects (by month) by creating time dummy variables.
- Population: If a fire department covers an area with a larger population, fire-based EMS responders may be more likely to be exposed to SARS-CoV-2, as well as receive certain types of calls, in comparison to departments who serve smaller populations, making population an important control variable.

Prior to performing the analyses, researchers examined the data. A root-mean square error (RMSE) and R2 were compared using a training sample of 80% and the remaining 20% as the designated test sample. Results were within the prescribed guidelines. Tolerance was also measured for each theme, and all were within an acceptable range between 0.32 to 0.69. Researchers concluded that multicollinearity was not a significant problem within the dataset and that the overall fit of the model was satisfactory.

2.4.1. SVI and Exposure to SARS-CoV-2

A binomial logit model was used to explain the effect of the four SVI themes on the probability of SARS-CoV-2 exposure during response calls controlling for total population, COVID-19 new cases, and department, as follows:

$$\begin{gathered}\text{Logit}(Y) = \text{Ln}\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1\text{THEME1} + \beta_2\text{THEME2} + \beta_3\text{THEME3} + \\ \beta_4\text{THEME4} + \beta_5\text{TOTPOP} + \beta_6\text{COVIDnewcases} + \beta_7\text{Department}\end{gathered} \quad (1)$$

After the logistic regression, a pair-wise comparison was conducted to assess the difference between New York and Ohio (Massachusetts was set as the baseline in the regression model). Additionally, due to the sample size, researchers performed a relative weights analysis [56,57] to determine the relative contribution of each predictor towards explaining variance in the criterion variable. Researchers partitioned R-squared into pseudo-orthogonal portions, with each portion representing the relative contribution of one predictor variable. The rescaled relative weights sum to 100% and the raw relative weights sum to the observed value of R-squared.

2.4.2. SVI and Types of Calls

To further understand the predictive utility of SVI, a multiple logistic regression was used, controlling for total population, COVID-19 new cases, and department. Further, relative risk ratios were determined through these analyses. Due to the sample size, researchers performed a relative weight analysis, as follows:

$$\begin{aligned} \mathrm{Ln}\left(\frac{\mathrm{P(calltype{=}FIRE)}}{\mathrm{P(calltype{=}EMS)}}\right) &= \beta_{10} + \beta_{11}\mathrm{THEME1} + \beta_{12}\mathrm{THEME2} + \beta_{13}\mathrm{THEME3} + \\ \beta_{14}\mathrm{THEME4} + \beta_{15}\mathrm{TOTPOP} + \beta_{16}\mathrm{COVIDnewcases} &+ \beta_{17}(\mathrm{department} = \mathrm{NY}) + \\ \beta_{18}(\mathrm{department} &= \mathrm{OH}) \end{aligned} \quad (2)$$

$$\begin{aligned} &\mathrm{Ln}\left(\frac{\mathrm{P(calltype{=}OTHER)}}{\mathrm{P(calltype{=}EMS)}}\right) \\ &= \beta_{20} + \beta_{21}\mathrm{THEME1} + \beta_{22}\mathrm{THEME2} + \beta_{23}\mathrm{THEME3} + \beta_{24}\mathrm{THEME4} \\ &+ \beta_{25}\mathrm{TOTPOP} + \beta_{26}\mathrm{COVIDnewcases} + \beta_{27}(\mathrm{department} = \mathrm{NY}) \\ &+ \beta_{28}(\mathrm{department} = \mathrm{OH}) \end{aligned}$$

where

β_{10}: intercept;
β_{11}: A one-unit increase in the variable Theme1 is associated with the change in the log odds of having FIRE call vs. EMS call in the amount of β_{11};
β_{21}: A one-unit increase in the variable Theme1 is associated with the change in the log odds of having OTHER call vs. EMS call in the amount of β_{21};
β_{17}: The log odds of having FIRE call vs. EMS call is associated with a change by β_{17} if moving from department MA to NY;
β_{28}: The log odds of having OTHER call vs. EMS call is associated with a change by β_{28} if moving from department MA to OH.

3. Results

3.1. Descriptive Statistics

Table 2 shows the descriptive statistics for the variables within the current study. Table 3 shows thematic vulnerability by SARS-CoV-2 exposure and emergency response call type, and Table 4 shows thematic vulnerability by exposure to SARS-CoV-2; department SVI mean plots for these variables are in Appendix A.

Table 2. Descriptive statistics.

Variables				
Continuous variables	*N*	Mean	SD	Description
Theme 1 (SES)	156,983	0.6086	0.3016	Percentile ranking of SES
Theme 2 (household/disability)	156,983	0.5220	0.3474	Percentile ranking of household composition/disability
Theme 3 (minority status/language)	156,983	0.6201	0.2287	Percentile ranking of minority status/language
Theme 4 (housing/transportation)	156,983	0.5843	0.2717	Percentile ranking of housing/transportation
Population	156,983	4504	2416	Total population of the geographic area
COVID-19 new cases	156,983	131	91.52	Monthly averaged COVID new cases of the specified geographic area (i.e., FIPS)
Categorical variables	*N*	percentage		
Potential SARS-CoV-2 Exposure	156,983			
Yes	8143	5.2%		
No	148,840	94.8%		
Department	156,983			
Massachusetts	41,917	26.7%		
New York	5692	3.6%		
Ohio	109,374	69.7%		
Call Type	156,983			
EMS	99,297	63.3%		
Fire	47,729	30.4%		
Other	9957	6.3%		

Table 3. Thematic vulnerability by SARS-CoV-2 exposure and emergency response call type.

	Theme 1 SES		Theme 2 Household/ Disability		Theme 3 Minority Status/Language		Theme 4 Housing/ Transportation	
Potential SARS-CoV-2 exposure	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Yes	0.6122	0.2793	0.5195	0.3329	0.7032	0.2191	0.6605	0.2557
No	0.6084	0.3028	0.5221	0.3481	0.6156	0.2283	0.5802	0.2719
Call Type	Mean	SD	Mean	SD	Mean	SD	Mean	SD
EMS	0.6382	0.2933	0.5732	0.3326	0.6015	0.2223	0.5581	0.2724
Fire	0.5566	0.3103	0.4401	0.3554	0.6439	0.2362	0.6185	0.2644
Other	0.5631	0.3019	0.4038	0.3489	0.6917	0.2298	0.6825	0.2570

Table 4. Thematic vulnerability by exposure to SARS-CoV-2 and department.

	Massachusetts		New York		Ohio	
Yes potential exposure	3212	7.7%	1338	23.5%	3593	3.3%
No potential exposure	38,705	92.3%	4354	76.5%	105,781	96.7%
Total	41,917		5692		109,374	
Vulnerability	Mean	SD	Mean	SD	Mean	SD
Theme 1	0.5524	0.2978	0.4650	0.2687	0.6377	0.2995
Theme 2	0.3778	0.3579	0.3662	0.2344	0.5854	0.3286
Theme 3	0.7555	0.2070	0.7434	0.2027	0.5618	0.2128
Theme 4	0.7370	0.1967	0.7074	0.2855	0.5194	0.2700

3.2. RQ1 Logit Regression for SVI and SARS-CoV-2 Exposure

In this analysis, logistic regression was performed on the potential exposure to SARS-CoV-2. All four SVI themes significantly predicted the probability of fire-based EMS responders' exposure to SARS-CoV-2 when responding to a call. Holding other variables constant, an increase in Themes 2, 3, and 4 was positively associated with exposure probability to SARS-CoV-2. Specifically, a one-unit increase (0.01 in RPL ranking percentile) in social vulnerability had the following impact (controlling for other variables):

- Theme 2—household composition increased the odds of exposure to SARS-CoV-2 by 49.3%;
- Theme 3—racial/ethnic minority/language increased the odds of exposure to SARS-CoV-2 by 94.4%;
- Theme 4—housing/transportation increased the odds of exposure to SARS-CoV-2 by 33.6%.

Regarding Theme 1, socioeconomic status was negatively associated with exposure to SARS-CoV-2. A one-unit increase in Theme 1 decreased the odds of having an exposure to SARS-CoV-2 by a factor of 0.210 (odds ratio = 0.810, $p = 0.004$), or 19%. Table 5 shows a full summary of results. Predicted probability plots are in Appendix B.

As indicated, due to the large sample size, a relative weights analysis was completed to ensure the integrity of the data in explaining potential exposure to SARS-CoV-2 during responses. The results demonstrated that the number of COVID-19 new cases had the heaviest weight of importance, meaning the number of new cases explained potential SARS-CoV-2 exposure the most (68.23%), followed by department (17.12%). The remaining 14.7% of the variance was explained by the SVI themes. Minority index (Theme 3) had the heaviest weight, followed by housing/transportation vulnerability (Theme 4).

Table 5. Summary of logit regression results.

	Est.	Std.Err	Pr (>|z|)	Odds Ratio	95% Confidence Interval	
					(2.5%)	(97.5%)
(intercept)	−4.020 *	0.063	0.000	0.018	0.016	0.0203
Theme 1 (SES)	−0.210 *	0.072	0.004	0.810	0.703	0.934
Theme 2 (household/disability)	0.401 *	0.052	0.000	1.493	1.349	1.653
Theme 3 (minority status/language)	0.665 *	0.080	0.000	1.944	1.663	2.274
Theme 4 (housing/transportation)	0.289 *	0.056	0.000	1.336	1.197	1.491
Department						
NY	0.869 *	0.042	0.000	2.383	2.196	2.585
OH	−0.807 *	0.033	0.000	0.446	0.418	0.476
Population	0.000 *	0.000	0.000	1.000	1.000	1.000
COVID-19 Cases	0.005 *	0.000	0.000	1.005	1.005	1.005

Pearson's chi-sq test (predicted vs. observed): X^2 = 25,326; df = 3511; $p < 0.001$; Pseudo R-squared: CoxSnell = 0.0407; Nagelkerke = 0.1215; McFadden = 0.1019; Log likelihood of each variable: $p < 0.001$; * $p < 0.01$.

3.3. RQ2: Multiple Logistic Regression for SVI and Call Type

Researchers further examined the utility of SVI as a leading indicator within the fire services. In this analysis, multinomial regression was performed on different fire-based EMS call types (EMS, Fire, and Other). Controlling for total population, COVID-19 new cases, and department, a higher SVI for Theme 1 was significantly associated with more EMS calls than non-EMS calls (i.e., Fire and Other). This was the same for Themes 2 and 3. For Theme 4, however, a higher SVI was associated with more EMS calls compared to Fire but was the opposite for other calls. Table 6 shows the multiple logistic regression results.

Table 6. Multinomial logistic regression results.

	FIRE			OTHER		
	Coefficient	RRR	95% CI	Coefficient	RRR	95% CI
(Intercept)	1.222 *	3.3931	3.3706–3.4157	−0.385 *	0.6803	0.6797–0.6809
SVI themes						
Theme 1	−0.254 *	0.7754	0.7697–0.7811	−0.062 *	0.9403	0.9395–0.9412
Theme 2	−0.368 *	0.6919	0.6873–0.6964	−0.637 *	0.5287	0.5283–0.5291
Theme 3	−0.281 *	0.7550	0.7511–0.7589	−0.048 *	0.9529	0.9522–0.9537
Theme 4	−0.036 *	0.9644	0.9593–0.9694	0.312 *	1.3668	1.3658–1.3678
Department						
NY	−1.656 *	0.1909	0.1908–0.1910	−1.362 *	0.2561	0.2561–0.2562
OH	−1.959 *	0.14106	0.1403–0.1418	−2.520 *	0.08043	0.0804–0.0805
Total population	−0.00000	1	1.0000–1.0000	−0.00002 *	1	1.0000–1.0000
COVID-19 cases	−0.0002 **	0.9998	0.9997–1.0000	−0.0003 *	0.9997	0.9995–0.9998
Residual deviance	227314					
AIC	227350					

Notes: * $p < 0.01$; ** $p < 0.05$; RRR = relative risk ratios; AIC = Akaika information criterion.

A relative weights analysis on the call type showed that department was the strongest predictor. After department, the four SVI themes had significantly higher relative weights than the other control variables (total population and COVID-19 new cases) at 22.8% of the variance in explaining the call type. Theme 2 had the heaviest weight, followed by Theme 3, Theme 4, and Theme 1.

4. Discussion

Using potential exposure to SARS-CoV-2, this study applied CDC's SVI as a leading indicator of fire-based EMS responders' potential health outcomes during response calls, rather than as a measure of emergency and disaster preparedness. Previous findings [47,48,58–60] have shown that COVID-19 disproportionately affects certain areas more

than others. The current results show that fire-based EMS responders who answer calls to these areas with a higher SVI can experience higher incidents of exposure to SARS-CoV-2. These risks are likely not only specific to occupational exposure to SARS-CoV-2 but also to other hazardous conditions faced during unknown emergency calls, requiring more patient interaction, which was also predicted by the SVI themes. Therefore, these results may have implications for emergency response planning, including resource allocation and supply distribution.

Specifically, this analysis provides evidence that adequate supplies and training are critical to fire-based EMS responders who serve populations with higher vulnerability. Consequently, results can be incorporated into fire-based EMS responders' approaches to prepare for, respond to, and communicate with patients. This information also provides a new level of situational awareness for advancing NIOSH's future of work initiative, including ways to control risks, monitor changes, and connect trends in the workplace, work, and workforce. NIOSH's future of work initiative encourages the use of a TWH® framework to collaborate on improving policies, programs, and practices [26]. To that end, this discussion focuses on several TWH® elements, as emphasized within NIOSH's future of work initiative, in which the identification of SVI as a leading health indicator can be used to improve fire-based EMS responder health outcomes and well-being.

4.1. Health Promotion Interventions That Engage Workers on and off the Job

Both research questions showed that areas with higher social vulnerability were predictive of fire-based EMS responders' direct interaction with patients through EMS calls and, not surprisingly, potential exposure to SARS-CoV-2. Consequently, it is important to emphasize research related to social determinants of health (SDOH) [61]. Addressing SDOH through the development of health promotion resources and interventions can indirectly benefit fire-based EMS responders who serve these communities, in addition to the residents. NIOSH has proposed such integrations of occupational safety and health protections in communities and workplace health promotion activities [25] to improve efficiency, resource management, and worker health [62]. These health promotion efforts such as safe work locations, worker housing, and community safety recognize the blurred boundaries between work, home, and community life [63]. However, there is a gap in empirical interventions within the fire service [64], making future research-to-practice in this area important.

Also, engaging workers in the development of health promotion resources and interventions is a key element of TWH® [25]. If fire-based EMS responders are involved in community–workplace intervention design, it is more likely that proposed initiatives will fit their workplace context, improve organizational learning, and improve sense of ownership and subsequent participation [65–68]. The current SVI results provide space for a variety of targeted interventions that can involve fire-based EMS responders, including the following:

- Incorporate and update SVI as a health leading indicator into safety and health programs around hazard recognition and risk assessment (for examples of such indicators, see [33,34,38]). As previously mentioned, some fire departments have made this addition to their risk assessment programs already e.g., [49]. This mindful addition will allow SVI to be included and acknowledged in organizational audits of fire departments' safety and health management systems.
- Incorporate SVI information into health promotion/wellness programs within the fire services, including easy-to-read materials on how psychosocial factors influence workers' health outcomes, for examples, see [69,70].
- Develop and include educational training materials to maintain safety and health when responding to areas with higher social vulnerability. For example, fire departments can work with their public health departments to develop and provide plain-language, culturally sensitive, and relevant public health messaging tailored to community needs. Regarding COVID-19 specifically, educational materials could be

multi-lingual and contain known risk factors for adverse outcomes [71]. Fire-based EMS responders can have these resources with them during emergency response calls to help educate the community and minimize communication gaps with community residents during good intent or other nonlife-threatening calls.

These efforts could be particularly helpful, as one study determined that inconsistent communication is associated with higher SVI [72]. Therefore, an advantage to working with public health departments during health promotion efforts is that all local public safety and health leaders can communicate the same message in the same way within their communities.

Taking NIOSH's future of work perspective into account, there are additional aspects to consider. Specifically, worker groups within the fire services that are disproportionately vulnerable to certain health risks should be involved in any type of program design and implementation [27,73]. For example, fire-based EMS responders who work rotating or night shifts and are more susceptible to fatigue, as well as older workers who are more susceptible to cardiovascular health issues, could be asked to give input regularly. Their involvement is necessary to identify job characteristics and work processes that impede participation in health promotion activities during emergency response calls [74]. Additionally, their feedback can help identify resource allocation issues before making larger changes to the workplace [24].

4.2. Improvement of Data Surveillance at the Organizational and Policy Levels

Another key element of TWH® that is also discussed in NIOSH's future of work initiative is the use of data-driven results to improve outcomes. The CDC has discussed the availability of timely surveillance data as a primary goal in its future of work data modernization initiatives [75]. Data modernization also includes the ability to use artificial intelligence (AI) and machine learning techniques on surveillance data. Regarding firefighter surveillance data, researchers have argued for the necessity of using AI to account for worker emotions during emergency responses, which can help with data objectivity and accurate risk identification [76]. These results demonstrate that not only improvements in data surveillance but also the application of those data by the fire service can be improved to identify latent, health leading indicators. The value of better surveillance from two perspectives is discussed: increased AI capabilities to predict future incidents and increased risk assessment capabilities on the ground to prepare workers.

4.2.1. Emergency Call Surveillance Data for Machine Learning

There is a critical need to advance occupational safety and health surveillance [50]. Improved data can allow researchers, practitioners, and organizations to identify groups at higher occupational risk and subsequently tailor interventions [73,74]. Specific to emergency response data, previous research has argued that a strained 911 system is responsible for inaccurately understanding resources needed during response calls [77], including the need for what PPE to bring and use during a response call [78]. In these referenced studies, participating EMS workers and firefighters discussed the need for improvements to the 911 data catalogue system to assist with accurate triage efforts, targeting the use of EMS resources, updating continuing education based on job demands, and improving a social safety net to address the persistent needs of populations of older adults (aged $\geq$65 years) and people with lower incomes [77].

The current results provide two recommended action items to improve surveillance efforts. First, SVI, as a publicly available data point, can be integrated and regularly updated in CAD systems and used as more than a measure for emergency response. Second, SVI can also be used as an objective data point in emergency call logs to provide advanced surveillance opportunities. Research has identified the value in updating computerized work systems for improving policy and practice standards [79], and this addition may inform such standards. Additionally, although machine learning has greatly advanced, there are still issues related to algorithm bias and trust in the results [80]. It is possible that,

over time, using SVI as a leading indicator with other details of emergency response call logs can help ensure that responders have the training and resources needed to protect themselves from potential exposures, including SARS-CoV-2, during every response call.

To illustrate, using the original data codes provided to NIOSH, regression models showed that higher SVI was associated with EMS calls over Fire and Other calls (except for one theme). To examine whether this trend remained, researchers further coded and created two new variables for response calls that were received in large quantities (i.e., automobile calls and hazmat calls). Using the same analyses as in RQ2, emergency calls involving automobile incidents were predicted by a higher SVI in Theme 1 and 2 in comparison to the remaining EMS calls. This small case example shows the value of improved surveillance data in the fire services and that objective data points are needed to inform higher-level predictive analytics. This barrier has also been referenced and discussed by others, e.g., [53,81], but it is necessary to improve it as the future of work changes.

4.2.2. Response Planning and Resource Allocation

It is possible that integrating SVI into more systematic surveillance efforts can elucidate some of the inconsistencies among available tools that are used to identify, plan for, and respond to areas of higher risk for workers [82]. All employees having access to available and useful resources is important, as a challenge regarding the future of work is ensuring the equitable distribution of benefits and risks that accompany phenomena such as nonstandard work arrangements [50]. It may be beneficial for fire departments to incorporate social vulnerability assessments into emergency management practices, including needs assessment tools and preparedness checklists. For example, research has indicated that SVI can be used to decide how many emergency personnel should be sent to assist during a response [49]. Using checklists has been deemed an appropriate method for involving fire-based EMS workers in needs assessment efforts [83,84]. They can also help address the needs of vulnerable workers through increased transparency [85]. Therefore, using SVI data to update needs assessment tools regularly may enhance public health planning and response efforts for these workers, allowing fire-based EMS responders to identify communities that may require more resources during a call (e.g., additional PPE, apparatus, or workers), or to have a more accurate understanding of the type of call to which they may be responding.

In the current results, a higher SVI in Themes 2, 3 and 4 were predictive of exposure to SARS-CoV-2. Fire departments can use these results to update aspects of not only COVID-19 health and safety plans to protect employees but also emergency preparedness plans for future occupational exposure risks. When deployed to areas with a higher SVI in these themes, EMS strategies can include maintaining familiarity with the CDC's COVID-19 resources for firefighters and EMS providers and employing recommended strategies such as wearing the recommended PPE or providing facemasks or cloth coverings to patients for source control if they do not have any [12]. A similar strategy has worked well in a recent field-based study, where an EMS location updated its dispatch systems to gather high- and low-risk criteria to determine whether an alert "PPE advised" should be provided to the EMS responders for a particular call [8]. SVI data can help inform part of this decision making in the future.

4.3. Limitations

This study demonstrated the utility of SVI as a health leading indicator in the fire services, identifying opportunities in future surveillance efforts, potential resources for adequate emergency response planning and supply management, and possible updates to community-organizational health promotion efforts in the areas to which fire-based EMS responders are deployed. These results suggest opportunities to make immediate changes to help protect fire-based EMS responders and provide implications for improving future of work initiatives. Although the suggested initiatives are promising, there are limitations to the data. First, researchers pointed to gaps in the current dataset around emergency system

call coding, which must be considered. Additionally, potential SARS-CoV-2 exposure was self-reported, and it is unclear whether these potential exposures resulted in COVID-19 diagnoses amongst exposed responders. Researchers controlled for these data limitations by further exploring and recoding the call type variable and controlling for actual COVID-19 cases in the three departments included in the sample. However, even the controlled COVID-19 cases are limited due to issues around testing availability, so the true prevalence is still unknown. Therefore, future surveillance research is necessary to best understand these results.

Second, there are many external factors that make implementing some of these suggestions difficult and thus illustrate limitations in the feasibility of the results. For example, although prioritizing resources during higher-risk calls such as PPE use may be desired, the availability of such resources may make adherence to suggestions difficult [86]. Additionally, this study did not take the size of these departments into consideration when providing potential future of work initiatives using SVI. Previous research has discussed the impact that organization size can have not only on the resources available to develop safety and health programs but also the efficacy in being able to effectively implement them to protect worker safety, health, and well-being, e.g., [87,88]. Therefore, future research should address the feasibility of using SVI to inform safety and health decision making at different-sized fire departments.

5. Conclusions

Despite the limitations of the current study, the results show promise in the value of health leading indicators in the fire services, as well as how these indicators can be used to address challenges associated with the future of work. A result of improved leading indicator identification, particularly within emergency management, is that organizations and their employees are aware of and can adjust to hazards to prevent negative outcomes. This study was unique in that most occupational safety and health research focuses on safety leading indicators [38], whereas this analysis focused on health leading indicators to prevent occupational exposure and improve worker preparedness and well-being.

Research has argued that emergency management must use the right technology and tools to support work processes needed during dynamic response scenarios [32]. Opportunities for improved work processes were revealed in this study, including (1) health promotion activities and interventions that engage workers, (2) improved data surveillance methods, and (3) the development of accurate, regularly updated needs assessments. The CDC has discussed the importance of using and integrating data to guide improvements in communication plans, emergency preparedness, and to develop comprehensive pictures of groups with higher occupational risk [73,89]. The results of this study illustrate the value of using data to not only compile an accurate understanding of groups with higher occupational risk, but also ways to positively impact fire-based EMS responders' health and well-being over time.

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Institutional Review Board Statement: Ethical review and approval were waived for this study because NIOSH did not support or conduct the data collection, was not engaged with study participants, and did not receive any personal identifiable information as part of this effort—45 CFR Part 46—Protection of Human Subjects did not apply to this work; no review on behalf of NIOSH Institutional Review Board (IRB) review was necessary.

Informed Consent Statement: Not applicable.

Data Availability Statement: Restrictions apply to the availability of these data. Data were obtained by a Research Collaboration Agreement with IPSDI and participating fire departments.

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Conflicts of Interest: The authors declare no conflict of interest.

Disclaimer: The findings and conclusions in this report are those of the authors, and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

Appendix A

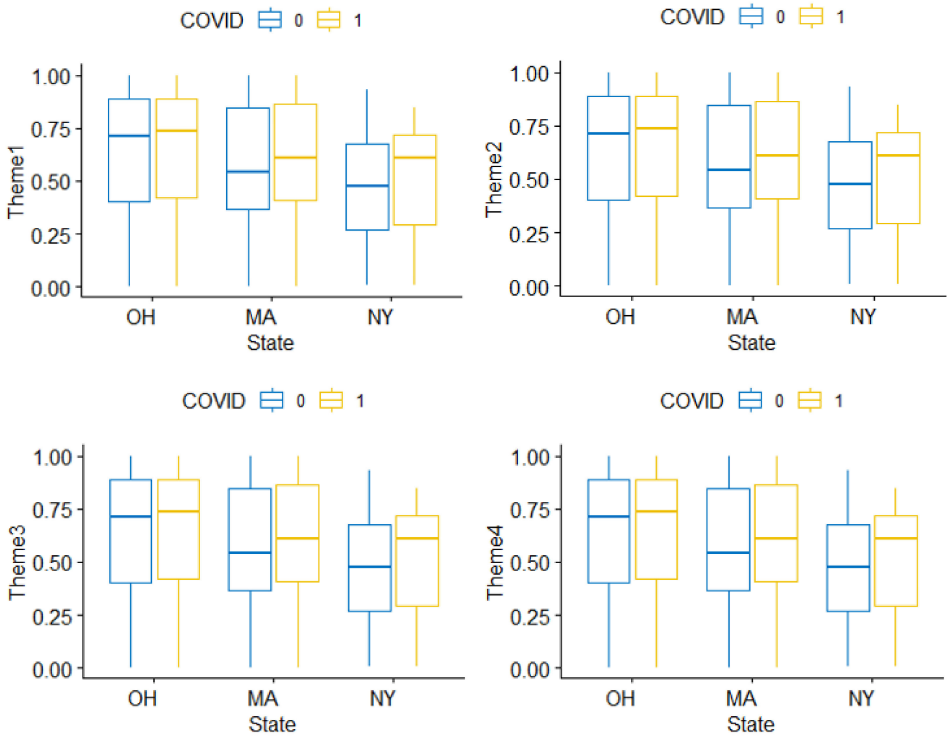


Figure A1. SVI mean plot with SE by exposure to COVID-19 and department.

Appendix B

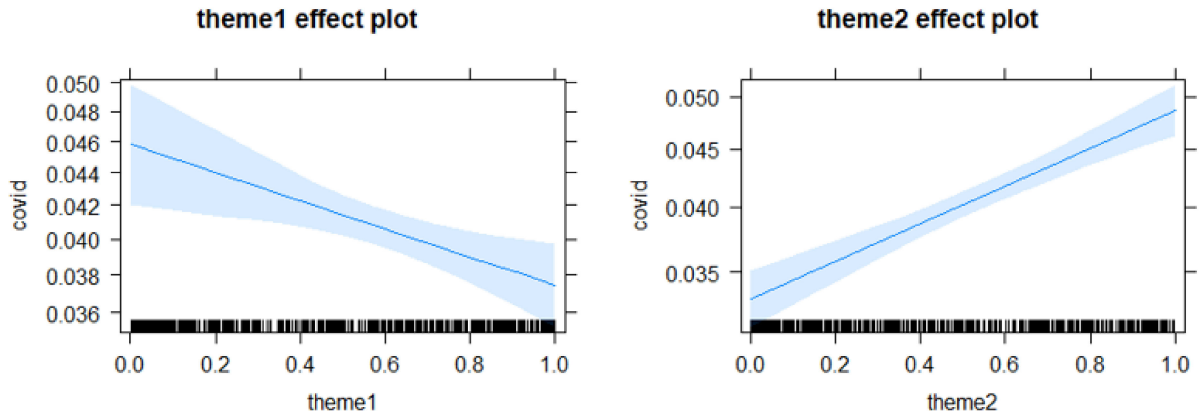


Figure A2. *Cont.*

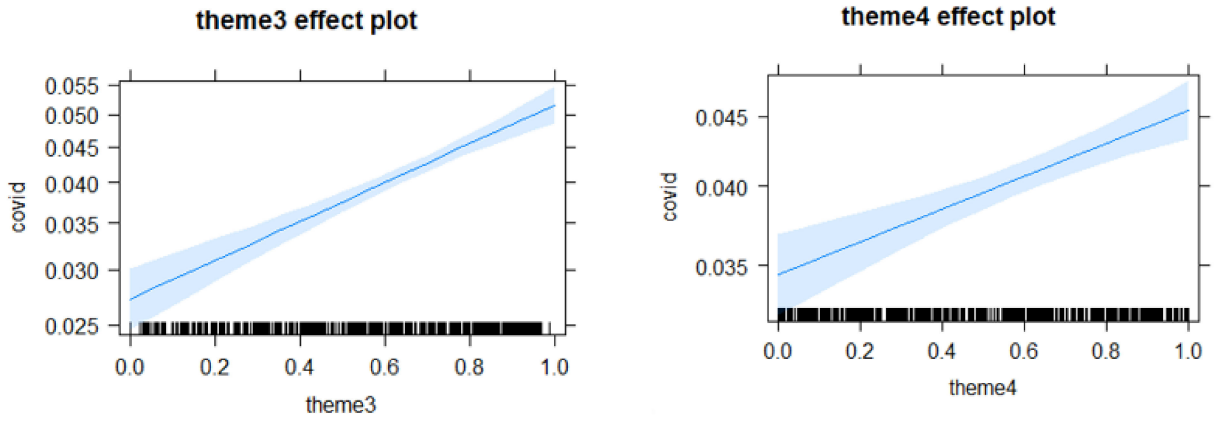


Figure A2. Predicted probability plots with 95% confidence interval by each predictor.

References

1. Reichard, A.A.; Jackson, L.L. Occupational injuries among emergency responders. *Am. J. Ind. Med.* **2009**, *53*, 1–11. [CrossRef]
2. EMS as an Essential Public Safety Service. *Ann. Emerg. Med.* **2017**, *70*, 942. [CrossRef] [PubMed]
3. NHTSA Office of EMS. What Is EMS? Available online: https://www.ems.gov/whatisems.html (accessed on 21 April 2021).
4. ILO (International Labour Organization). CHAPTER V: Substantive Provisions of Labour Legislation. Available online: https://www.ilo.org/legacy/english/dialogue/ifpdial/llg/noframes/ch5.htm#6 (accessed on 14 December 2020).
5. NFPA. National Fire Protection Association. Fire Department Calls. Available online: https://www.nfpa.org/News-and-Research/Data-research-and-tools/Emergency-Responders/Fire-department-calls (accessed on 17 April 2021).
6. Keisling, P. Why We Need to Take the 'Fire' out of 'Fire Department'. Available online: https://www.governing.com/archive/col-fire-departments-rethink-delivery-emergency-medical-services.html (accessed on 15 April 2021).
7. Maguire, B.J.; O'Neill, B.J.; Phelps, S.; Maniscalo, P.M.; Gerard, D.R.; Handal, K.A. COVID-19 Fatalities among EMS Clinicians. *EMS*. 2020. Available online: https://www.ems1.com/ems-products/personal-protective-equipment-ppe/articles/covid-19-fatalities-among-ems-clinicians-BMzHbuegIn1xNLrP/ (accessed on 15 April 2021).
8. Murphy, D.L.; Barnard, L.M.; Drucker, C.J.; Yang, B.; Emert, J.M.; Schwarcz, L.; Counts, C.; Jacinto, T.Y.; McCoy, A.M.; Morgan, A.T.; et al. Occupational exposures and programmatic response to COVID-19 pandemic: An emergency medical services experience. *Emerg. Med. J.* **2020**, *37*, 707–713. [CrossRef] [PubMed]
9. Harrison, R.; Shusterman, D.; Kurtz, T.; Grant, M.; Brokaw, J.; Phelps, S.; Nunez, A. SFFD COVID-19 Antibody Study: Prelim-Inary Information. Available online: https://sffd19.ucsf.edu/sites/g/files/tkssra5726/f/wysiwyg/SFFD%20COVID19%20Seroprev%20Summary%20wo%20.pdf (accessed on 4 July 2021).
10. Weiden, M.D.; Zeig-Owens, R.; Singh, A.; Schwartz, T.; Liu, Y.; Vaeth, B.; Nolan, A.; Cleven, K.L.; Hurwitz, K.; Beecher, S.; et al. Pre-COVID-19 lung function and other risk factors for severe COVID-19 in first responders. *ERJ Open Res.* **2021**, *7*, 1–4. [CrossRef]
11. Jamieson, A. What Happens as More Police, Firefighters, and Paramedics Get Sick with COVID-19? Available online: https://www.healthline.com/health-news/what-do-we-do-if-our-police-firefighters-and-paramedics-all-get-sick-with-covid-19 (accessed on 3 July 2021).
12. CDC (Centers for Disease Control and Prevention). What Firefighters and EMS Providers Need to Know about COVID-19. 2021. Available online: https://www.cdc.gov/coronavirus/2019-ncov/community/organizations/firefighter-EMS.html (accessed on 18 April 2021).
13. Butler, C.; Marsh, S.; Domitrovich, J.W.; Helmkamp, J. Wildland firefighter deaths in the United States: A comparison of existing surveillance systems. *J. Occup. Environ. Hyg.* **2017**, *14*, 258–270. [CrossRef] [PubMed]
14. Estes, C.R.; Marsh, S.M.; Castillo, D.N. Surveillance of traumatic firefighter fatalities: An assessment of four systems. *Public Health Rep.* **2011**, *126*, 540–551. [CrossRef] [PubMed]
15. Poplin, G.S.; Pollack, K.M.; Griffin, S.; Day-Nash, V.; Peate, W.F.; Nied, E.; Gulotta, J.; Burgess, J.L. Establishing a proactive safety and health risk management system in the fire service. *BMC Public Health* **2015**, *15*, 407. [CrossRef]
16. Walton, S.M.; Conrad, K.M.; Furner, S.E.; Samo, D.G. Cause, type, and workers' compensation costs of injury to fire fighters. *Am. J. Ind. Med.* **2003**, *43*, 454–458. [CrossRef] [PubMed]
17. Marsh, S.M.; Gwilliam, M.; Konda, S.; Tiesman, H.M.; Fahy, R. Nonfatal injuries to firefighters treated in U.S. emergency departments, 2003–2014. *Am. J. Prev. Med.* **2018**, *55*, 353–360. [CrossRef]
18. Lee, D.J.; Fleming, L.E.; Gomez-Marín, O.; Leblanc, W. Risk of hospitalization among firefighters: The national health interview survey, 1986–1994. *Am. J. Public Health* **2004**, *94*, 1938–1939. [CrossRef]
19. Smith, T.D.; DeJoy, D.M.; Dyal, M.-A.; Pu, Y.; Dickinson, S. Multi-level safety climate associations with safety behaviors in the fire service. *J. Saf. Res.* **2019**, *69*, 53–60. [CrossRef]

20. Smith, T.; Hughes, K.; DeJoy, D.M.; Dyal, M.-A. Assessment of relationships between work stress, work-family conflict, burnout and firefighter safety behavior outcomes. *Saf. Sci.* **2018**, *103*, 287–292. [CrossRef]
21. Tiesman, H.M.; Gwilliam, M.; Konda, S.; Rojek, J.; Marsh, S. Nonfatal injuries to law enforcement officers: A rise in assaults. *Am. J. Prev. Med.* **2018**, *54*, 503–509. [CrossRef]
22. El Sayed, S.A.; Sanford, S.M.; Kerley, K.R. Understanding workplace stress among federal law enforcement officers. *Am. J. Crim. Justice* **2019**, *44*, 409–429. [CrossRef]
23. CDC (Centers for Disease Control and Prevention). *Planning for an Emergency: Strategies for Identifying and Engaging at-Risk Groups. A Guidance Document for Emergency Managers*, 1st ed.; CDC: Atlanta, GA, USA, 2015. Available online: https://www.cdc.gov/nceh/hsb/disaster/atriskguidance.pdf (accessed on 3 July 2021).
24. Smith, T.D.; Mullins-Jaime, C.; Dyal, M.-A.; DeJoy, D.M. Stress, burnout and diminished safety behaviors: An argument for Total Worker Health® approaches in the fire service. *J. Saf. Res.* **2020**, *75*, 189–195. [CrossRef]
25. NIOSH (National Institute for Occupational Safety and Health). What Is Total Worker Health? Available online: https://www.cdc.gov/niosh/twh/totalhealth.html (accessed on 12 April 2021).
26. NIOSH (National Institute for Occupational Safety and Health). The NIOSH Future of Work Initiative. 2020. Available online: https://www.cdc.gov/niosh/topics/future-of-work/default.html (accessed on 8 April 2021).
27. NIOSH (National Institute for Occupational Safety and Health). *Fundamentals of Total Worker Health Approaches: Essential Elements for Advancing Worker Safety, Health, and Well-Being*; Publication No. 2017-112; Lee, M.P., Hudson, H., Richards, R., Chang, C.C., Chosewood, L.C., Schill, A.L., Eds.; NIOSH: Cincinnati, OH, USA, 2016.
28. Tamers, S.L.; Chosewood, L.C.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.C. Total Worker Health® 2014–2018: The novel approach to worker safety, health, and well-being evolves. *Int. J. Environ. Res. Public Health* **2019**, *16*, 321. [CrossRef] [PubMed]
29. ASSP (American Society of Safety Professionals). *ASSP/ISO TR-45005-2021 Occupational Health and Safety Management—Safe Working During the COVID-19 pandemic—General Guidelines for Organizations*; A technical report prepared by ASSP and registered with ANSI; American Society of Safety Professionals: Park Ridge, IL, USA, 2021.
30. Sinclair, R.R.; Allen, T.; Barber, L.; Bergman, M.; Britt, T.; Butler, A.; Ford, M.; Hammer, L.; Kath, L.; Probst, T.; et al. Occupational health science in the time of COVID-19: Now more than ever. *Occup. Health Sci.* **2020**, *4*, 1–22. [CrossRef] [PubMed]
31. ADPC (Asian Disaster Preparedness Center). Integrating Disaster Risk Management into the Development Process. Disaster Risk Management Practitioner's Handbook Series, Bangkok. 2013. Available online: https://www.adpc.net/igo/category/ID407/doc/2013-pKb4FR-ADPC-ADPC_DRM_Practitioners_Handbook_-_The_Development_Process.pdf (accessed on 17 April 2021).
32. Tveiten, C.K.; Albrechtsen, E.; Wærø, I.; Wahl, A.M. Building resilience into emergency management. *Saf. Sci.* **2012**, *50*, 1960–1966. [CrossRef]
33. NSC, National Safety Council, Campbell Institute. Elevating EHS Leading Indicators: From Defining to Designing. 2017. Available online: https://www.thecampbellinstitute.org/wp-content/uploads/2017/05/Campbell-Institute-Elevating-EHS-Leading-Indicators-From-Defining-to-Designing-WP.pdf (accessed on 17 April 2021).
34. NSC, National Safety Council, Campbell Institute. Transforming EHS Performance Measurement through Leading Indicators. 2017. Available online: https://www.thecampbellinstitute.org/wp-content/uploads/2017/07/Campbell-Institute-Transforming-EHS-through-Leading-Indicators-WP.pdf (accessed on 17 April 2021).
35. NSC, National Safety Council, Campbell Institute. An Implementation Guide to Leading Indicators. 2019. Available online: https://www.thecampbellinstitute.org/wp-content/uploads/2019/08/Campbell-Institute-An-Implementation-Guide-to-Leading-Indicators.pdf (accessed on 17 April 2021).
36. NASEM. *Leading Health Indicators 2030: Advancing Health, Equity, and Well-Being*; National Academies of Sciences, Engineering, and Medicine: Washington, DC, USA, 2020.
37. IOM (Institute of Medicine). *Leading health indicators for health people 2020: Letter report*; The National Academies Press: Washington, DC, USA, 2011. [CrossRef]
38. AIHA (American Industrial Hygiene Association). Best Practice Guide for Leading Health Metrics in Occupational Health and Safety Programs. 2020. Available online: https://aiha-assets.sfo2.digitaloceanspaces.com/AIHA/resources/Guidance-Documents/Best-Practice-Guide-for-Leading-Health-Metrics-in-Occupational-Health-and-Safety-Programs-Guidance-Document.pdf (accessed on 15 April 2021).
39. Morrow, B.H. Identifying and Mapping Community Vulnerability. *Disasters* **1999**, *23*, 1–18. [CrossRef]
40. O'Brien, G.; O'Keefe, P.; Rose, J.; Wisner, B. Climate change and disaster management. *Disasters* **2006**, *30*, 64–80. [CrossRef]
41. Phillips, B.D.; Thomas, D.S.; Fothergill, A.; Blinn-Pike, L. *Social Vulnerability to Disasters*; CRC Press: Boca Raton, FL, USA, 2010.
42. Cutter, S.L.; Burton, C.G.; Emrich, C.T. Disaster resilience indicators for benchmarking baseline conditions. *J. Homel. Secur. Emerg. Manag.* **2010**, *7*, 1–22.
43. Cutter, S.L. GI science, disasters, and emergency management. *Trans GIS* **2003**, *7*, 439–446. [CrossRef]
44. Cutter, S.L.; Mitchell, J.T.; Scott, M.S. Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina. *Ann. Assoc. Am. Geogr.* **2000**, *90*, 713–737. [CrossRef]
45. Flanagan, B.E.; Gregory, E.W.; Hallisey, E.J.; Heitgerd, J.L.; Lewis, B. A social vulnerability index for disaster management. *J. Homel. Secur. Emerg. Manag.* **2011**, *8*, 1–22. [CrossRef]

46. CDC (Centers for Disease Control and Prevention). Health Equity Considerations and Racial and Ethnic Minority Groups. 2021. Available online: https://www.cdc.gov/coronavirus/2019-ncov/community/health-equity/race-ethnicity.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcoronavirus%2F2019-ncov%2Fneed-extra-precautions%2Fracial-ethnic-minorities.html (accessed on 21 April 2021).
47. ATSDR (Agency for Toxic Substances and Disease Registry). Social Vulnerability Index. 2021. Available online: https://www.atsdr.cdc.gov/placeandhealth/svi/index.html (accessed on 18 April 2021).
48. Dasgupta, S.; Bowen, V.B.; Leidner, A.; Fletcher, K.; Musial, T.; Rose, C.; Cha, A.; Kang, G.; Dirlikov, E.; Pevzner, E.; et al. Association between social vulnerability and a county's risk for becoming a COVID-19 hotspot—United States, June 1–July 25, 2020. *Morb. Mortal Wkly. Rep.* **2020**, *69*, 1535. [CrossRef] [PubMed]
49. City of Columbus. Columbus Fire and EMS Standards of Cover/Community Risk Assessment. 2020. Available online: https://www.columbusga.gov/Portals/FireEMS/StandardsOfCover2020.pdf?ver=BQu8fFyIs1WfBj3beL4ZaQ%3D%3D (accessed on 8 July 2021).
50. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
51. OSHA (Occupational Safety and Health Administration). Part 1910.1030—Bloodborne Pathogens. Available online: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1030 (accessed on 18 April 2021).
52. IPSDI (International Public Safety Data Institute). NFORS Changes Everything. Available online: https://i-psdi.org/nfors-overview.html (accessed on 20 April 2021).
53. Kinsey, K.; Ahrens, M. *NFIRS Incident Types: Why Aren't They Telling a Clearer Story?* National Fire Protection Association: Quincy, MA, USA, 2016. Available online: https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Emergency-responders/osNFIRSIncidentType.ashx?la=en (accessed on 10 April 2021).
54. GitHub. NY Times COVID-19 Data. Available online: https://github.com/nytimes/covid-19-data (accessed on 10 April 2021).
55. ATSDR (Agency for Toxic Substances and Disease Registry). Geospatial Research, Analysis, and Service Program. Social Vulnerability Index. Available online: https://svi.cdc.gov/data-and-tools-download.html (accessed on 1 February 2021).
56. Tonidandel, S.; LeBreton, J.M. Relative importance analysis: A useful supplement to regression analysis. *J. Bus. Psychol.* **2011**, *26*, 1–9. [CrossRef]
57. Tonidandel, S.; Lebreton, J.M.; Johnson, J.W. Determining the statistical significance of relative weights. *Psychol. Methods* **2009**, *14*, 387–399. [CrossRef]
58. Millett, G.A.; Jones, A.T.; Benkeser, D.; Baral, S.; Mercer, L.; Beyrer, C.; Honermann, B.; Lankiewicz, E.; Mena, L.; Crowley, J.S.; et al. Assessing differential impacts of COVID-19 on black communities. *Ann. Epidemiol.* **2020**, *47*, 37–44. [CrossRef]
59. Kaiser Family Foundation. Low-Income and Communities of Color at Higher Risk of Serious Illness If Infected with Coronavirus. Available online: https://www.kff.org/coronavirus-covid-19/issue-brief/low-income-and-communities-of-color-at-higher-risk-of-serious-illness-if-infected-with-coronavirus/ (accessed on 15 April 2021).
60. Rodriguez-Diaz, C.E.; Guilamo-Ramos, V.; Mena, L.; Hall, E.; Honermann, B.; Crowley, J.S.; Baral, S.; Prado, G.J.; Marzan-Rodriguez, M.; Beyrer, C.; et al. Risk for COVID-19 infection and death among Latinos in the United States: Examining heterogeneity in transmission dynamics. *Ann. Epidemiol.* **2020**, *52*, 46–53.e2. [CrossRef]
61. Karaye, I.M.; Horney, J.A. The Impact of social vulnerability on COVID-19 in the U.S.: An analysis of spatially varying relationships. *Am. J. Prev. Med.* **2020**, *59*, 317–325. [CrossRef]
62. Punnett, L.; Cavallari, J.M.; Henning, R.A.; Nobrega, S.; Dugan, A.G.; Cherniack, M.G. Defining 'integration for Total Worker Health®: A new proposal. *Ann. Work. Expo. Health* **2020**, *64*, 223–235. [CrossRef]
63. Schill, A.L. Advancing well-being through Total Worker Health®. *Work. Health Saf.* **2017**, *65*, 158–163. [CrossRef]
64. Maguire, B.J.; Smith, S. Injuries and fatalities among emergency medical technicians and paramedics in the United States. *Prehosp. Disaster Med.* **2013**, *28*, 376–382. [CrossRef] [PubMed]
65. Henning, R.; Warren, N.; Robertson, M.; Faghri, P.; Cherniack, M. The CPH-NEW research team workplace health protection and promotion through participatory ergonomics: An integrated approach. *Public Health Rep.* **2009**, *124*, 26–35. [CrossRef] [PubMed]
66. Punnett, L.; Cherniack, M.; Henning, R.; Morse, T.; Faghri, P. The CPH-NEW Research Team A conceptual framework for integrating workplace health promotion and occupational ergonomics programs. *Public Health Rep.* **2009**, *124*, 16–25. [CrossRef] [PubMed]
67. Punnett, L.; Warren, N.; Henning, R.; Nobrega, S.; Cherniack, M. Participatory ergonomics as a model for integrated programs to prevent chronic disease. *J. Occup. Environ. Med.* **2013**, *55*, S19–S24. [CrossRef]
68. Cherniack, M.; Dussetschleger, J.; Dugan, A.; Farr, D.; Namazi, S.; El Ghaziri, M.; Henning, R. Participatory action research in corrections: The HITEC 2 program. *Appl. Ergon.* **2016**, *53*, 169–180. [CrossRef]
69. CDC (Centers for Disease Control and Prevention). The CDC Worksite Health ScoreCard. Available online: https://www.cdc.gov/dhdsp/pubs/docs/HSC_Manual.pdf (accessed on 15 April 2021).
70. CDC (Centers for Disease Control and Prevention). Introduction to the "New and Improved" CDC Worksite Health ScoreCard. Available online: www.cdc.gov/workplacehealthpromotion/initiatives/healthscorecard/pdf/CDC-Scorecard-Update-Webinar-Final-508.pdf (accessed on 15 April 2021).

71. Cromer, S.J.; Lakhani, C.M.; Wexler, D.J.; Burnett-Bowie, S.A.M.; Udler, M.; Patel, C.J. Geospatial Analysis of Individual and Community-Level Socioeconomic Factors Impacting SARS-CoV-2 Prevalence and Outcomes. Available online: https://www.medrxiv.org/content/10.1101/2020.09.30.20201830v1 (accessed on 17 April 2021).
72. Chau, P.H.; Gusmano, M.K.; Cheng, J.O.Y.; Cheung, S.H.; Woo, J. Social vulnerability index for the older people—Hong Kong and New York City as examples. *J. Hered.* **2014**, *91*, 1048–1064. [CrossRef] [PubMed]
73. National Institute for Occupational Safety and Health and American Society of Safety Professionals. *Overlapping Vulnerabilities: The Occupational Safety and Health of Young Immigrant Workers in Small Construction Firms*; Publication No. 2015-178; NIOSH: Cincinnati, OH, USA, 2015.
74. Jørgensen, M.B.; Villadsen, E.; Burr, H.; Punnett, L.; Holtermann, A. Does employee participation in workplace health promotion depend on the working environment? A cross-sectional study of Danish workers. *BMJ Open* **2016**, *6*, e010516. [CrossRef]
75. CDC (Centers for Disease Control and Prevention). Public Health Surveillance: Preparing for the Future. 2021. Available online: https://www.cdc.gov/surveillance/pdfs/Surveillance-Series-Bookleth.pdf (accessed on 5 May 2021).
76. EENA (European Emergency Number Association). *Artificial Intelligence and Machine Learning in Public Safety*; EENA: Brussels, Belgium, 2019. Available online: https://eena.org/knowledge-hub/documents/artificial-intelligence-machine-learning-in-public-safety/ (accessed on 5 May 2021).
77. Cannuscio, C.C.; Davis, A.L.; Kermis, A.D.; Khan, Y.; Dupuis, R.; Taylor, J.A. A Strained 9-1-1 system and threats to public health. *J. Community Health* **2016**, *41*, 658–666. [CrossRef]
78. Nethercott, K. Security. Defense mechanisms. *Health Serv. J.* **1997**, *107*, 30–31.
79. Bigham, B.L.; Kennedy, S.M.; Drennan, I.; Morrison, L.J. Expanding paramedic scope of practice in the community: A systematic review of the literature. *Prehosp. Emerg. Care* **2013**, *17*, 361–372. [CrossRef]
80. Lahav, O.; Mastronarde, N.; van der Schaar, M. What is interpretable? Using machine learning to design interpretable decision-support systems machine learning for health (ML4H). In Proceedings of the 32nd Conference on Neural Information Processing Systems, Workshop at NeurIPS 2018, Montreal, QC, Canada, 8 December 2018.
81. Ferenchik, M. Columbus Pilot Program Determines First Responder or Social Worker Response for 911 Calls. The Columbus Dispatch. 18 May. Available online: https://www.firefighternation.com/leadership/columbus-pilot-program-determines-first-responder-or-social-worker-response-for-911-calls/#gref (accessed on 4 July 2021).
82. Wolkin, A.; Patterson, J.R.; Harris, S.; Soler, E.; Burrer, S.; McGeehin, M.; Greene, S. Reducing public health risk during disasters: Identifying social vulnerabilities. *J. Homel. Secur. Emerg. Manag.* **2015**, *12*, 809–822. [CrossRef]
83. Murray, R.M.; Allen, J.A.; Davis, A.L.; Taylor, J.A. Meeting science meets public health: Results from the "Stress and Violence in fire-based EMS Responders (SAVER)" systems checklist consensus conference (SC3). *J. Saf. Res.* **2020**, *74*, 249–261. [CrossRef]
84. Taylor, J.A.; Murray, R.M.; Davis, A.L.; Shepler, L.J.; Harrison, C.K.; Novinger, N.A.; Allen, J.A. Creation of a systems-level checklist to address stress and violence in fire-based emergency medical services responders. *Occup. Health Sci.* **2019**, *3*, 265–295. [CrossRef]
85. Mendes, J.M.D.O. Social vulnerability indexes as planning tools: Beyond the preparedness paradigm. *J. Risk Res.* **2009**, *12*, 43–58. [CrossRef]
86. Dennerlein, J.T.; Burke, L.; Sabbath, E.L.; Williams, J.A.R.; Peters, S.; Wallace, L.; Karapanos, M.; Sorensen, G. An integrative total worker health framework for keeping workers safe and healthy during the COVID-19 pandemic. *Hum. Factors J. Hum. Factors Ergon. Soc.* **2020**, *62*, 689–696. [CrossRef] [PubMed]
87. Haas, E.J.; Yorio, P.L. Exploring the differences in safety climate among mining sectors. *Min. Met. Explor.* **2021**, *38*, 655–668. [CrossRef]
88. McLellan, D.L.; Cabán-Martinez, A.J.; Nelson, C.C.; Pronk, N.P.; Katz, J.N.; Allen, J.D.; Sorensen, G. Organizational characteristics influence implementation of worksite health protection and promotion programs: Evidence from smaller businesses. *J. Occup. Environ. Med.* **2015**, *57*, 1009. [CrossRef] [PubMed]
89. NIOSH (National Institute for Occupational Safety and Health). Productive Aging and Work: Safety and Health Outcomes. 2015. Available online: https://www.cdc.gov/niosh/topics/productiveaging/safetyandhealth.html (accessed on 16 April 2021).

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Impact of a Total Worker Health® Mentoring Program in a Correctional Workforce

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Abstract: (1) Background: Correctional Officers show signs of adverse health early in their careers. We evaluated the impact of a one-year peer health mentoring program for new officers based on a Total Worker Health® approach; (2) Methods: Cadets (n = 269) were randomly assigned to a mentored or control group. Cadets in this mixed methods design completed physical assessments, and surveys at three time points to assess demographics, health, mentoring, and workplace variables. Physical testing included several health markers. Surveys and physical data were analyzed as repeated measures. Regression analyses were used to analyze the relationship between mentoring characteristics and outcomes. A semi-structured interview of mentors was analyzed qualitatively. (3) Results: Higher mentoring frequency was associated with lower burnout. Health behaviors and outcomes declined over time in all groups, but mentees displayed slower decline for body mass index (BMI) and hypertension compared to controls. (4) Conclusions: A continuous peer health mentoring program seemed protective to new officers in reducing burnout and also declines in BMI and hypertension. Short-term physical health markers in younger officers may not be an index of psycho-social effects. A participatory design approach is recommended for a long-term health mentoring program to be both effective and sustainable.

Keywords: corrections; health mentoring; healthy workforce participatory program; total worker health; peer mentoring; participatory action research

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1. Introduction

The risk to hazardous duty and law enforcement personnel (e.g., correctional officers (COs) and police officers) of developing serious chronic health conditions, such as cardiovascular disease, high blood pressure, and metabolic syndrome has been well-documented [1,2]. COs have the highest number of cases of non-fatal occupational injuries of all State employees [3]. In addition, COs are often exposed to mental health stressors at work and face high risk for anxiety, depression, and post-traumatic disorders [4,5]. Work stress and burnout in COs are linked to adverse health behaviors such as smoking, alcohol use, poor eating habits, and less physical exercise [1,4–8]. Job stress in COs is associated with substance abuse, work family conflict, suicide, and shortened life span [9–11].

Most COs begin their careers relatively early in adult life and retire younger than the average working population, which is related to the 20–25 year threshold for full pension benefits. New COs are required to pass a fitness test to demonstrate their physical health while entering employment, but their physical health, including musculoskeletal health, tends to quickly deteriorate within 24 months and stagnate in a pre-morbid state [11]. Increased obesity among COs during their early work tenure has also been reported, with

mean body mass index (BMI) and body fat percentage increasing in the first three years of their employment [12]. These decrements in health indicators are concerning, as they may be linked to early-life chronic health problems, as well as chronic health problems in later adult working life, and to premature mortality.

Because of the early onset of health decline, it is critical to educate new COs about health risks associated with their job tasks during job orientation. Peer mentoring has been advocated as one way to help new COs adjust to their roles [13], and also may be a useful avenue specifically for health and well-being interventions at work. Traditional mentoring in the workplace is based on the constructs of Bandura's social learning theory, as individuals learn from hierarchically senior members (mentors) in the organization [14–16]. Mentoring theory suggests benefitting individuals' career progression as well as psychosocial aspects at work [15,16]. Peer mentoring refers to "relationships among individuals who are at a comparable organizational level in terms of pay, status, and job responsibilities" which have been found to have similar benefits as traditional mentoring with hierarchy [15,17]. Apart from corrections, "mentorship programs aid in mentees' development of professional identity and competence and provide mentors a sense of generativity and purpose" [15,18–20]. Peer mentoring has been routinely instituted in many fields, but is new for the occupational health field [21].

Peer mentoring can have positive effects on organizational as well as individual outcomes. Mentoring may be helpful in reducing the effects of occupational stress. Specifically, occupational stressors are linked with reduced organizational commitment among COs [22], and organizational commitment has a well-supported negative relationship with turnover intentions [13,23–25]. A recent study suggests that early career CO peer mentoring could improve organizational commitment and reduce future turnover intentions [13]. It is important to note that mentoring programs are not monolithic, therefore, the quality of a mentoring relationship varies. We argue that the quality of mentoring may positively influence organizational outcomes. Peer mentoring programs can potentially be tailored to benefit individual health and organizational outcomes. From an analytic perspective, peer mentoring also provides a tripartite format for measuring outcome effectiveness (i.e., program: mentor: mentee) in contrast to bivariate associations (i.e., mentor: mentee).

The main aim of this study was to evaluate the impact of a peer health mentoring program (HMP) for new COs that involved peer mentors and was based on Total Worker Health® (TWH) principles [26]. Principles of participatory action research (PAR) were applied to this peer HMP by involving experienced COs, union leaders, and representatives from management in program design, development and administration both for purposes of benefiting health and achieving program sustainability [27]. In general, we hypothesized that mentored cadets would demonstrate better health and perceived working conditions compared to their non-mentored counterparts across time points.

Hypothesis 1. *Mentored cadets will display better physical health (body mass index, body fat percentage, blood pressure) across time points relative to control groups.*

Hypothesis 2. *Mentored cadets will have better self-reported health/health behaviors across time points relative to control groups.*

Hypothesis 3. *Mentored cadets will have better self-assessed working conditions across time points than control groups.*

A previous study in this population recognized a significant and long-lasting deterioration in health status in the first 2–5 years of employment [12]. Accordingly, we elected to conduct a longitudinal surveillance to evaluate health outcomes in the current study.

2. Materials and Methods

The peer HMP in corrections was a collaborative effort of investigators from the Health Improvement Through Employee Control 2 (HITEC II) program and the Connecticut Department of Correction (DOC) [12]. HITEC II is a research program in the Center for the Promotion of Health in the New England Workplace (CPH-NEW) funded by The National Institute for Occupational Safety and Health (NIOSH) Total Worker Health Program. The study was approved by the Connecticut DOC and the University of Connecticut Institutional Review Board (IRB), protocol # IE-13-033S-2.

2.1. Study Design

A mixed methods study with a convergent parallel design was employed to evaluate the impact of the HMP based on TWH principles. A subset of new officer cadets assigned to mentors from the HMP were compared with a subset of new officer cadets that received conventional on-the-job training (OJT; Control group) using quantitative data. Additionally, qualitative data were extracted from semi-structured interviews of peer mentors to assess mentorship quality and emphasized CO's individual experiences and perspectives rather than their representativeness of a distinct occupational group. The qualitative analysis was conducted using a phenomenological approach to understand the barriers to and facilitators of HMP success. This triangulation of the mentee quantitative data with the mentor qualitative data can be used to inform an in-depth understanding of the study design and impact of the program [28,29].

The key features of the peer HMP were (1) the labor-management participation in its design and implementation, and (2) line-level peer mentoring by COs guided by TWH principles.

A Study Wide Steering Committee (SWSC) provided oversight to HITEC II and also the HMP. The SWSC consisted of members of DOC management (e.g., deputy commissioner, director of human resources, research compliance officer), leaders at the facility level (wardens and their deputies), line-level COs and their bargaining unit, representatives of the supervisor's bargaining unit, representative peer mentors, and research staff. The SWSC allocated compensated time for the HMP by covering release time for volunteer mentors training, peer mentoring, and evaluation, and also instructed supervisory staff in program accommodation. In addition, the presidents or designees of the three CO union bargaining units met separately to maintain the integrity of this CO-centric program.

The peer HMP approach to TWH featured individualized integration of work and health [30]. TWH is a central initiative from NIOSH and is defined as policies, programs, and practices that integrate protection from work-related safety and health hazards with promotion of injury and illness-prevention efforts to advance worker well-being. The TWH model adapted by our study center, CPH-NEW, involves integration of occupational safety and health with workplace health promotion using a core participatory approach which goes beyond a focus on individual behaviors in preventing chronic diseases [27]. TWH approaches incorporated into the HMP were distinct from the OJT with the addition of education on a set of health topics including behavioral strategies, such as exercising regularly despite a challenging shift schedule, eating healthy, managing stress, and addressing work-family issues. Thus, health mentoring considerably expanded upon conventional OJT for new officers by pairing them with specially trained peer mentors. Peer mentors were trained in an instructional class setting.

2.2. Materials

Participatory design focus groups were utilized to develop a training curriculum and reference handbook through a participatory design approach. A detailed description of the outcomes from these participatory design focus groups and the process of developing this HMP are beyond the scope of the current study and are described elsewhere in this special issue [31]. The handbook "Health Mentoring in the Correctional Workplace" was adapted

from an existing career mentoring workbook from the Regionalization Project of 2002 by the Southern Region Division of the National Institute of Corrections Academy [32].

An additional focus group of supervisors and COs provided input on the best ways to train and recruit mentors and mentees. In order to recruit peer-mentors, and to encourage acceptance of unmentored comparison control groups, researchers presented the rationale for comparing mentored and non-mentored cadets, desired qualifications for mentorship, and mentors' obligations and expected time commitment to all COs. Some experienced COs who volunteered to be mentors were recruited and recommended by their unions. Recruited peer-mentors were then trained in an instructional setting on health mentoring topics, and mentoring practices and procedures. Mentors received the handbook and a binder that included record keeping forms, an initial goal setting contract, and evaluation materials for mentee personal development and career goals at three months, six months, nine months, and at completion of the one-year HMP.

2.3. Participants and Procedures

Mentees were recruited by inviting new cadets into successive cadet classes at the DOC Training Academy and randomly assigning them to the HMP (intervention) or the conventional OJT (Control). In the project years, there were five classes matriculating at the Officers' Training Academy in 2013 and 2014. Two classes were assigned to the Control, and three classes were assigned to the HMP. All cadets in each class were invited to participate in the study or to demur without consequence. Those choosing to participate were consented into the study. We distinguished study arms through separate training classes to minimize inter-group contamination.

Once peer-mentors were trained, research staff assigned mentees to a mentor as early as possible within their facility. Following mentor–mentee assignments, research study staff sent reminder emails and conducted follow-up visits to monitor the peer-mentors.

2.4. Instrumentation and Data Collection

All participant cadets (both HMP and Controls) completed a brief physical assessment and a comprehensive survey at three time points: Baseline at the academy while training as new cadets; Time 2 (T2) at the conclusion of the one-year peer HMP; and Time 3 (T3) at a later interval at the 5-year mark of employment.

The quality of the mentor–mentee relationship was assessed onsite with quarterly meetings between researchers and mentors with a brief semi-structured interview. The semi-structured interview was conducted with each peer-mentor by appointment to evaluate progress as well as barriers and facilitators to HMP processes. More specifically, the interview questions were structured to gain information on general mentoring progress, frequency and type of meetings with mentees (formal or informal), discussion topics with mentees, the creation of health goals with mentees, perception of mentoring, obstacles to mentoring success, and facilitators of peer health mentoring. Researchers collected a copy of progress notes if mentors provided them. Researchers made efforts to address any scheduling issues that mentors faced.

All evaluation results, once stripped of potential identifiers, were made available to the SWSC and participants in the mentoring program. This open programmatic review of findings was consistent with PAR principles and contributed to a process of continuous improvement.

The physical assessment measured height, weight, blood pressure, body mass index (BMI), and body fat percentage. Hypertension was categorized into five groups based on the systolic and diastolic measures; normal, elevated, stage 1, stage 2, and hypertension crisis [33]. BMI was calculated utilizing height and weight. Body fat percentage was calculated using the bioelectrical impedance method [34].

The HITEC All-Employee Survey assessed self-reported safety, physical and mental health, health behaviors, working conditions, and job factors. Job factors and working conditions consisted of items on physical and psychological job demands, decision latitude (decision authority, skill discretion), social support, emotional exhaustion (a component of burnout), work–family and family–work conflict, sense of coherence, and organizational health climate [34–37]. Details of these validated survey scales are described elsewhere [28]. The Center for Epidemiologic Studies depression scale (CESD-10) was used to assess depression symptoms. CESD-10 scores can range from 0 to 30, with a score of 10 or more indicating depressive symptoms [38–40]. Physical and Mental Health Composite Scores (PCS & MCS, 12 items) were computed using norming and calculation steps established by Ware and colleagues [40]. Scores can range from 0 to 100, where zero indicates lowest possible level of health and 100 indicates the highest level of health. The national norm for both physical and mental health composite scales are interpreted with a mean score of 50.0 and a standard deviation of 10.0 [41].

Health behaviors for nutrition (5 items; scale range 1–5), diet (5 items; scale range 1–4), and physical activity (4 items; scale range 1–6) were scored by calculating mean scores for all survey items within the topic. For these scales, higher scores indicate increased health-promoting behavior. Alcohol use was measured using two items: average number of alcoholic drinks consumed per week (1 = none or <1 drink to 5 = 21 + drinks) and number of times per week participants consumed 6 or more drinks in one sitting (i.e., binge drinking; 1 = never to 5 = daily or almost daily). Smoking was measured using one item with the following response options: "Have never smoked," "Quit smoking 2 or more years ago," "Smoke pipe or cigar only," "Currently smoke less than 10 cigarettes per day," and "Currently smoke 10 or more cigarettes per day."

Workplace and job-related questions were eliminated at baseline as they were irrelevant prior to work assignment for the cadets but were included in the two follow-up surveys. All follow-up surveys and physical assessments were conducted at the mentee's assigned facility, and all participants were provided their physical test results. Reliability measures (Cronbach's alpha) of the previously validated scaled items utilized in this study sample were calculated and are reported in Section 3.1 of the Results section.

Mentees completed a quality of mentorship survey during their first follow-up evaluation that was used to assess the association between relationship quality, mentoring frequency, and outcomes at the first and second follow-ups.

2.5. Data Management and Analysis Plan

Participants were assigned random IDs and the de-identified dataset was used for the analysis. As noted, surveys and physical exams were voluntary and were approved by the University IRB. All data were confidential and were stored and secured within the university with access restricted to PI and research staff.

Data from the baseline All-Employee Survey, quality of mentorship survey of mentees, and physical health assessment were merged into one dataset by matching participant IDs. Follow ups at T2 and T3 surveys and physical assessments were linked to the baseline dataset by participant IDs.

All validated scale items were converted to scaled measures with scores for comparison analyses [34]. Survey descriptive statistics and cross-correlations for key subjective measures were also calculated.

As noted, a significant portion of participants in the HMP group were not assigned mentors or happened to terminate early; therefore, participants were grouped based on successful assignment and completion (see Table 1). There were potential mentees who were either unable to have or meet a mentor due to varying shifts or posts, or because they simply decided to no longer participate in the mentoring process. In order to avoid a dilution of effect, we assigned these participants to a "Non-compliant group" (n = 55), made up of individuals who were originally assigned into the mentoring group but never

had a mentor for various reasons, which was separate from the "HMP group (n = 128)" and also from the Control (n = 86) group. Thus, comparisons were made on a grouped basis rather than intention to treat; the HMP group (mentored with assigned mentor), the Non-compliant group (no mentoring received from assigned mentor for HMP), and the Control group (on-the-job training).

One-way ANOVA and chi-square tests were conducted to establish differences between the groups at baseline on scored and categorical variables, respectively. Hypotheses 1 and 2 were tested with paired t-tests to evaluate health changes from physical assessments and self-reported health/health behaviors respectively among participants completing both baseline and T3 assessments in each study group. Hypotheses 1–3 were tested separately by conducting repeated measures ANOVA to determine differences in focal variables within and between HMP, Non-compliant, and Control groups across time points, while controlling for the focal variable at baseline. For Hypothesis 3 changes in working conditions were evaluated with paired t-tests from T2 to T3. Paired t-tests were appropriate for analysis of observed program impact on health and work changes, but the sample size reduced within each group across time points, thus limiting more differentiated analysis. Finally, additional regression analyses were conducted to determine if the quality of mentorship rating, or if the intensity of mentoring (meeting frequency), predicted subjective outcomes. The effect of mentoring was further evaluated by comparing mentees' intention to turnover from follow-up surveys (T2 and T3). All analyses were performed in SPSS version 25.

All the semi-structured mentor interviews (n = 98) were transcribed and analyzed with NVivo qualitative software version 12.0. Commonly occurring themes discussed by all mentors were identified in this content analysis and analyzed by manual coding in the software. Verbatim quotes from the interviews are not presented in the results to protect confidentiality as per the institutional IRB approved protocol and participant consent.

3. Results

3.1. Health Mentoring Program Assessment

Among 406 eligible cadets in the HMP classes, 183 (45%) elected to participate; The Control group had a 42% (n = 170) participation rate. Participation was voluntary and participants were randomly assigned into mentoring or Control groups by class (rather than individually). Most mentors were assigned one mentee, but several mentors had either two or three mentees. The mean number of mentees per mentor was 1.14. Gender matching was done to the extent possible. Most of the mentees were male (76.4%), matching the high proportion of males in this working population. All cadets were assessed while at the Training Academy prior to facility assignment.

Our previous studies on COs found good reliability on survey items similar to the ones used here. This sample showed fair to good reliability for most measures. Reliability for various job factor measures were: physical job demands (Cronbach's $\alpha = 0.74$) psychological job demands ($\alpha = 0.44$), decision latitude ($\alpha = 0.56$), decision authority ($\alpha = 0.27$), skill discretion ($\alpha = 0.49$), social support ($\alpha = 0.71$); supervisor support ($\alpha = 0.83$), co-worker support ($\alpha = 0.57$), burnout-emotional exhaustion ($\alpha = 0.59$), work-family ($\alpha = 0.49$), family-work conflict ($\alpha = 0.66$), sense of coherence ($\alpha = 0.31$), and organizational health climate ($\alpha = 0.85$). Health behavior scales for nutrition ($\alpha = 0.77$), diet ($\alpha = 0.88$), and physical activity ($\alpha = 0.65$) all demonstrated good reliability. The depressive symptoms score ($\alpha = 0.59$) had somewhat lower reliability.

The baseline demographics of the three study cohort groups—HMP, Non-compliant, and Control—are reported in Table 1.

The HMP group was younger than the 'Non-compliant' and Control groups. For unknown reasons, the 'Non-compliant' group had a significantly higher level of education than the other two groups. The Control group had a slightly higher proportion of male cadets and lower education levels than the other groups (Table 1).

Table 1. Demographics within study groups at baseline (n = 269).

		Health Mentoring Program (HMP) Group (n = 128)	Non-Compliant Group (n = 55)	Control Group (n = 86)
Mean Age (SD)		30.38 (5.76)	32.38 (7.19)	32.47 (7.22)
Gender (%)	Male	75.8%	74.5%	84.9%
	Female	24.2%	25.5%	15.1%
Education Level		Percent (n)	Percent (n)	Percent (n)
High school graduate or GED		16.4% (20)	14.9% (7)	22.7% (15)
Some college		41.0% (50)	25.5% (12)	34.8% (23)
College degree (2 or 4 year)		39.3% (48)	57.4% (27)	37.9% (25)
Graduate degree		3.3% (4)	2.1% (1)	4.5% (3)

3.2. Baseline Mean Differences among Groups

Mean differences of physical health assessment, self-reported health, and health behaviors across the three mentor groups were evaluated at baseline. Sample size varied across all variables at baseline, as participation was voluntary and some participants chose to skip the survey and/or the physical assessment.

Overall, health status was not optimal at baseline, but it was similar across the three study groups (Table 2). Although there were no significant differences between the groups, the majority of participants had elevated blood pressure or hypertension stage 1 or 2 at baseline (83% in HMP group; 81% in Non-compliant group; and 77% in Control). Mean BMI and body fat percentage indicated all three groups in the overweight category at baseline based on standard weight status [41].

Chronic disorders diagnosis, defined as doctor-diagnosed heart attack, stroke, pre-diabetes, diabetes, hypertension, hyperlipidemia, asthma, chronic obstructive pulmonary disease (COPD), depression, skin cancer, other cancer, chronic recurrent back pain, or hearing loss, was low and similar across the groups at baseline. At baseline, more than one chronic disorder diagnosis was reported by 38% in the HMP group, 25% in the Non-compliant group, and 38% in the Control group, with no significant differences between groups ($p > 0.05$; Table 2).

Overall physical and mental health composite scales (PCS and MCS) at baseline were similar between groups and comparable to the general U.S. population scores (PCS = 50.2, MCS = 53.2; Table 2). Mean depression scores were low in all groups at baseline which indicated no clinically significant depressive symptoms (<10) (Table 2).

Baseline health behavior scores of nutrition, diet, and physical activity ranged from low to moderate and were similar across groups (Table 2). Of all participants at baseline, 17% reported currently smoking tobacco, 7.5% reported having more than 7 alcoholic drinks in a week, and 5.1% reported having 6 or more drinks in one sitting weekly. Chi-square tests revealed that these health behavior scores did not significantly vary between mentoring groups at baseline ($p > 0.05$).

Mean differences in self-assessed working conditions among study groups at baseline were not compared because cadets had just begun their jobs at DOC (Table 3).

Table 2. Comparison of physical health assessments, and self-assessed health outcomes among study groups in all 3 time points.

		Health Mentoring Program (HMP) Group (*n* = 128), Mean (SD)			**Non-Compliant Group (*n* = 55), Mean (SD)**			**Control Group (*n* = 86), Mean (SD)**		
		Baseline	T2	T3	Baseline	T2	T3	Baseline	T2	T3
Physical Health Assessments	Body fat %	24.76 (7.70)	25.32 (7.97)	28.19 (9.09)	24.58 (8.66)	26.63 (10.43)	30.67 (7.23)	22.85 (7.54)	24.62 (7.23)	26.19 (6.58)
	Body Mass Index (BMI)	28.95 (4.61)	29.91 (4.98)	30.37 (5.22)	28.73 (4.74)	31.12 (6.35)	32.03 (5.26)	29.09 (4.39)	30.46 (4.76)	30.98 (4.18)
	Hypertension score	2.68 (1.03)	3.10 (0.99)	2.95 (1.12)	2.68 (1.07)	3.03 (1.08)	2.50 (1.16)	2.64 (1.12)	2.97 (1.01)	3.06 (1.08)
Self-Assessed Health	Physical Health Composite Score (PCS)	51.36 (5.31)	50.46 (6.28)	50.50 (6.96)	52.11 (5.45)	52.31 (5.46)	51.74 (5.35)	51.36 (4.76)	51.85 (4.78)	48.32 (8.45)
	Mental Health Composite Score (MCS)	53.41 (5.80)	52.06 (6.79)	40.46 (7.50)	53.92 (4.69)	51.70 (7.86)	41.42 (5.57)	53.36 (6.49)	53.61 (6.05)	41.44 (7.03)
	Depression score	3.93 (1.52)	4.59 (2.16)	7.54 (4.28)	3.49 (1.47)	4.00 (1.75)	7.00 (3.94)	3.52 (1.88)	3.98 (1.84)	7.80 (7.14)
	Chronic disorder diagnosis score	0.55 (1.02)	0.39 (1.13)	1.46 (0.59)	0.38 (0.73)	0.30 (0.52)	1.57 (0.53)	0.65 (1.16)	0.49 (0.89)	1.83 (1.20)
Health Behaviors	Nutrition behavior score	2.84 (0.77)	2.62 (0.82)	2.27 (0.79)	2.71 (0.73)	2.56 (0.87)	2.43 (0.79)	2.99 (0.79)	2.84 (0.79)	2.35 (0.57)
	Diet score	3.03 (0.52)	2.95 (0.61)	2.56 (0.70)	3.02 (0.52)	2.93 (0.64)	2.75 (0.41)	3.07 (0.57)	3.08 (0.66)	2.44 (0.63)
	Activity	3.08 (0.81)	3.07 (0.93)	3.09 (1.05)	2.99 (0.87)	3.07 (0.89)	2.92 (0.95)	2.94 (0.80)	3.10 (0.93)	3.00 (1.15)
	Smoking (% have never smoked)	57.38%	56.57%	48.15%	64.58%	64.86%	53.85%	58.46%	59.09%	56.67%
	Alcohol Use (1 = none or <1 drink, 5 = ≥ 21 drinks/week)	1.50 (0.66)	1.63 (0.67)	1.76 (0.75)	1.65 (0.83)	1.65 (0.71)	2.08 (0.86)	1.65 (0.76)	1.70 (0.85)	2.10 (0.99)
	Binge drinking (≥6 drinks in one sitting; 1 = never, 5 = daily/almost daily)	1.72 (0.87)	1.90 (0.95)	1.98 (0.96)	1.75 (0.93)	1.78 (1.02)	2.23 (1.09)	2.00 (0.88)	1.96 (0.99)	2.20 (1.13)

Note: One-way ANOVAs for scored variables and Chi-square tests for categorical variables showed no significant differences among study groups at baseline. Sample size (*n*) varies among variables due to missing responses.

Table 3. Comparison of self-assessed working conditions among study groups in all 3 time points.

		Health Mentoring Program Group (n = 128), Mean (SD)			Non-Compliant Group (n = 55), Mean (SD)			Control Group (n = 86), Mean (SD)		
		Baseline	T2	T3	Baseline	T2	T3	Baseline	T2	T3
Self-Assessed Working Conditions	Sense of coherence	3.84 (0.61)	3.83 (0.60)	3.82 (0.49)	3.98 (0.58)	3.78 (0.55)	3.50 (0.84)	3.89 (0.58)	3.98 (0.67)	3.82 (0.79)
	Exhaustion-burnout	—	3.73 (1.21)	4.15 (1.19)	—	3.52 (1.22)	3.67 (1.05)	—	3.43 (1.13)	4.20 (1.27)
	Health climate	5.67 (1.42)	4.40 (1.74)	4.19 (1.10)	5.75 (1.20)	3.93 (1.56)	4.36 (0.73)	5.54 (1.58)	4.41 (1.54)	4.02 (0.97)
	Family to work conflict	1.41 (0.47)	1.39 (0.43)	1.69 (0.52)	1.35 (0.45)	1.32 (0.43)	1.40 (0.52)	1.38 (0.51)	1.27 (0.37)	1.78 (0.61)
	Work to family conflict	1.64 (0.48)	1.79 (0.56)	1.92 (0.74)	1.61 (0.47)	1.66 (0.44)	2.00 (0.58)	1.66 (0.51)	1.66 (0.56)	2.00 (0.71)
	Decision authority	—	3.30 (0.44)	2.60 (0.50)	—	3.28 (0.35)	2.63 (0.51)	—	3.38 (0.35)	2.58 (0.63)
	Decision latitude	—	2.90 (0.28)	2.66 (0.46)	—	2.89 (0.22)	2.85 (0.44)	—	2.94 (0.25)	2.64 (0.60)
	Skill discretion	—	2.51 (0.28)	2.73 (0.63)	—	2.51 (0.29)	3.07 (0.41)	—	2.51 (0.33)	2.70 (0.71)
	Physical job demands	—	3.05 (0.46)	1.98 (0.50)	—	2.89 (0.38)	2.47 (0.55)	—	3.02 (0.42)	2.10 (0.52)
	Psychological job demands	—	3.23 (0.30)	2.43 (0.46)	—	3.09 (0.32)	2.41 (0.39)	—	3.24 (0.35)	2.30 (0.38)
	Social support	—	2.70 (0.33)	2.76 (0.62)	—	2.67 (0.25)	2.73 (0.53)	—	2.64 (0.34)	2.75 (0.70)

Note: One-way ANOVAs for scored variables showed no significant differences among study groups at baseline. Sample size (n) varies among variables due to missing responses.

3.3. Change in Health Measures, Health Behaviors, and Working Conditions within Each Mentor Group over Time

Because health changes emerge over time and because we chose to examine the longest possible interval to evaluate program effectiveness, we compared baseline to T3 to evaluate the health impact of the HMP. Overall, within-group differences for physical assessment variables and self-reported health measures on a paired t-test indicated declining health over time in all groups (Table 4).

The physical health quantitative measures of BMI and body fat percentage increased significantly in the HMP and Control groups from baseline to T3 follow-up. Hypertension increased from baseline to T3 significantly more in the Control group than in the HMP group (Table 4).

Self-assessed health data showed declining physical and mental health over time. Physical Health Composite scores declined from baseline to T3 significantly in the Control group ($p < 0.05$) but showed slight improvement in the HMP group (although not statistically significant, $p > 0.05$). Mental Health Composite scores declined significantly ($p < 0.001$) in each group from baseline to T3 (Table 4). Mean depression scores significantly increased in all groups over time from baseline to T3 (Table 4). Chronic disorder diagnoses increased over time, with more participants reporting doctor-diagnosed chronic disorders at T3 in all groups, but with significant increases in HMP and Non-compliant groups.

Healthy nutrition behavior and diet perception worsened significantly over time among all groups. The Control group worsened more from baseline to T3 than the other groups. Alcohol consumption (in terms of number of drinks per week) increased over time in all groups, but only increased significantly in the Non-compliant group between

baseline and T3 (t (11) = 3.02, p = 0.012). Binge drinking did not change significantly within any of the three groups. Physical activity scores increased slightly over time in both the HMP and Control groups, but differences were not statistically significant (Table 4).

Table 4. Change in physical health assessments and self-assessed health outcome mean scores from baseline to T3 within each study group.

		Health Mentoring Program (HMP) Group-Mean Difference T3-Baseline (SD), *t* (df)	**Non-Compliant Group-Mean Difference T3-Baseline (SD), *t* (df)**	**Control Group-Mean Difference T3-Baseline (SD), *t* (df)**
Physical Health Assessments	Body Mass Index (BMI)	1.95 (2.82), t (50) = 4.93 ***	1.97 (3.04), t (12) = 2.35 *	2.03 (2.77), t (34) = 4.34 ***
	Body fat %	3.40 (5.63), t (46) = 4.14 ***	2.47 (4.02), t (10) = 2.04	3.45 (4.88), t (33) = 4.12 ***
	Hypertension score	0.24 (1.24), t (53) = 1.42	−0.14 (1.56), t (13) = −0.34	0.51 (1.31), t (34) = 2.32 *
Self-Assessed Health	Physical Health Composite Score (PCS)	0.05 (6.99), t (49) = 0.049	−0.29 (5.62), t (12) = −0.19	−3.87 (8.25), t (23) = −2.30 *
	Mental Health Composite Score (MCS)	−13.16 (7.71), t (49) = −12.07 ***	−11.57 (8.13), t (12) = −5.14 ***	−12.53 (7.38), t (23) = −8.31 ***
	Depression score	3.25 (3.50), t (51) = 6.69 ***	3.17 (4.76), t (11) = 2.30 *	4.27 (6.71), t (25) = 3.25 **
	Chronic disorder diagnosis score	0.74 (0.81), t (22) = 4.38 ***	0.85 (0.69), t (6) = 3.29 *	0.69 (2.36), t (15) = 1.17
Health Behaviors	Nutrition behavior score	−0.43 (0.82), t (52) = −3.80 ***	−0.38 (0.55), t (10) = −2.31 *	−0.58 (0.63), t (25) = −4.66 ***
	Diet score	−0.38 (0.71), t (51) = −3.85 ***	−0.22 (0.44), t (10) = −1.68	−0.64 (0.81), t (22) = −3.80 **
	Activity	0.26 (0.99), t (51) = 1.88	−0.31 (0.72), t (11) = −1.51	0.19 (1.01), t (25) = 0.97
	Alcohol Use (1 = none or < 1 drink, 5 = ≥ 21 drinks/week)	0.12 (0.78), t (51) = 1.06	0.58 (0.67), t (11) = 3.02 *	0.24 (0.83), t (24) = 1.45
	Binge drinking (≥6 drinks in one sitting; 1 = never, 5 = daily/almost daily)	0.10 (0.91), t (51) = 0.76	0.42 (1.16), t (11) = 1.24	0.08 (1.19), t (24) = 0.34

Significance levels for paired t-tests within each group: * Significant at $p < 0.05$; ** Significant at $p < 0.01$; *** Significant at $p < 0.001$.

Changes in working conditions perceived by COs were assessed from T2 to T3 and were compared within each group with paired t-tests (Table 5). As noted previously, most perceptions of working conditions were not evaluated at baseline.

Overall perception of both physical and psychological job demands decreased significantly by T3 in all groups. Skill discretion increased in all three groups, although decision latitude decreased significantly in HMP and Control groups (Table 5).

Family-to-work conflict increased notably in both HMP and Control groups and decreased slightly in the Non-compliant group, but with no statistical significance. Work-to-family conflict significantly increased by T3 in the Non-compliant and Control groups but did not significantly increase in the HMP group (Table 5).

Although organizational health climate was perceived as slightly lower at T3 in all groups, the change was significant only in the Control group ($p < 0.05$; Table 5).

Table 5. Changes in self-assessed working conditions means from T2 to T3 within each study group.

		Health Mentoring Program Group-Mean Difference T3–T2 (SD), *t* (df)	Non-Compliant Group-Mean Difference T3–T2 (SD), *t* (df)	Control Group-Mean Difference T3–T2 (SD), *t* (df)
Self-Assessed Working Conditions	Sense of coherence	0.03 (0.61), *t* (44) = 0.32	−0.37 (0.76), *t* (9) = −1.52	−0.27 (0.80), *t* (26) = −1.76
	Exhaustion-burnout	0.24 (1.17), *t* (44) = 1.40	0.07 (1.00), *t* (8) = 0.22	0.57 (1.56), *t* (26) = 1.92
	Health climate	−0.41 (1.75), *t* (43) = −1.55	0.11 (1.25), *t* (7) = 0.25	−0.46 (1.02), *t* (26) = −2.34 *
	Family to work conflict	0.34 (0.65), *t* (46) = 3.58 **	−0.15 (0.53), *t* (9) = −0.90	0.52 (0.69), *t* (26) = 3.93 **
	Work to family conflict	0.09 (0.63), *t* (45) = 0.93	0.40 (0.39), *t* (9) = 3.21 *	0.39 (0.76), *t* (26) = 2.65 *
	Decision authority	−0.67 (0.63), *t* (43) = −7.06 ***	−0.73 (0.80), *t* (9) = −2.91 *	−0.81 (0.68), *t* (26) = −6.27 ***
	Decision latitude	−0.22 (0.46), *t* (43) = −3.20**	−0.13 (0.53), *t* (9) = −0.79	−0.29 (0.53), *t* (26) = −2.82 **
	Skill discretion	0.22 (0.69), *t* (43) = 2.15 *	0.47 (0.49), *t* (9) = 3.01 *	0.24 (0.62), *t* (26) = 2.03
	Physical job demands	−1.08 (0.60), *t* (43) = −11.94 ***	−0.50 (0.79), *t* (8) = −1.90	−0.92 (0.67), *t* (26) = −7.16 ***
	Psychological job demands	−0.77 (0.50), *t* (43) = −10.15 ***	−0.75 (0.50), *t* (8) = −4.50 **	−0.82 (0.54), *t* (26) = −7.87 ***
	Social support	0.04 (0.75), *t* (43) = 0.40	0.08 (0.63), *t* (8) = 0.56	0.09 (0.74), *t* (26) = 0.65

Significance levels for paired *t*-tests within each group: * Significant at $p < 0.05$; ** Significant at $p < 0.01$; *** Significant at $p < 0.001$.

3.4. Comparison of the Three Groups over the Three Time Points with Repeated Health Measures and Working Conditions

No significant differences in health measures, health behaviors and working conditions were observed between the three study groups with repeated measures ANOVA. We have indicated only the statistically significant changes within groups over time in Table 6. The significant increase in BMI over time significantly differed among groups (Table 6).

Perceptions of physical demands, psychological demands, and decision latitude decreased in all groups from T2 to T3. Skill discretion improved slightly. As seen in Table 5, work-to-family and family-to-work conflict and health climate perception worsened in all three groups (Table 6).

Among health measures, depression, BMI, and hypertension increased significantly within groups over time (Table 6).

We did not see the hypothesized effect of peer health mentoring on health behaviors, as the nutrition and health importance scores declined in all groups over time (Table 6).

Additional regression analyses were conducted to determine if mentee-rated quality of mentorship and mentoring frequency at follow-up period T2 predicted the outcomes at T2 and T3 (scores for activity, depression, diet, exhaustion-burnout, physical composite scale, health climate, and sense of coherence) with age, gender, tenure, and shift at T3 as covariates.

Table 6. Repeated measures comparison across groups for health and working conditions.

		Within Groups (Time * Study Group)		Between Groups
		Time	Time * Study group	Study group
		F-statistic [a] (df)	F-statistic (df)	F-statistic (df)
Physical Health Assessments (Baseline, T2, T3)	Body Mass Index (BMI) (n = 85)	41.10 (1) ***	5.23 (2) **	0.45 (2)
	Hypertension (n = 90)	5.07 (1) *	0.16 (2)	0.33 (2)
Self-Assessed Health (Baseline, T2, T3)	Depression (n = 73)	21.60 (1) ***	0.02 (2)	2.03 (2)
Health Behaviors (Baseline, T2, T3)	Nutrition score (n = 76)	14.07 (1) ***	0.69 (2)	1.29 (2)
	Health importance score (n = 75)	6.71 (1) *	0.24 (2)	3.07 (2)
Self-Assessed Working Conditions (T2, T3)	Physical demands (n = 80)	87.82 (1) ***	3.11 (2)	1.32 (2)
	Psychological demands (n = 80)	120.01 (1) ***	0.10 (2)	1.11 (2)
	Decision latitude (n = 81)	10.64 (1) **	0.38 (2)	0.82 (2)
	Skill discretion (n = 81)	12.98 (1) **	0.58 (2)	1.59 (2)
	Work to family conflict (n = 76)	8.43 (1) **	0.26 (2)	0.03 (2)
	Family to work conflict (n = 77)	4.35 (1) *	0.28 (2)	0.08 (2)
	Health climate (n = 71)	22.23 [b] (1.8) ***	0.30 (3.6)	0.36 (2)
	Sense of coherence (n = 75)	5.12 (1) *	2.72 (2)	0.94 (2)

[a] F-statistic from repeated measures ANOVA for quadratic trend reported where linear trend was non-significant. [b] Greenhouse–Geisser values used because sphericity assumption was violated. Significance levels for F-statistic: * Significant at $p < 0.05$; ** Significant at $p < 0.01$; *** Significant at $p < 0.001$.

Mentoring frequency was significant for reducing exhaustion-burnout at follow-up period T2 ($\beta = -0.385$, $p < 0.01$). It appeared that mentor quality and mentoring frequency did not predict any of the measured scores significantly at T3, several years after the mentoring relationship had ended.

3.5. Intention to Turnover among Groups

Response to the item, "I often think about quitting my job" was compared at T2 and T3 follow-ups. About 6% (HMP group), 11% (Non-compliant group), and 4.5% (Control group) (Bonferroni adjusted $p > 0.05$) at T2 responded "agree" or "strongly agree." This proportion changed at T3 with about 25% (HMP group), 15.4% (Non-compliant group), and 30% (Control group) (Bonferroni adjusted $p > 0.05$) responding "agree" or "strongly agree."

Reason for turnover intention was evaluated by the question "I am likely to leave this job in the next 2 years because I am dissatisfied" for both T2 and T3. About 5% (HMP group), 11% (Non-compliant group), and 1.5% (Control group) (Bonferroni adjusted $p > 0.05$) at T2 responded "agree" or "strongly agree." This percentage changed at T3 with about 7.8% (HMP group), 7.7% (Non-compliant group), and 23.3% (Control group) (Bonferroni adjusted $p > 0.05$) responding "agree" or "strongly agree."

3.6. Qualitative Analyses of Semi-Structured Quarterly Interviews with Mentors

Most mentors in the HMP group indicated that the content of their mentoring was mainly focused on work issues followed by stress management and healthy lifestyle, even though the latter two topics were the original focus of the HMP. Some mentors said that the reasons why they focused meetings on work issues were due to their lack of expertise and confidence in engaging in health mentoring. Mentors mostly met with their mentees informally. The binder provided to mentors to record meeting details was never used or maintained by most mentors; the reasons reported were that it was not short and simple to use.

A few mentors mentioned the mutual benefit of learning about themselves while working with their mentees. Some mentors mentioned becoming friends with mentees and meeting outside of work, or even receiving emotional support from their mentee. Some mentors were friends or acquaintances with their mentees through family or friends, and performed very well in these mentoring situations.

Mentors identified that meeting with mentees was easier when the mentees worked the same shift and in the same building/unit; when this was not the case, it was difficult for mentors to set up informal meetings with their mentees.

Mentors indicated the importance of supervisor support to meeting with mentees; in particular, supervisors providing relief time to meet with mentees was critical. Relief time provided by rover staff was found to be especially helpful. Only a limited number of mentors indicated that their supervisors and management were uncaring or being passive about the program. Other reasons for not meeting included disinterest in it even after receiving multiple reminders to meet and mentees' lack of awareness about the long-term nature of the mentoring program. To improve the mentoring program, mentors suggested changes to mentee selection, with an option to choose their mentees, and also to have mentors formally introduced to mentees during their training classes at the academy.

Figure 1 demonstrates the number of times these obstacles for HMP were identified by mentors within these interviews.

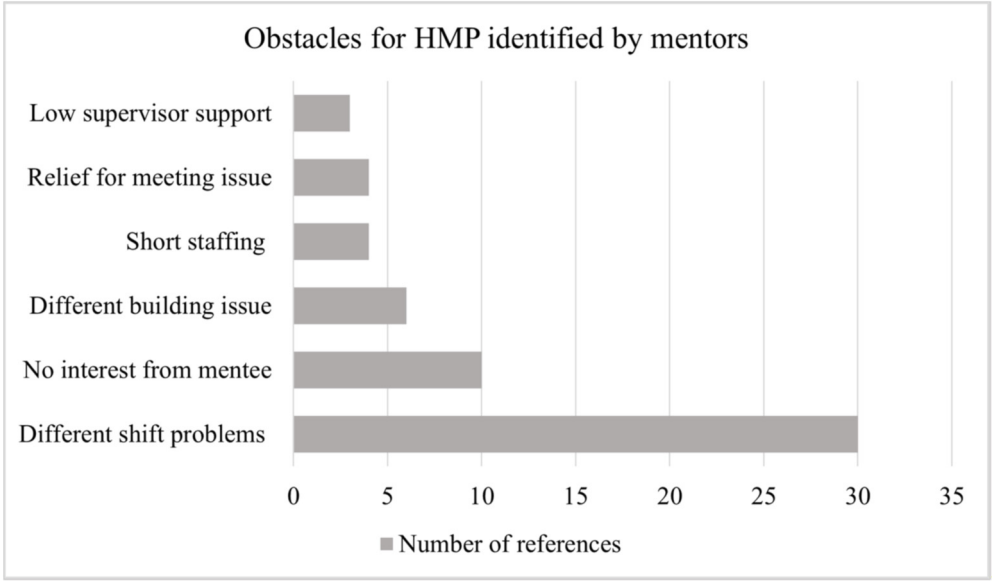


Figure 1. Obstacles for HMP.

4. Discussion

The main aim of this study was to evaluate the impact of the peer HMP on physical health measures and self-reported health perceptions, behaviors, and health outcomes. Overall, the differences between the HMP, Non-compliant, and Control groups in terms of physical health and psychosocial measures were relatively modest. Although hypertension

worsened in all groups over time, it was lower in the mentoring group. BMI significantly worsened over time and significantly differed between groups, with the Control group having a greater increase in BMI than the other groups over time. Mentoring frequency was significant only for reducing exhaustion-burnout at T2 follow-up ($\beta = -0.385$, $p < 0.01$). We observed that unexplained variance within each group was large despite statistical and study controls.

Associations between meeting frequency with mentors and reduced exhaustion burnout among mentees in our study could be considered a positive impact of HMP, but additional research utilizing a larger mentee sample is warranted. A number of studies corroborate the need for further studies on exhaustion and burnout in this sector. Recent evidence from a TWH-based study among jail officers and deputies revealed higher post-traumatic stress disorder symptoms associated with job burnout among COs [42]. A related study reported high prevalence of depression among jail officers where job burnout was a significant predictor of depression symptoms after controlling for demographics and mental and physical health characteristics [43].

A mentoring study in Italy recently demonstrated that one year of formal mentoring promoted job adjustment and was protective against all facets of burnout (personal accomplishment, cynicism, and interpersonal strain) except for emotional exhaustion among new COs [44]. Our results from this longitudinal study show the protective role of peer mentoring in regard to emotional exhaustion as a component of burnout in new COs. Our results showing the positive effect of mentoring frequency and quality at the one-year conclusion of formal mentoring replicate the Italian results, although we did observe an extinction of protection by the fifth year during the follow-up evaluation of the longer-term effects of our HMP which had ended after one year. Significantly, new and improved mentoring program interventions are currently emerging in the DOC at this writing, thus substantiating the importance of a long-term and sustaining design.

Health behaviors such as smoking, alcohol use, and exercise worsened in all groups over the years in our study. Mentees exhibited slightly better health behaviors compared to controls, although not statistically significant. We consider this a positive observation and a protective effect of HMP that warrants further study. Shepherd et al. [7] reported that burnout among COs was associated with emotional demands and alcohol use for coping [7], suggesting that closer examination of emotional demands may be in order.

Our health measures were similar across all groups at baseline, and over time the differences between groups remained minimal. Our longitudinal findings replicate other studies on new COs that also indicate declining CO health with employment [1,12]. BMI and hypertension significantly increased within all groups in this study. Depression symptoms also increased significantly, with declining overall mental health composite scores of cadets. Physical composite scores decreased as well in all groups over time, but with no significant difference between groups. Cherniack et al. [12] reported similar health indicators in a cross-sectional study of established COs (n = 326). Although COs were relatively young in their study, with a mean age of 41 (7.2) years, the sample displayed numerous indicators of poor health. Eighty-five percent (85%) were considered overweight or obese (BMI of >25), 56% were either pre-hypertensive or hypertensive, and 31% screened positive for depressive disorders as measured by the CESD-10 [12]. COs in our study at T3 were younger than in previously reported studies [12], and depression with CESD-10 was screened positive in 30% of the HMP group and 30% of the Control group. The new cadets' health at the start of their career was comparable to young COs in previous cross-sectional studies [1,12], thus confirming the robustness of the findings. Study results on self-reported work conditions varied. Physical and psychological demands were lower and skill discretion improved at T3 follow-up. Although it is tempting to conclude that adaptation leads to acceptance of work conditions, the results were not uniform, and turnover intentions increased. Evidence suggests that COs tend to have low decision latitude due to the hierarchical organizational structure within corrections and law enforcement workforces [5,45], and it seems likely this was also the case in the present sample.

COs' intention to turnover was low at T2 (end of first year on the job) and had increased in all groups by the T3 follow-up. At the T3 follow-up, the proportion of individuals with the intention to leave their job was notably higher among the Control group as compared to the HMP group, although the difference was not statistically significant. Griffin et al. [13] examined turnover intent in COs over their career stages and reported a similar finding that turnover intent was lowest in COs in the first year of their job. They also reported that midcareer (5–9-year tenure) and younger COs who experienced a low level of organizational commitment expressed higher intent to leave the job [13]. Similarly, in our study, COs who were younger and had been working for five years had a higher intention to leave the job than their older age counterparts. We cannot ascertain whether mentoring could partially explain reduced turnover intention at T3 (at 5 years of employment) among the HMP group.

It is important to note that implementing the HMP required a significant investment of resources. Despite the high ranking of mentors and mentees of the program overall, a legitimate question is whether the results justify replication. While acknowledging that most health changes over time continued to be adverse, active mentoring lasted for only one year. The changes at the conclusion of the mentoring program did not appear to reflect better comparative health at T3.

The lack of more positive survey outcomes at T2 motivated closer examination of the underlying distribution of response patterns. We suspected the extreme working conditions COs face every day might contribute to response irregularities. For example, the high ratings of emotional labor in our analyses reflected that COs were likely managing their expressions and interactions out of fear of unfavorable inmate response, or the "tough" culture pressure from fellow officers, something described as the "John Wayne Syndrome" [6]. Problematic survey items that violated statistical assumptions (n = 21) were identified in the T1 and T2 datasets; twenty items had abnormal distributions (positively or negatively skewed, kurtosis, and heteroscedasticity issues) with one trending towards abnormal [46]. An effort was then made to address the root causes of item skewness before data collection at T3 [47]. Survey items identified as problematic were contextualized by subject matter experts on the research team so they would be more applicable to corrections. For example, we attempted to address potential ceiling effects in the original item, "How would you describe the quality of your sleep on a typical night?," by removing "on a typical night" and adding "during the work week." A preliminary examination of T3 data however, revealed only slight improvements in item skewness in adapted items [48]. This suggests that the value of using standardized survey items to evaluate targeted interventions like the HMP may be quite limited. Indeed, related work shows that participant-designed survey items can outperform standardized items because they incorporate individuals' appraisals of their specific working conditions [48]. Therefore, we recommend that participatory design of survey items is utilized in any evaluation of peer HMPs in corrections [49]. We also see participatory design of survey items as central to the evaluation of TWH interventions in general. Program interventions are not likely to be "one and done" and will normally require continuous improvement over time through iterative design improvements that allow the program to respond to any new internal and external factors influencing work organization [50]. Findings from program evaluations with participants' active role in designing are also more likely to be trusted and used to guide iterative design efforts. In fact, the present corrections organization's new HMP reflects these iterative design efforts by now offering mentoring to officers throughout their tenure rather than only during their first year on the job.

The results indicate a decline in many measures of health over the first five years of employment in corrections, with mentoring during the first year not associated with the significant protective effect. There is no particular reason to believe that a one-year non-targeted program would be sustaining through the subsequent three decades of a working life, nor that measured effects would be large. The unanswered question is whether a longer-term continuous prevention program, or whether a program targeted to specific

at-risk individuals, might have a more observable efficacy. Mentoring alone cannot control the working conditions or chronic physiological changes with work stress encountered by COs; however, a full-scale TWH approach to mentoring that combines individualized health interventions with organizational change could be helpful in combatting work stress and its health effects.

More than a decade before the HMP, the organization had experimented with a traditional mentoring program which was principally top-down in its implementation and was not sustainable. Its duration was short-term, its measures conventional, and it failed to secure any long-term health improvements. The peer HMP, created over a period of five years by an experienced and immersed study team, was largely a bottom-up creation which became a platform for further program development work. Its application was participatory, relying on the COs themselves to design and administer the interventions and to make corrections with the approach where needed. As such, it represented a significant progression of intervention techniques. Significantly, it reinforced in a very public way that COs are a high-risk population whose health status is a central problem in corrections. Addressing the implicit hazards of the job is tempered by the reality that COs are often a mobile group, and line officers require administrative support and experience to maintain their own peer-led program. The scheduling and staff coverage issues alone pose a challenge to a peer-based participatory program. Nielsen et al. [48] noted the complexity of evaluating participatory intervention programs due to their layered complexity [48]. Nielsen and Randall [51] also cited the lack of suitability of conventional survey methods in the assessment of this type of multi-featured intervention [51]. The HMP program relied on conventional design and assessment measures: (1) standard validated survey items, (2) a generic non-targeted approach to intervention, and (3) longitudinal introduction and refreshing deriving from the study team, not the participating workforce. Consequently, the HMP remained a blunt instrument, although, because of its participatory nature, it represented a significant evolution beyond the conventional administratively-provided mentoring intervention. As such, its next and ongoing iterations have incorporated our two most important observations: (1) that participatory mentoring developed and applied by the workforce itself is feasible, and (2) that the health and well-being needs of COs are potent and resistant to a generic approach.

Although well-being initiatives such as peer mentoring provide resources to COs adapting to their new environment, the prison system appears to need a culture change to reduce stress in the work environment and to reduce risks for associated chronic disease outcomes. Indeed, studies on COs' well-being across multiple countries have indicated the value of a humane culture and lower violence and stress in prison systems [44,52]. A recent study on a correctional culture change intervention in the United States reported that a humane, health-promoting, and rehabilitation-focused prison system benefits the health and safety of correctional workforce as well as the incarcerated population [52]. Sustainability requires that CO enthusiasm and dedication to participatory health interventions should be met by institutional support and a recognition that improving a work culture is a continuous process. Our decade-long work with participatory health interventions within corrections has generated a culture change process marked by instances such as COs' open discussions of mental health. Mental health interventions have and are currently being designed to improve workplace safety and officer health. Given the holistic nature of TWH interventions, it is imperative to evaluate effects on organizational support and culture along with physical and mental health outcomes of COs.

The declining health behaviors and health outcomes of new officers does not vitiate the importance of intervention. Correctional work culture differs by region and facility, thus requiring some customization. Overcoming the barriers to acceptance, including pessimism among COs, was a significant accomplishment of the HMP. A PAR mentor program facilitates adaptation of employees within a sector [27].

These lessons have been absorbed overall by the HITEC program as it continues with the evolution of the mentoring process. The ongoing descendant phase of interventions has

incorporated the principal findings from the HMP. The first and most important was proof of the concept that trained personnel could conduct and improve a peer mentoring program. The second was that generic interventions were not fully suitable for the CO population with its variety of crises and issues, different states of urgency, and modest preparation of mentors. A third consideration was the language and construction of surveys, which were agnostic to the situational particularities of the CO workforce. In an earlier analysis on this same workforce, we had observed surprisingly blunted CO responses [34].

Because the resources invested were substantial and effects modest, unmodified duplication of the HMP seems unadvisable. However, there are several merits to the HMP and its approach and, as noted, there is active modification which builds on the process that can be expected to be self-correcting via continuous improvement. These merits include the high morale of participating mentors and mentees towards the HMP, the enthusiasm of COs and union leadership towards participatory action, and the willingness of upper management to support these grassroots efforts.

First, by involving COs in the development and continuation of the HMP, we were able to overcome widespread CO resistance and distrust towards preventive health and work programs. CO involvement was also effective in alleviating privacy concerns and COs' general reluctance to share personal health information with fellow officers. Additionally, the labor-management group was able to dissolve formidable obstacles and maintain the participatory program, which is a considerable organizational process achievement. Furthermore, the participatory labor-management approach provides a platform for revision and continuous improvement of the program over time. Currently, the mentoring program has been adapted for peer involvement of all COs at the facility level regardless of job tenure. There is utilization of the training materials and ongoing training of engaged COs in mental health supports and interventions. While that process is not the subject of this manuscript, it may justify the degree of investment in a joint labor management program for peer health mentoring.

The emphasis on voluntary participation in a hierarchical environment also influenced self-selection and adherence. We had a small study cohort of 269 with unequal distribution of groups due to programmatic challenges, which may have diluted results. Efforts were made to align peer-mentor and mentee work shifts, but experienced potential mentors were first shift workers, whereas assignment to the second and third shifts was more common for new officers.

The complexity of testing three groups at three time points with repeated measures can lead to sampling bias and Type-1 error. To reduce bias statistically, we conducted tests for unequal variances and sphericity violations.

One of the inherent problems with a repeated-measures design is participant attrition over time and sample reduction. Although we had acquired relief time for participants, we acknowledge that the survey length and pressure to get back to post during follow-ups may have affected participation. Nonetheless, mentor recruitment efforts at the cadets' destination facilities were found to be effective, with the number of volunteer mentors more than doubling in the second year of the program, and few established mentors dropping out over two years. As a programmatic issue, the recruitment process resulted in three groups rather than the planned two groups, because of the distinct status of what we termed 'non-compliance,' which reduced statistical power. This might have affected the lower Cronbach's alpha of scales in our study compared to a similar population in corrections utilizing similar scaled measures [34].

Due to varying schedules and officers being transferred to other facilities, some mentor pairs were considered non-compliant. However, consistent with a PAR approach, programmatic adjustments were made over time, such as securing greater program facilitation by captain and lieutenant supervisors so that meetings between mentors and mentees working on the same shift could occur on a more regular basis. Our qualitative data indicate that it is also helpful to work in the same building/unit such that physical meetings are more feasible. Introducing mentees to mentors in a more formal way at the training academy

was another suggested program improvement yielded by the qualitative data. Informal mentoring was adopted by many mentors in this study; future studies could explore the effectiveness of formal versus informal peer health mentoring of COs.

Finally, this was not, contextually, a negative study. Its lessons go beyond the conventional defaults applied to public health studies that no single study is definitive, or that longer duration and larger populations are necessarily merited. In the context of ongoing participatory interventions directed to organizational and cultural change, the outputs from the HMP program were highly positive and effective. Viewed contextually, a conventional and conservative study design produced non-enduring positive results that returned to the null over a more extended period of observation. Both the short duration effectiveness of the participatory program and the limitations of transience are being addressed through this process of cultural change in corrections.

5. Conclusions

This study presents these key contributions to the literature and applied work on correctional officer health:

1. A longitudinal study which tracked new correctional officer demographic variables, work conditions, subjective health, and physical health indicators over a period of 5 years.
2. Development of a peer health mentoring program using participatory action research principles in a correctional officer population which included a labor-management participatory design approach.
3. Programmatic approaches for workplace health promotion consistent with Total Worker Health principles.
4. Documentation of health risks specific to the correctional officer population.

Mentoring frequency was associated with reduced exhaustion-burnout among mentees. Slow decline in health measures of body mass index and hypertension among mentees can be considered a positive effect of mentoring. We did not observe any other direct impact of the mentoring program on health behaviors and health outcomes in this study. It is of utmost importance to address work and health conditions to improve COs' declining physical and mental health for a healthy future of work in corrections. Although the impact was limited, this PAR approach that engaged COs and union leaders with the support of management was effective in developing and implementing this officer-led peer health mentoring program based on TWH principles. A health mentoring program can be expected to be more effective over the long term with a built-in participatory design approach for continuous improvement that empowers COs to advance the well-being of their workforce.

The barriers to successful health interventions in corrections can be formidable. However, this initial HMP provided a pathway towards establishing more effective and sustainable mentoring programs to improve the quality of work life and support improved health for COs. As noted, the HMP is part of an iterative continuous improvement process in the organization that can grow over time. CPH-NEW has developed a new toolkit to guide participatory development of HMPs that incorporates lessons learned from this HMP and subsequent adaptations of the program [49], with plans for updating this tool in the years ahead.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data presented in this study is available on request from the corresponding author. The data are not publicly available due to confidentiality concerns with consent agreement and organizational rules/policies with IRB and DOC.

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Abbreviations

CO	correctional officer
HMP	health mentoring program
HITEC	Health Improvement Through Employee Control
CPH-NEW	Center for the Promotion of Health in the New England Workforce
PAR	participatory action research
DOC	Department of Correction
SWSC	study-wide steering committee
OJT	on the job training

References

1. Morse, T.; Dussetschleger, J.; Warren, N.; Cherniack, M. Talking about health: Correction employees' assessments of obstacles to healthy living. *J. Occup. Environ. Med.* **2011**, *53*, 1037–1045. [CrossRef] [PubMed]
2. Gu, J.K.; Charles, L.E.; Burchfiel, C.M.; Fekedulegn, D.; Sarkisian, K.; Andrew, M.E.; Ma, C.; Violanti, J.M. Long work hours and adiposity among police officers in a US Northeast city. *J. Occup. Environ. Med.* **2012**, *54*, 1374–1381. [CrossRef] [PubMed]
3. U.S. Bureau of Labor Statistics. U.S. Department of Labor 2017 Survey of Occupational Injuries and Illnesses Charts Package. Available online: https://www.bls.gov/iif/osch0062.pdf (accessed on 27 August 2020).
4. Wright, L.; Borrill, J.; Teers, R.; Cassidy, T. The mental health consequences of dealing with self-inflicted death in custody. *Couns. Psychol. Q.* **2006**, *19*, 165–180. [CrossRef]
5. Viotti, S. Work-related stress among correctional officers: A qualitative study. *Work* **2016**, *53*, 871–884. [CrossRef]
6. Schaufeli, W.B.; Peeters, M.C. Job stress and burnout among correctional officers: A literature review. *Int J. Stress Manag.* **2000**, *7*, 19–48. [CrossRef]
7. Shepherd, B.R.; Fritz, C.; Hammer, L.B.; Guros, F.; Meier, D. Emotional demands and alcohol use in corrections: A moderated mediation model. *J. Occup. Health Psychol.* **2019**, *24*, 438–449. [CrossRef]
8. Wright, L.N.; Northrup, M.K. Examining the Health Risks for Corrections Professionals. *Correct. Today* **2001**, *63*, 106–109.
9. Cheek, F.E.; Miller, M.D.S. The experience of stress for correction officers: A double-bind theory of correctional stress. *J. Crim. Justice* **1983**, *11*, 105–120. [CrossRef]
10. Lambert, E.G.; Paoline, E.A.I. The influence of individual, job, and organizational characteristics on correctional staff job stress, job satisfaction, and organizational commitment. *Crim. Justice Rev.* **2008**, *33*, 541–564. [CrossRef]
11. Warren, N.; Dussetschleger, J.; Punnett, L.; Cherniack, M.G. Musculoskeletal disorder symptoms in correction officers: Why do they increase rapidly with job tenure? *Hum. Factors* **2015**, *57*, 262–275. [CrossRef]
12. Cherniack, M.; Dussetschleger, J.; Dugan, A.; Farr, D.; Namazi, S.; El Ghaziri, M.; Henning, R. Participatory action research in corrections: The HITEC 2 program. *Appl. Ergon.* **2016**, *53*, 169–180. [CrossRef] [PubMed]
13. Griffin, M.L.; Hogan, N.L.; Lambert, E.G. Career stage theory and turnover intent among correctional officers. *Crim. Justice Behav.* **2014**, *41*, 4–19. [CrossRef]

14. Bandura, A.; Walters, R.H. *Social Learning Theory*; Prentice Hall: Englewood Cliffs, NJ, USA, 1977; Volume 1.
15. Kram, K.E. *Mentoring at Work: Developmental Relationships in Organizational Life*; University Press of America: Lanham, MD, USA, 1985.
16. Allen, T.D.; Eby, L.T.; Poteet, M.L.; Lentz, E.; Lima, L. Career benefits associated with mentoring for protégés: A meta-analysis. *J. Appl. Psychol.* **2004**, *89*, 127. [CrossRef]
17. Eby, L.T. Alternative forms of mentoring in changing organizational environments: A conceptual extension of the mentoring literature. *J. Vocat. behavior.* **1997**, *51*, 125–144. [CrossRef]
18. Allen, T.D.; Eby, L.T.; Lentz, E. Mentorship Behaviors and Mentorship Quality Associated with Formal Mentoring Programs: Closing the Gap Between Research and Practice. *J. Appl. Psychol.* **2006**, *91*, 567–578. [CrossRef] [PubMed]
19. Erikson, E.H. *Childhood and Society*; Norton: New York, NY, USA, 1964.
20. Levinson, D.J. *The Seasons of A Man's Life*; Ballantine Books: New York, NY, USA, 1979.
21. Delisle, A.T.; Delisle, A.L.; Chaney, B.H.; Stopka, C.B.; Northcutt, W. Methods for fostering a community academic partner-ship in a firefighter community. *Am. J. Health. Behav.* **2013**, *37*, 721–733. [CrossRef] [PubMed]
22. Hogan, N.L.; Lambert, E.G.; Jenkins, M.; Wambold, S. The Impact of Occupational Stressors on Correctional Staff Organiza-tional Commitment: A Preliminary Study. *J. Contemp. Crim. Justice* **2006**, *22*, 44–62. [CrossRef]
23. Donaldson, S.I.; Ensher, E.A.; Grant-Vallone, E. Longitudinal examination of mentoring relationships on organizational commitment and citizenship behavior. *J. Career Dev.* **2000**, *26*, 233–249. [CrossRef]
24. Whitaker, S.D. Mentoring beginning special education teachers and the relationship to attrition. *Except. Child.* **2000**, *66*, 546–566. [CrossRef]
25. Payne, S.C.; Huffman, A.H. A Longitudinal Examination of the Influence of Mentoring on Organizational Commitment and Turnover. *Acad. Manag. J.* **2005**, *48*, 158–168. [CrossRef]
26. Tamers, S.L.; Chosewood, L.C.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C. Total Worker Health® 2014–2018: The novel approach to worker safety, health, and well-being evolves. *Int. J. Environ. Res. Public Health* **2019**, *16*, 321. [CrossRef]
27. Punnett, L.; Warren, N.; Henning, R.; Nobrega, S.; Cherniack, M. CPH-NEW Research Team Participatory ergonomics as a model for integrated programs to prevent chronic disease. *J. Occup. Environ. Med.* **2013**, *55*, S19–S24. [CrossRef]
28. Creswell, J.W.; Clark, V.L.P. Chapter 4. Choosing a Mixed Methods Design. In *Designing and Conducting Mixed Methods Research*, 1st ed.; Sage Publications: Thousand Oaks, CA, USA, 2007.
29. Turner, S.F.; Cardinal, L.B.; Burton, R.M. Research design for mixed methods: A triangulation-based framework and roadmap. *Organ. Res. Methods* **2017**, *20*, 243–267. [CrossRef]
30. Anger, W.K.; Elliot, D.L.; Bodner, T.; Olson, R.; Rohlman, D.S.; Truxillo, D.M.; Kuehl, K.S.; Hammer, L.B.; Montgomery, D. Effectiveness of total worker health interventions. *J. Occup. Health Psychol.* **2015**, *20*, 226–247. [CrossRef]
31. Namazi, S.; Farr, D.; Kotejoshyer, R.; Henning, A.R.; Dugan, G.A.; El Ghaziri, M.; Cherniack, D.M. Development and implementation of a Total Worker Health® mentoring program in a correctional workforce. *Int. J. Environ. Res. Public Health* **2021**. under review.
32. Mentoring in the Corrections Workplace: A Self-Paced Workbook. The Southern Region of The National Institute of Corrections Academy Division's Regionalization Project. Available online: https://nicic.gov/mentoring-corrections-workplace-self-paced-workbook (accessed on 27 August 2020).
33. Whelton, P.K.; Carey, R.M.; Aronow, W.S.; Casey, D.E.; Collins, K.J.; Dennison Himmelfarb, C.; DePalma, S.M.; Gidding, S.; Jamerson, K.A.; Jones, D.W.; et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: Executive Summary: A Report of the American College of Cardiolo-gy/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension* **2018**, *71*, 1269–1324.
34. Obidoa, C.; Reeves, D.; Warren, N.; Reisine, S.; Cherniack, M. Depression and work family conflict among corrections officers. *J. Occup. Environ. Med.* **2011**, *53*, 1294–1301. [CrossRef]
35. Karasek, R. Job demands, job decision latitude, and mental strain: Implications for job redesign. *Adm. Sci. Q.* **1979**, *24*, 285–308. [CrossRef]
36. Lundberg, O.; Peck, M.N. A simplified way of measuring sense of coherence. *Eur. J. Public Health* **1995**, *5*, 56–59. [CrossRef]
37. Zweber, Z.M.; Henning, R.A.; Magley, V.J. A practical scale for Multi-Faceted Organizational Health Climate Assessment. *J. Occup. Health Psychol.* **2016**, *21*, 250–259. [CrossRef]
38. Radloff, L.S. The CES-D Scale: A self-report depression scale for research in the general population. *Appl. Psychol. Meas.* **1977**, *1*, 385–401. [CrossRef]
39. Zhang, W.; O'Brien, N.; Forrest, J.I.; Salters, K.A.; Patterson, T.L.; Montaner, J.S.; Hogg, R.S.; Lima, V.D. Validating a short-ened depression scale (10 item CES-D) among HIV-positive people in British Columbia, Canada. *PLoS ONE* **2012**, *7*, e40793.
40. Andresen, E.M.; Malmgren, J.A.; Carter, W.B.; Patrick, D.L. Screening for depression in well older adults: Evaluation of a short form of the CES-D. *Am. J. Prev. Med.* **1994**, *10*, 77–84. [CrossRef]
41. Ware, J.E. *User's Manual for the SF-12v2® Health Survey (with A Supplement Documenting SF-12® Health Survey)*; QualityMetric In-corporated: Lincoln, RI, USA, 2002.
42. Jaegers, L.A.; Matthieu, M.M.; Vaughn, M.G.; Werth, P.; Katz, I.M.; Ahmad, S.O. Posttraumatic stress disorder and job burn-out among jail officers. *J. Occup. Environ. Med.* **2019**, *61*, 505–510. [CrossRef]

43. Jaegers, L.A.; Matthieu, M.M.; Werth, P.; Ahmad, S.O.; Barnidge, E.; Vaughn, M.G. Stressed Out: Predictors of depression among jail officers and deputies. *Prison. J.* **2020**, *100*, 240–261. [CrossRef]
44. Farnese, M.L.; Barbieri, B.; Bellò, B.; Bartone, P.T. Don't abandon hope all ye who enter here: The protective role of formal mentoring and learning processes on burnout in correctional officers. *Work* **2017**, *58*, 319–331. [CrossRef]
45. Lambert, E.G.; Hogan, N.L.; Barton, S.M. Satisfied correctional staff a review of the literature on the correlates of correc-tional staff job satisfaction. *Crim. Justice Behav.* **2002**, *29*, 115–143. [CrossRef]
46. Barr, T.; Gannon, L.; Tubbs, D.; Cherniack, M.; Henning, R.; Berger, S. *When Conventional Doesn't Cut It: Measurement Challenges for Correctional Officers*; Work Stress & Health, American Psychological Association/National Institute for Occupational Safety and Health: Minneapolis, MN, USA, 2017.
47. Hanrahan, J.; Berger, S.; Namazi, S.; Barr, T.; Henning, R.; Cherniack, M. Contextualizing Surveys for American Correctional Officers. In R. Henning (Chair), A Second Generation of Tools and Approaches for Supporting Employee Participation in Total Worker Health® Programmes. In Proceedings of the Symposium Conducted at the Meeting of the European Academy of Occupational Health Psychology Conference, Lisbon, Portugal, 5–7 September 2018.
48. Nielsen, K.; Abildgaard, J.S.; Daniels, K. Putting context into organizational intervention design: Using tailored questionnaires to measure initiatives for worker well-being. *Hum. Relat.* **2014**, *67*, 1537–1560. [CrossRef]
49. Introduction to Total Worker Health Mentoring Toolkit for the Corrections Workforce. Center for the Promotion of Health in the New England Workplace (CPH-NEW). Available online: https://www.uml.edu/Research/CPH-NEW/Resources/Corrections-Officer-Health-Resources/TWH-Mentoring-Toolkit-Corrections.aspx (accessed on 6 August 2021).
50. Punnett, L.; Cavallari, J.M.; Henning, R.A.; Nobrega, S.; Dugan, A.G.; Cherniack, M.G. Defining 'integration' for Total Worker Health®: A new proposal. *Ann. Work. Expo. Health* **2020**, *64*, 223–235. [CrossRef]
51. Nielsen, K.; Randall, R. Opening the black box: Presenting a model for evaluating organizational-level interventions. *Eur. J. Work. Organ. Psychol.* **2013**, *22*, 601–617. [CrossRef]
52. Ahalt, C.; Haney, C.; Ekhaugen, K.; Williams, B. Role of a US–Norway exchange in placing health and well-being at the center of US prison reform. *Am. J. Public Health* **2020**, *110*, S27–S29. [CrossRef] [PubMed]

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Review

Leveraging Strategic Foresight to Advance Worker Safety, Health, and Well-Being

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Abstract: Attending to the ever-expanding list of factors impacting work, the workplace, and the workforce will require innovative methods and approaches for occupational safety and health (OSH) research and practice. This paper explores strategic foresight as a tool that can enhance OSH capacity to anticipate, and even shape, the future as it pertains to work. Equal parts science and art, strategic foresight includes the development and analysis of plausible alternative futures as inputs to strategic plans and actions. Here, we review several published foresight approaches and examples of work-related futures scenarios. We also present a working foresight framework tailored for OSH and offer recommendations for next steps to incorporate strategic foresight into research and practice in order to advance worker safety, health, and well-being.

Keywords: occupational safety and health; methods and approaches; strategic foresight; forecast; scenario; work-related future; worker well-being

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1. Introduction

In recent decades, factors affecting worker safety, health, and well-being in advanced industrialized countries like the United States have undergone a fundamental shift. Today, numerous social, technological, economic, environmental, and political (STEEP) trends demonstrate complex patterns of influence on work, the workplace, and the workforce [1–7]. Because the number of relevant trends is too vast to comprehensively address in this paper, examples representing the different categories of STEEP are offered here. Rapid market shifts and advances in technology have contributed to a dramatic rise in part-time, temporary, contract, on-call, contingent, and 'gig' work. While these nonstandard work arrangements may increase work-life flexibility, they also tend to leave workers at risk by offering fewer protections and comparatively lower rates of pay [8–10]. Workplace automation has created new jobs and improved job safety in certain industries while concurrently contributing to widespread work intensification, job displacement, and wage reductions [11–13]. Demographic shifts and environmental changes, including climate change, have resulted in a highly diverse labor force with varying wants, needs, lifestyles, and vulnerabilities, which further exacerbate the effects of other STEEP trends [14–18]. Furthermore, since 2020, the COVID-19 pandemic has demonstrated how quickly a lack of preparation for events such as public health crises can accelerate changes that transform entire industries and have a compounding effect on worker safety, health, and well-being [19,20].

The occupational safety and health (OSH) community has already acknowledged the need for a transformation to keep up with the pace of the rapid and profound changes affecting workers [2,4,5,21–23]. As part of that transformation, an approach for expanding the focus of OSH was proposed in 2019 to more fully consider how traditional job risks and hazards combine with personal, social, and economic factors to affect health and well-being across the working life continuum [5]. Proactively managing this broader—and

growing—list of issues will require innovative and systems-focused OSH methods and approaches [2,4,5,21,22]. To that end, this paper proposes integrating *strategic foresight* into OSH research and practice. This future-oriented way of thinking and planning can help OSH professionals more actively anticipate, and even shape, the systems influencing the future of worker safety, health, and well-being.

1.1. A Brief Overview of Strategic Foresight

Strategic foresight is a practice rooted in futures studies that is designed to help better understand, prepare for, and influence the future [24]. At its core, strategic foresight recognizes that the future is not predetermined or predictable [25]. Instead, the roots of multiple plausible futures exist today in the form of weak or early signals of potential change [26]. Identifying and monitoring these signals can reduce the likelihood of being unprepared for or surprised by emerging trends and changes as they arrive in the mainstream. It can also uncover points at which today's decisions and actions can be leveraged to move toward desirable futures.

Engaging in strategic foresight involves the completion of two distinct, yet interrelated, tasks. Because the future is not preordained, the first task includes mapping futures, or developing functional views of alternative futures that are sometimes referred to as *forecasts* by strategic foresight practitioners in the United States [27–29]. These functional futures are the product of the systematic observation, organization, and synthesis of the weak and early signals of change found in the present. They are not intended to be accurate predictions of the future. Rather, they are designed to be provocative but realistic visions of what the future could reasonably be, based on the signals of change that exist today. For the second task, the implications and critical issues associated with the alternative functional futures are assessed to influence the future by informing the design and implementation of feasible and responsive strategic options [26].

It is important to note that strategic foresight is a complement to, not a substitute for, strategic planning. Traditional strategic planning reviews evidence from the past and asks how we might do things better, faster, or more proficiently in the future. This backward-to-the-future approach is very useful and efficient in stable and unchanging environments [30]. Conversely, strategic foresight looks ahead and asks what *may* be coming, how it *might* affect us, and what we *can* do today to start moving toward a preferred outcome. This forward-facing perspective is particularly useful during periods of complex instability, the conditions of which are often described as being volatile, uncertain, chaotic, and ambiguous (VUCA) or turbulent, uncertain, novel, and ambiguous (TUNA) [30,31].

1.2. Approaches to Strategic Foresight

Many different models and frameworks have been created to facilitate the application of strategic foresight as part of planning efforts, often in response to VUCA or TUNA conditions [32]. Some of the formalized approaches frequently cited in the published literature are presented in Table 1. Other approaches, such as the Institute for the Future's copyrighted *Foresight Toolkit* and the digital Futures Platform, are available via direct distribution for a nominal fee [33,34]. Though there may be advocates for one approach over another, it is important to note that the relative effectiveness and utility of the various approaches have not been directly compared, and there is no clear evidence to suggest that one strategic foresight approach is superior to any other. Instead, practitioners typically select an approach based on its fit with critical contextual factors, such as past and current conditions and the needs and interests of key stakeholders [35].

Table 1. Popular formalized approaches to strategic foresight described in the published literature.

Approach	Originating Organization	Overview of Steps (with *Step Name* Included, Where Applicable)
Assumption-based planning [36,37]	The RAND Corporation	• Identify assumptions underlying current operations or plans • Identify assumptions that may be vulnerable to or violated by future changes • Define signposts, or events that would indicate an assumption is becoming more or less vulnerable over time • Define shaping actions that will either cause or prevent the failure of a vulnerable assumption • Define hedging actions that can help better prepare for a potential assumption failure in the future
FORLEAN [38]	European Commission	• *Diagnosis:* Reflect on the current system • *Exploration:* Build scenarios of possible evolutions of the system • *Strategic Orientation:* Discuss possible strategies • *Making Choices:* Encourage open debate to reach consensus • *Implementation and Coordination:* Translate findings into action
Framework Foresight [28,39]	University of Houston	• *Framing:* Identify the domain, or boundaries and key categories of what will be explored • *Scanning:* Scan the internal and external environments for information and trends related to the domain • *Forecasting:* Identify drivers and uncertainties, then create alternative futures • *Visioning:* Identify implications, challenge assumptions, and develop a strategic vision • *Planning:* Develop strategic options • *Acting:* Communicate results, create an action plan, and institutionalize strategic thinking
Generic Foresight Process [40]	Swinburne University of Technology	• *Inputs:* Scan the external environment to identify changes that are shaping the future • *Analysis:* Analyze the scanning results to explore potential shifts needed to identify strategic implications • *Interpretation:* Identify assumptions and worldviews affecting how the future is interpreted • *Prospection:* Develop alternative images, or scenarios, for plausible and preferred futures • *Outputs:* Identify strategic options • *Strategy:* Agree on action to take today
Manoa Futures Visioning Process [41]	University of Hawaii	• *Appreciate the Past:* Explore the history of the community or group involved • *Understand the Present:* Discuss the problems and possibilities of the present • *Forecast Aspects of the Future:* Discuss possible challenges and opportunities from the futures • *Experience Alternative Futures:* Craft alternative futures trends, emerging issues, challenges, and opportunities from the future • *Envision the Futures:* Envision a preferred future • *Create the Futures:* Decide the sequence of what to do now to move toward the preferred future • *Institutionalize Futures Research:* Set up an ongoing 'futures' unit to keep the process going
Oxford Scenario Planning Approach [31]	University of Oxford	• Develop an understanding of the problematic situation • Define, develop, verify, and refine a set of strategic frames—the underlying structures of belief, perception, and appreciation used to make sense of the world • Generate alternative scenarios • Engage in iterative learning cycles comprised of: • *Reframing:* Contrasting alternative scenarios of the future to reveal, test, and redefine the official future, generate alternatives, and generate new knowledge and insights • *Reperception:* Defining a new course of action
Exploring the Future [42]	Royal Dutch Shell	• *Preparation:* Assembling a clear description of the project, goals, and resources • *Pioneering:* Challenging assumptions and identifying themes • *Map-making:* Building and vetting the scenarios • *Navigation:* Presenting the scenarios to inform plans and actions of key stakeholders, and refining the scenarios based on feedback • *Reconnaissance:* Examining implications, interpreting signals of change, and further disseminating the scenarios • *Preparation:* Beginning the process anew to develop fresh scenarios in response to change over time

Though the popular models and frameworks each have a slightly different approach to strategic foresight, they all include steps that align with the two main activities of strategic foresight: (1) Generating alternative futures; and (2) assessing implications to inform decisions and actions. They also share two other important features. First, each approach conceptualizes time in terms of near-, mid-, and far-term horizons. Second, they all produce alternative futures in the form of scenarios. These two critical strategic foresight concepts—*time horizons* and *scenarios*—are described here in greater detail.

1.2.1. Time Horizons

A flexible method commonly used to delineate the near-, mid-, and far-term futures is Three-Horizon Foresight, which is typically depicted with a schematic similar to Figure 1 [43,44]. As its name implies, Three-Horizon Foresight divides time into three horizons. Horizon 1 is the current prevailing system, or way of doing things. As time moves forward and change inevitably occurs, the Horizon 1 system becomes increasingly less likely to align with the challenges and opportunities found in the STEEP environment. In contrast, Horizon 3 represents marginal ideas and arguments falling outside the current prevailing system, hints of which are seen as weak or early signals in the present. Over time, these early signals may increase in both strength and strategic fit with the changing STEEP environment and eventually become mainstream in a new prevailing system. Horizon 2 is the period of transition between Horizon 1, the near-term state, and Horizon 3, the far-term state.

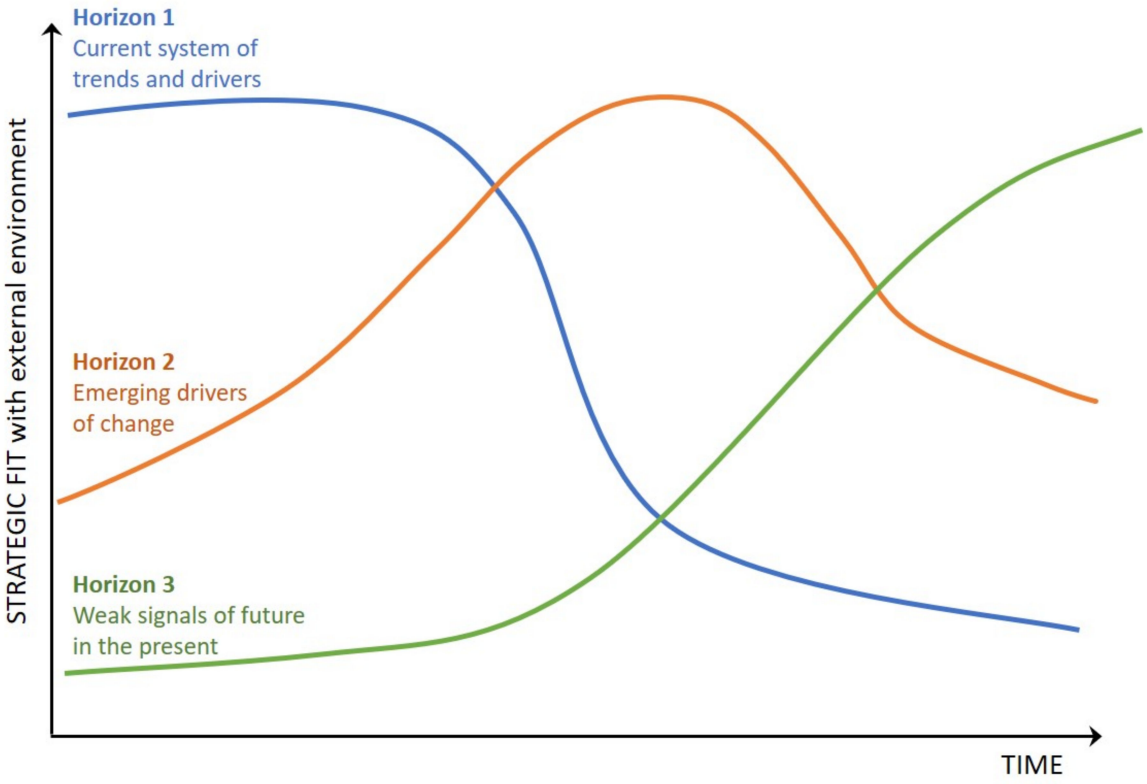


Figure 1. Visual representation of Three-Horizon Foresight [43].

While it is common to define Horizon 3 (the far-term future) as 10 to 20 years from the present, this is not a hard-and-fast rule [45]. The amount of time accounted for by each Horizon should be determined by the most useful planning or business cycles that are relevant to the focal topic and its key stakeholders [35,43]. For topics with a history of being slow to change (e.g., cultural norms, environmental climate), foresight practitioners are more likely to define longer horizons because it takes more time for change to occur and manifest in the mainstream. For projects investigating topics that experience change

more rapidly (e.g., technological innovations), or those tied to faster-paced business cycles, time horizons may be shorter.

1.2.2. Scenarios

A *scenario* is a story with a carefully constructed plotline describing one plausible future [39,46,47]. Because the future is not predetermined or predictable, multiple future visions are usually articulated as separate scenarios during a strategic foresight project. Exactly how many scenarios should be produced will vary based on end-user needs and the scenario development techniques used, the latter of which are discussed later in this paper. However, published recommendations typically range from two to six scenarios per foresight project [48]. More important than the number of scenarios produced is ensuring that each one represents a unique, plausible, and logical story offering new insights into future possibilities, threats, and opportunities based on careful analysis of inputs [49,50].

There is no one right or best way to communicate alternative futures scenarios. In practice, a variety of formats and products can be used to describe different scenarios [39,51]. Some common options are identified in Table 2.

Table 2. Common products used to communicate alternative futures scenarios.

Product Type *	Definition
Artifact	Linguistic, conceptual, cultural, and material objects and articles, including physical tools, technical processes or procedures, or symbols and logos [52]
Headline or News Story	Brief captions or stories describing events that may happen in the future [53]
Narrative	Stories of organizations and the people in them that rethink the past, reconsider present conditions, and reimagine the future [54]
Persona	Characters who live in one plausible future and fully embody the human representation in that future [55]

* Multiple products can be used to convey a single scenario.

1.3. Uses of Scenario-Based Strategic Foresight

Scenarios have long been utilized as part of business, military, public policy, and emergency preparedness strategic planning efforts [50,56–58]. The practice originated in the 1950s, when the RAND Corporation first began using scenario techniques to develop U.S. military strategies [59]. Around the same time, the Centre d'Etudes Prospectives was established to develop scenarios of possible political, social, and cultural futures for France [60]. In the 1960s, futures groups such as the Institute of the Future, the Stanford Research Institute's (SRI) 'Futures Group,' and the California Institute of Technology began using scenarios as a public policy planning tool [56]. Soon after, Royal Dutch Shell permanently adopted scenario planning as part of its business strategy. Through its 'Year 2000 Project,' the company developed scenarios that depicted looming oil scarcities and price increases, which helped Royal Dutch Shell prepare for major adverse events in the oil industry, such as the 1973 oil crisis and the 1980s oil bust, which resulted in a competitive advantage during those times of turbulence [61]. Following the success of Royal Dutch Shell's scenario planning efforts, major organizations across a variety of industries began to incorporate scenario planning into their business culture. Examples include Motorola, General Electric, United Parcel Service, Philips Corporation, Nokia Corporation, Siemens, and Daimler AG [58]. Using scenarios as a planning tool has allowed these and many other organizations to remain resilient through—and even thrive on—the many changes and challenges they have faced over time [62].

The current widespread use of strategic foresight to anticipate future uncertainties across a variety of domains is well-documented in the published literature. Numerous private and public sector organizations around the world report regularly engaging in the practice to gather and make sense of information about the future contexts in which they

will operate [63,64]. Today, a growing worldwide community of organizations engages in scenario-based strategic foresight to explore the implications of plausible future changes to work, the workplace, and the workforce. A list of some of the most active organizations in this space culled from a comprehensive search is presented in Table 3. The search exhausted combinations of keywords from three categories: Organization type (organization/organization, center/centre, council, foundation, initiative, institute, lab, office, program/programme, work group, workgroup), foresight activities (strategic foresight, changing patterns, forecasting, foresight, future scenarios, horizons, horizon scanning, scenario), and work futures orientation (future of work, changing nature of work, digital, fourth/4th industrial revolution, future of employment, future of jobs, future workplace, industry 4.0). Though the organizations uncovered by this search are primarily headquartered in North America and Europe, OSH-related foresight initiatives are growing in other areas of the world as well. Examples include the Institute for Futures Research at Stellenbosch University in South Africa and the Ajman Department of Economic Development's "Future Foresight Initiative" in the United Arab Emirates, announced in 2020 [65,66].

Table 3. Organizations using strategic foresight to create and explore plausible future changes to work, the workplace, and the workforce.

Headquarters Location	Organization Name	Organization Type *
Australia	Institute for Safety, Compensation, and Recovery Research	Research
Belgium	European Parliamentary Research Service	Government
Canada	Brookfield Institute for Innovation + Entrepreneurship	Research
	Centre for International Governance Innovation	Think Tank
	Institut National de la Recherche Scientifique (INRS)	Academic
	Policy Horizons Canada	Government
Finland	Demos Helsinki	Think Tank
France	Organisation for Economic Co-Operation and Development	IGO
Germany	Federal Ministry of Labour and Social Affairs	Government
	Fraunhofer-Gesellschaft	Research
Ireland	European Foundation for the Improvement of Living and Working Conditions (Eurofound)	IGO
Netherlands	Netherlands Organisation for Applied Scientific Research (TNO)	Research
Scotland	Scotland's Futures Forum	Think Tank
Spain	European Agency for Safety and Health at Work (EU-OSHA)	IGO
Switzerland	International Labour Organisation (ILO)	IGO
	World Economic Forum (WEF)	NGO
United Kingdom	Deloitte	Consulting
	Health and Safety Executive	Government
	PricewaterhouseCoopers (PwC)	Consulting
	Rethinkery Foresight	Consulting
	The Royal Society for Arts, Manufactures and Commerce (RSA)	Research
	Schumacher Institute	Think Tank
	University of Oxford, Saïd Business School	Academic
United States	Cognizant	Consulting
	Data & Society Research Institute	Research
	Future-IQ	Consulting

Table 3. *Cont.*

Headquarters Location	Organization Name	Organization Type *
	The Institute for the Future	Think Tank
	International Association of Outsourcing Professionals	Consulting
	McKinsey Global Institute	Consulting
	Millennium Project	Think Tank
	RAND Corporation	Research
	Toffler Associates	Consulting

* IGO = Intergovernmental Organization; NGO = Non-Governmental Organization.

The remaining sections of this paper explore how strategic foresight has been and could be applied to anticipate future challenges and opportunities in OSH that may affect worker safety, health, and well-being. First, we review two popular methods for constructing plausible future scenarios and demonstrate how each has been used to explicate possible work-related futures and their potential risks and hazards (Section 2. Developing Plausible Future Scenarios for Worker Safety, Health, and Well-Being). Next, we highlight several examples showing how strategic foresight has been used to develop recommendations and policy options that protect and promote worker safety, health, and well-being (Section 3. Using Scenarios to Protect and Promote Worker Safety, Health, and Well-Being). Then, we describe a foresight framework currently being tailored for the OSH community (Section 4. Foresight Framework for Occupational Safety and Health (OSH)). Finally, we discuss future directions and recommendations for applying strategic foresight to OSH research and practice (Section 5. Conclusions and Recommendations).

2. Developing Plausible Future Scenarios for Worker Safety, Health, and Well-Being

Constructing scenarios as part of a strategic foresight effort is, arguably, equal parts science and art [67]. A variety of techniques and methods exist to aid and guide the scenario development process. This section offers a deeper look into two popular methods that are frequently used to construct alternative work futures scenarios: The matrix method and the archetypes method.

2.1. The Matrix Method of Constructing Future Scenarios

The matrix method, also known as the 2 × 2 double uncertainty method, is one of the most widely used scenario building techniques in advanced industrialized nations like the United States [51,68]. The method rose in popularity after Royal Dutch Shell's success in using scenario-based planning to prepare for changes in mid- to long-range global energy demands and costs [69]. An overview of the matrix method is also included as an appendix in *The art of the long view: Planning for the future in an uncertain world*, considered by many as the seminal publication on scenario-based planning [62].

The matrix method begins with the identification of two high-impact, high-uncertainty issues that will influence the future for a domain of interest [45]. The issues then become the perpendicular axes of a 2 × 2 matrix, and the poles of each axis are defined. The result is a grid of four quadrants, into which scenarios of alternative futures for the focal domain can be mapped.

2.2. Applying the Matrix Method to Develop Alternative Work Scenarios

The following examples demonstrate the use of the matrix method to construct scenarios describing alternative futures and their potential effects to worker safety, health, and well-being.

The European Agency for Safety and Health at Work (EU-OSHA) used the matrix method to explore potential future OSH risks associated with digitalization [70]. The

resulting four futures, presented in Table 4, are driven by the key uncertainties of economic growth and technology application (supportive vs. resistive) and governance and public attitude (low vs. high). Work-related risks shared across the scenarios include (1) the use of technologies—particularly automation—eliminating some known job hazards while also introducing new ones; (2) changes to work flexibility, work pace, and work management; (3) alternative business and employment models; (4) increased job instability; (5) loss of privacy to surveillance; and (6) increased sedentariness.

Table 4. EU-OSHA's four futures of occupational safety and health risks from digitalization [70].

	Low economic growth and technology application	High economic growth and technology application
Supportive governance and public attitude	**Evolution** Technology significantly changes half of all jobs. There is continued investment in OSH to address dangerous and unhealthy work.	**Transformation** Technology significantly impacts most jobs. At the same time, work safety and quality remain a high priority.
Resistive governance and public attitude	**Fragmentation** Technology has had a low impact on jobs overall, though many low-skill repetitive jobs have been fully automated.	**Exploitation** Technology use varies by industry. Routine, repetitive jobs have been fully automated to save costs. Job competition is high.

PricewaterhouseCoopers (PwC) espoused four plausible futures for the 2030 workforce [71]. These futures, built around the dichotomies of individualism vs. collectivism and corporate integration vs. business fragmentation, are depicted in Table 5. Together, these four futures shed light on possible long-range challenges for workforce selection and recruitment, performance and personnel management systems, and learning and development programs. They also highlight the staying power of automation as a megatrend affecting worker safety, health, and well-being.

Table 5. PwC's four futures for the 2030 workforce [71].

	Individualism	Collectivism
Corporate Integration	**Blue World** Capitalism rules, widening the wage gap. Performance-enhancing augmentation technologies, medications, and implants are normalized. Privacy is lost to continuous employer surveillance inside and outside the workplace.	**Green World** Corporate social responsibility rules. Employers offer fair pay, family-friendly policies, and skills development. The increased use of technology for ethical and environmental reasons reduces the number of available jobs.
Business Fragmentation	**Red World** Innovation rules. High rates of technology use decrease job opportunities, inflate market pressures, and increase work pace. Skills, not workers, are valued.	**Yellow World** Business ethics rules. A collective desire for the fair distribution of wealth and resources drives policy. Autonomous and flexible work provides purpose and fulfillment.

The World Economic Forum (WEF) extended the 2 × 2 method and included a third uncertainty, yielding a 2 × 2 × 2 matrix describing eight alternative scenarios of work in 2030 [72]. These are described briefly in Table 6. The rate of technological change (steady vs. accelerating), the evolution of learning (slow vs. fast), and talent mobility (low vs. high) served as the key uncertainties around which the scenarios were constructed in order to identify strategic options that can begin proactively shaping a better future for workers.

Table 6. WEF's eight futures of work by 2030 [72].

	Steady Technological Change		Accelerated Technological Change	
	Low Talent Mobility	High Talent Mobility	Low Talent Mobility	High Talent Mobility
Slow Learning Evolution	**Workforce Autarkies** A large number of displaced workers compete for few jobs. Governmental policies restrict international labor mobility.	**Mass Movement** Worker mobility has resulted in steady incomes, lower living costs, and high levels of competition between workers at all skill levels.	**Robot Replacement** Widening skills gaps have increased inequalities and polarized views. Borders are tightly controlled in an effort to keep talent local.	**Polarized World** Due to fast-paced tech and low-paced learning, large portions of the workforce are unemployable. 'Super economies' of high-skilled people trade only with one another.
Fast Learning Evolution	**Empowered Entrepreneurs** Lifelong learning is embraced. Workers are able to create their own opportunities in dynamic markets, but migration is restricted in an attempt to retain talent.	**Skilled Flows** A fast-paced skills evolution enhances creativity and productivity. Abundant opportunities normalize labor mobility. Inequality at the country level increases based on access to tech resources.	**Productive Locals** There is high demand for workers to complement machines. Borders are tightly controlled in an effort to keep talent local.	**Agile Adapters** The global workforce is mobile and agile. There is worldwide harmony of social and workforce policies, standards, and credentials. Rapid tech changes, however, have created instability for the economy and society.

2.3. The Archetypes Method of Constructing Future Scenarios

Like the 2x2 matrix method, the archetypes method of scenario building also results in the development of up to four plausible alternative futures. Rather than being constructed around two polarized key drivers, however, the futures are constructed using a larger set of drivers and prototypical archetypes that describe common patterns of change. There are a number of potential archetype sets that can be applied to generate futures scenarios [73]. One of the most popular is a set of four archetypes, which are the product of the Hawaii Research Center on Futures Studies' extensive cross-cultural research on images of the future [41,74]. Over time, multiple well-known foresight practitioners have genericized the definitions of these four popular archetypes to facilitate the exploration of the future for a variety of topics [75,76]. These broader archetype definitions include:

- *Continuation* (or *Continued Growth*): A future where the trends of the present accelerate without any major changes or disruptions.
- *Collapse*: A future where the current system fails due to some negative force(s) or dysfunction.
- *New Equilibrium* (or *Constraint*): A future where the current system is challenged in some way and must respond with some type of change to achieve a new sense of balance and stability.
- *Transformation*: A future where there is a fundamental change and the current system is discarded for an entirely new one.

2.4. Applying the Archetypes Method to Develop Future Work Scenarios

The futures constructed using the archetypes method will vary based on the focal domain and selection of key issues and drivers of change. Two examples are presented here to demonstrate the potential diversity of the resultant scenarios.

Using 15 global challenges ranging from climate change and public health to energy and technology, The Millennium Project Team developed three plausible futures for work and technology by 2050 [77,78]. In the "It's Complicated—A Mixed Bag" continuation scenario, an accelerated use of technology, high rates of unemployment, and the mixed success of a universal basic income yield a multipolar world where large corporations have

more power and control than the government. In the "Political/Economic Turmoil—Future Despair" collapse scenario, an unanticipated explosion of unemployment in the 2030s leads to political turmoil, terrorism, and high rates of organized crime by 2050. In the "If Humans Were Free—The Self-Actualization Economy" transformation scenario, governments are able to achieve a self-actualized, steady-state economy by adequately preparing for the effects of artificial intelligence in the workplace, researching methods to phase in universal basic income, and promoting self-employment.

In another example, the Organisation for Economic Co-operation and Development (OECD) generated three different plausible archetypal futures by focusing on potential directions for national policies to support economic growth and job development [53]. In the "Quick Fixes" continuation scenario, policymakers attempt to address the inequalities created by technological advances, nonstandard arrangements, and high unemployment rates with redistribution strategies, such as high wealth taxation rates. In the "Multipolar" constraint scenario, low interest rates, private credit programs, and education systems built around lifelong learning allow governmental policy to focus on the creation of new jobs and industries and the regulation of technology—in particular, augmentation—to prevent the creation of new inequalities. In the "City Power" transformation scenario, technologies are used to address climate and food scarcity issues and support collaboration between cities, businesses, and governments while national-level policies are enacted to regulate nonstandard work arrangements, leverage the use of private data for public good, and develop social good metrics.

3. Using Scenarios to Protect and Promote Worker Safety, Health, and Well-Being

Well-constructed scenarios can present interesting, and sometimes entertaining, views of the future. However, their real value lies in their ability to spark strategic conversation and action [62]. As previously noted, the strategic foresight process is not complete after the development of scenarios. Instead, a comprehensive strategic foresight project should also support the creation of strategies that help individuals and organizations prepare for a range of plausible alternatives and move toward a preferred future outcome [41,79].

Some published scenarios related to the future of work have been developed for the sole purpose of spurring additional dialogue about the current state of preparedness for potential future conditions. These scenarios do not result in the development of specific strategic options and plans for stakeholders. Instead, they are analyzed to a limited extent to shed light on key issues and the need for strategies to address them. The scenarios from EU-OSHA, PwC, and OECD described in Section 2 were constructed for this purpose [53,70,71].

In other instances, scenarios describing plausible futures related to work have been analyzed not only to identify key themes and challenges, but also to yield specific and feasible recommendations for stakeholder action [68]. This additional layer of analysis typically involves several steps: (1) Establishing a vision and goals for the future, (2) examining multiple scenarios to identify common opportunities and threats, (3) creating a timeline of viable actions that will aid in accomplishing the established goals within the context of the opportunities and threats, and (4) pinpointing key decisions and resources required for each action [80]. WEF, for example, analyzed the eight scenarios for the future of work by 2030 presented in Table 6 to generate recommendations for collaborative action by governments, businesses, and academia. These include workforce reskilling and education reform; expanded access to communication technologies; increased incentives and support for job creation and protection, labor force participation, and entrepreneurship; enhanced oversight and management of platform work and talent mobility; and the development of agile and sustainable social safety nets [72]. Similarly, The Millennium Project Team analyzed its three archetype scenarios described in Section 2.4 to identify over 90 possible stakeholder actions with accompanying implementation guidance in support of creating an equitable, humanitarian future economy. These actions were clustered into five major groupings: Government and governance; business and labor; science and technology; education and learning; and culture, arts, and media [77]. Other scenario-based studies

have yielded similar results, generating action and policy recommendations for specific OSH topics, industry sectors, and geographic regions [19,81–83]. Though the publication of follow-on impact studies is rare, the available evidence suggests future of work scenarios and recommendations generated by the application of strategic foresight can be used to inform the development of government initiatives; increase subject matter knowledge among stakeholders and the general public; enhance professional education, training, and development offerings; and expand foresight awareness and capacity [82].

4. Foresight Framework for Occupational Safety and Health (OSH)

The concept of applying strategic foresight to the exploration of work-related futures is not entirely new. A number of scenarios have been published describing potential futures with respect to work [68]. However, compared to its use in other business planning and decision-making efforts, strategic foresight has been arguably underutilized for OSH. This may be due, at least in part, to the fact that the majority of foresight research and practice lives within futures studies and technology studies, which have not historically been considered OSH disciplines. Consequently, strategic foresight experts often tend to publish on topics outside those central to OSH in outlets beyond those on which the OSH community most often relies for new information [84].

To further the application of strategic foresight in the OSH domain, the Centers for Disease Control (CDC) National Institute for Occupational Safety and Health (NIOSH) has adapted the widely used University of Houston Framework Foresight [28,85,86]. NIOSH elected to build on Framework Foresight because it is an internationally renowned approach that is versatile and flexible enough to accommodate a variety of project topics and aims while also providing a clear, step-by-step roadmap through the foresight process. The intent of this NIOSH Foresight Framework for OSH, presented in Figure 2, is to help bridge the current OSH-foresight gap and bring foresight into OSH conversations and planning practices.

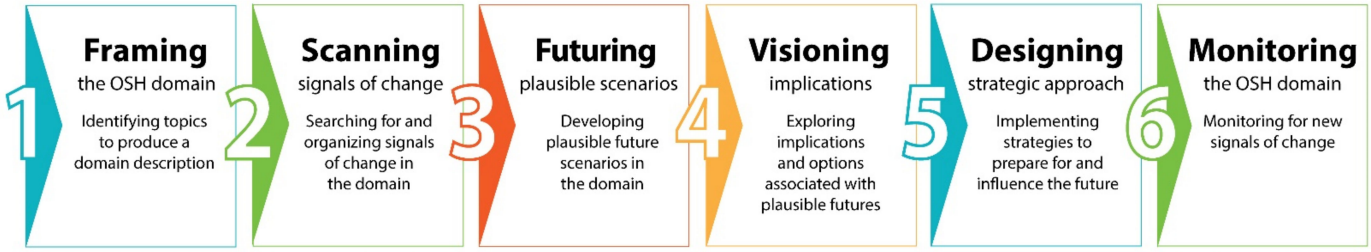


Figure 2. Foresight Framework for Occupational Safety and Health (OSH). Adapted from the UH Foresight Framework [85,86].

Like the University of Houston Framework Foresight, the NIOSH Foresight Framework for OSH has six discrete stages that are interrelated and interdependent. The first stage of *Framing* the OSH domain involves identifying the domain or topic of interest and developing a description of the domain, including the central question or issue to be explored, the 'client' or intended audience of the foresight effort, the geographic scope of the domain to be explored, and the time horizons the project will consider. It is important to devote ample time to the *Framing* stage to ensure the domain, central question, client and client needs, scope, and time horizons are adequately and accurately defined, as these factors largely influence the activities completed in the subsequent framework stages. The second stage, *Scanning*, is central to the foresight effort and involves searching for information about how things might be different in the future. During this stage, practitioners look for and organize signals of change within the domain of interest and the broader STEEP context. A variety of information sources should be reviewed during the scan, not only including refereed publications and major surveillance systems, but also government and stakeholder reports, legislative records, trade and technical journals, newsletters, monographs, blogs, mainstream and fringe media, general internet searches, and individuals

with a variety of perspectives on the domain topic [86]. The information gathered is used to construct key drivers of the future for the selected domain. The third stage, *Futuring*, involves developing alternative future scenarios from the drivers using techniques that meet the needs of the identified client. Common techniques will likely include the four scenario archetypes method or the 2x2 matrix method described in Section 2. In the fourth stage, *Visioning*, the implications of the different scenarios are considered for the client. Assessing implications can uncover potential risks, challenges, and opportunities associated with each scenario and identify the client's degree of preparedness for implementing the changes needed to create and sustain the client's preferred future. The fifth stage of *Designing* involves planning and constructing strategic approaches that can guide the client's actions today in support of the desired future. The last stage of *Monitoring* involves continuing to scan for new signals of change and updating the domain topic as needed to further refine future foresight efforts. Engagement with and integration of relevant stakeholders is encouraged throughout the entire foresight process and should be tailored at each stage to effectively support the project purpose.

Though the framework is presented as a sequential model, the strategic foresight process is not entirely linear. Both during and at the end of each stage within the framework, users are encouraged to reflect upon the activities they have completed in previous stages and determine if any additional work is needed before moving on the to the next stage. Signals of change detected in the *Scanning* stage, for example, may highlight the need to revise the domain description, central question or issue, or geographic scope defined during the *Framing* stage. Similarly, attempts to develop alternative scenarios during the *Futuring* stage may uncover the need to revisit *Scanning* to search for additional signals of change to create provocative but realistic stories for what the future could entail. In addition, the sixth stage of *Monitoring*, which involves continued scanning for signals of change over time, is an inherent extension of the second stage of *Scanning*, which involves a time-bound, dedicated initial scan for signals of change as part of a foresight project. Over time, signals uncovered during *Monitoring* may suggest the need to revisit *Framing* to redefine the domain or to re-enter the *Futuring* stage to update the plausible scenarios for a given domain.

To test this framework, NIOSH has designed a foresight pilot project exploring "the future of OSH" as a priority domain. NIOSH has convened a diverse team of subject matter experts from across the OSH discipline to participate in this pilot test of the framework. This approach aligns with recommendations of bringing together multidisciplinary research teams when using scenario-based strategic foresight to explore complex issues and topics [87]. The project was currently underway at the time this paper was written, and the project team, led by authors of this paper, plan to report the process and results of the effort in a future peer-reviewed publication. In addition, at the time this paper was written, NIOSH had formal agreements in place with international strategic foresight experts to evaluate the utility of the Foresight Framework for OSH. It is anticipated that the results and lessons learned from the pilot test and evaluation will inform the development of strategic options and recommendations for NIOSH's future research and service activities and contribute to the refinement of the NIOSH Foresight Framework for OSH.

5. Conclusions and Recommendations

The world of work today is not what it was ten, five, or even two years ago. Socioeconomic, geopolitical, demographic, and technological megatrends are anticipated to have disruptive influences on the future of work [88]. Exactly how these trends will change and unfold over time is largely unknowable, and their potential future impacts to workers are unclear. Because of VUCA/TUNA conditions, the OSH community cannot sufficiently identify and prepare for the potential future risks and hazards that may influence worker safety, health, and well-being using only conventional strategic planning. Complementary forward-looking methods are also needed to help us design and refine proactive risk management programs and strategies for the future of work before it arrives.

Strategic foresight is a tool the OSH community can leverage to bring futures thinking into research and practice. Generating and assessing the implications of multiple plausible work-related futures can help OSH prepare for, plan, and influence the future by combatting two critical errors of decision making: The human tendencies to over- and underpredict change [50]. Strategic foresight can expand the range of possibilities OSH envisions for work, the workplace, and the workforce of the future while ensuring those visions remain grounded in reality. This broader consideration of possible, yet realistic, future conditions can provide insights into environmental and market changes; facilitate meaningful strategic conversations; and aid in the identification of opportunities and threats, the reduction and management of uncertainties, the coordination of objectives, and the consideration and adoption of alternative perspectives [89].

Existing OSH research initiatives and programs, such as the NIOSH Future of Work Initiative and *Total Worker Health*® Program, can provide pathways to prospective domains to explore using strategic foresight. The NIOSH Future of Work Initiative, for example, has developed a framework to guide research and practice-based activities relevant to the future of work, the workplace, and the workforce in the United States [6]. The nine central priority topics include organizational design, technological job displacement, work arrangements, artificial intelligence, robotics, technologies, worker demographics, economic security, and skills. The framework also recognizes additional high-level issues, including globalization, extreme weather conditions, and emergency and disaster preparedness and response for situations such as the COVID-19 pandemic, that have a widespread impact on work, the workplace, and the workforce. Collectively, these priorities can help focus inquiry into plausible future scenarios related to work. Similarly, the NIOSH *Total Worker Health*® Program has published an extensive list of key issues relevant to advancing worker well-being [5,23]. These issues are associated with the organization of work, built environment, leadership, compensation and benefits, community, workforce demographics, policy, and new employment patterns. These issues, as well as many others identified throughout NIOSH's entire Program Portfolio, which is organized by industrial sectors and health and safety outcomes, could be used to help focus future strategic foresight efforts within the OSH domain [90].

To ensure strategic foresight has staying power in the OSH community, it will be imperative to invest time and resources into building strategic foresight capacity. Enhancing OSH awareness and knowledge of strategic foresight will be key. The Foresight Competency Model (FCM) developed by the international Association of Professional Futurists (APF) can serve as a guide for enhancing foresight knowledge, skills, and abilities in OSH. The FCM identifies six core competencies for foresight practitioners—framing, scanning, futuring, designing, visioning, and adapting—which align 1:1 with the steps of the University of Houston Framework Foresight model and, subsequently, NIOSH's adapted Foresight Framework for OSH [28,85,91]. APF also offers a prototypical plan for developing these six competencies in individuals, individual team members, and entire teams [91]. Mentoring and training opportunities will be central to competency development for all three groups. To this end, a number of internationally recognized foresight organizations in the United States (e.g., the University of Houston and the Institute for the Future) and Europe (e.g., Saïd Business School at the University of Oxford and Copenhagen Institute for Futures Studies) offer professional foresight training programs and consulting for a nominal fee [33,92–94]. A number of foresight guidance documents and recorded presentations are also available online, free of charge [30,95–97]. Building formal and informal partnerships with entities already active in strategic foresight can serve as a complement to structured learning. Table 3 provides a reasonable starting list of potential partner organizations, though they do not represent the entire universe of viable strategic foresight partners for OSH. The Federal Foresight Community of Interest (FFCOI), for example, was established in 2013 as an interagency organization to provide a forum for federal agencies in the United States interested in applying foresight [98]. Though many of FFCOI's participating agencies may not practice foresight in the OSH space, FFCOI is

well-positioned to provide OSH with insights on foresight best practices and strategies for building and sustaining a connected community of foresight practitioners.

The future may be largely unpredictable, but it does not have to be a complete surprise when it arrives. Clues of what the future may hold exist today in the form of weak and early signals of change. The practice of strategic foresight empowers individuals and organizations to leverage those signals to gain realistic insights into the future and begin developing plans and options to move forward in preferred directions. Applied to OSH, strategic foresight may help inform the development of proactive systems to prevent injury, illness, death, and disability and promote worker well-being across the working life continuum for generations of future workers.

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References

1. Amick, B.; McLeod, C.; Bültmann, U. Labor markets and health: An integrated life course perspective. *Scand. J. Work. Environ. Health* **2016**, *42*, 346–353. [CrossRef] [PubMed]
2. Chia, G.; Lim, S.; Sng, G.; Hwand, Y.-F.J.; Chia, K. Need for a new workplaces safety and health (WSH) strategy for the Fourth Industrial Revolution. *Am. J. Ind. Med.* **2019**, *62*, 275–281. [CrossRef]
3. International Labour Organization International Training Centre. The Future of Work Centenary Initiative. Available online: https://www.ilo.org/wcmsp5/groups/public/---ed_norm/---relconf/documents/meetingdocument/wcms_369026.pdf (accessed on 20 February 2021).
4. Peckham, T.; Baker, M.; JE, C.; Kaufman, J.; Seixas, N. Creating a future for occupational health. *Ann. Work. Expo. Health* **2017**, *61*, 3–15. [CrossRef]
5. Schulte, P.; Delclos, G.; Felknor, S.; Chosewood, L. Toward an expanded focus for occupational safety and health: A commentary. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4946. [CrossRef] [PubMed]
6. Tamers, S.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
7. The World Bank. The World Development Report (WDR) 2019: The Changing Nature of Work. Available online: https://www.worldbank.org/en/publication/wdr2019 (accessed on 12 May 2020).
8. Katz, L.; Krueger, A. The rise and nature of alternative work arrangements in the United States, 1995–2015. *Int. Labor Rev.* **2018**, *72*, 382–416. [CrossRef]
9. Cummings, K.; Kreiss, K. Contingent workers and contingent health: Risks of a modern economy. *J. Am. Med. Assoc.* **2008**, *299*, 448–450. [CrossRef] [PubMed]
10. Howard, J. Nonstandard work arrangements and worker health and safety. *Am. J. Ind. Med.* **2017**, *60*, 1–10. [CrossRef]
11. Eurofound & the International Labour Office. Working Anytime, Anywhere: The Effects on the World of Work. Available online: http://eurofound.link/ef1658 (accessed on 4 June 2020).
12. Arntz, M.; Gregory, T.; Zierahn, U. The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis. OECD Social, Employment and Migration Working Papers No. 189. Available online: https://www.oecd-ilibrary.org/social-issues-migration-health/the-risk-of-automation-for-jobs-in-oecd-countries_5jlz9h56dvq7-en (accessed on 1 March 2021).

13. Eichhorst, W. Labor Market Institutions and the Future of Work: Good jobs for all? IZA Policy Paper, No. 122, Institute of Labor Economics. Available online: https://www.econstor.eu/bitstream/10419/162533/1/87818922X.pdf (accessed on 20 February 2021).
14. Bureau of Labor Statistics (BLS). Women in the Workforce. Available online: https://www.bls.gov/opub/reports/womens-databook/2019/home.htm (accessed on 12 May 2020).
15. Dodgen, D.; Donato, D.; Kelly, N.; La Greca, A.; Morganstein, J.; Reser, J.; Ruzek, J.; Schweitzer, S.; Shimamoto, M.; Thigpen, K.; et al. Ch. 8: Mental Health and Well-Being. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. pp. 217–246. Available online: https://health2016.globalchange.gov/mental-health-and-well-being (accessed on 19 March 2021).
16. Hayutin, A.; Beals, M.; Borges, E. The Aging U.S. Workforce: A Chartbook of Demographic Shifts. Available online: http://longevity3.stanford.edu/wp-content/uploads/2014/01/The_Aging_U.S.-Workforce.pdf (accessed on 1 March 2021).
17. Toosi, M. Projections of the Labor Force to 2050: A Visual Essay. Available online: https://www.bls.gov/opub/mlr/2012/10/art1full.pdf (accessed on 1 March 2021).
18. Budiman, A. Key Findings about U.S. Immigrants. Pew Research Center FactTank. Available online: https://www.pewresearch.org/fact-tank/2020/08/20/key-findings-about-u-s-immigrants/ (accessed on 23 March 2021).
19. Blit, J.; Amand, S.; Wajda, J. Automation and the Future of Work: Scenarios and Policy Options. CIGI Paper No. 174. Available online: https://www.cigionline.org/publications/automation-and-future-work-scenarios-and-policy-options?utm_source=twitter&utm_medium=social&utm_campaign=imf-fall-18 (accessed on 23 February 2021).
20. Sinclair, R.; Allen, T.; Barber, L.; Bergman, M.; Britt, T.; Butler, A.; Ford, M.; Hammer, L.; Kath, L.; Probst, T.; et al. Occupational health science in the time of COVID-19: Now more than ever. *Occup. Health Sci.* **2020**, *4*, 1–22. [CrossRef]
21. Felknor, S.; Streit, J.; Chosewood, L.; McDaniel, M.; Schulte, P.; Delclos, G. How will the future of work shape the OSH professional of the future? A workshop summary. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7154. [CrossRef]
22. Felknor, S.; Streit, J.; Chosewood, L.; McDaniel, M.; Schulte, P.; Delclos, G. How will the future of work shape OSH research and practice? A workshop summary. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5696. [CrossRef]
23. Tamers, S.; Chosewood, L.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.-C. Total Worker Health® 2014–2018: The novel approach to worker safety, health, and well-being evolves. *Int. J. Environ. Res. Public Health* **2019**, *16*, 321. [CrossRef] [PubMed]
24. Iden, J.; Methlie, L.; Christensen, G. The nature of strategic foresight research: A systematic literature review. *Technol. Forecast. Soc. Chang.* **2017**, *116*, 87–97. [CrossRef]
25. Voros, J. A Primer on Futures Studies, Foresight, and the Use of Scenarios. *Prospect. Foresight Bull.* **2001**, *6*, 1–8. Available online: https://foresightinternational.com.au/wp-content/uploads/2020/03/Voros-Primer-on-FS-2001-Final.pdf (accessed on 15 April 2021).
26. Bishop, P.; Hines, A. *Teaching about the Future*; Palgrave Macmillan: New York, NY, USA, 2012.
27. Hines, A. Strategic foresight: The state of the art. *Futurist* **2006**, *40*, 18–21.
28. Hines, A.; Bishop, P. *Thinking about the Future: Guidelines for Strategic Foresight*, 2nd ed.; Hinesight: Houston, TX, USA, 2015.
29. Institute for the Future (IFTF). Forecasts + Perspectives. Available online: https://www.iftf.org/what-we-do/forecasts/ (accessed on 21 March 2021).
30. Association of Governmental Risk Pools (AGRiP). Framing the Future: A Guide to Strategic Foresight. Available online: https://www.agrip.org/intelligence/strategic-foresight (accessed on 15 April 2021).
31. Ramirez, R.; Wilkinson, A. *Strategic Reframing: The Oxford Scenario Planning Approach*; Oxford University Press: Oxford, UK, 2016.
32. Wilkinson, A. Strategic Foresight Primer. Available online: https://cor.europa.eu/Documents/Migrated/Events/EPSC_strategic_foresight_primer.pdf (accessed on 4 May 2021).
33. Institute for the Future (IFTF). IFTF Foresight Essentials. Available online: https://www.iftf.org/foresightessentials/ (accessed on 22 April 2021).
34. Platform, F. Collaborative Foresight for Decision-Makers. Available online: https://www.futuresplatform.com/ (accessed on 22 April 2021).
35. Keenan, M.; Popper, R. Comparing foresight "style" in six world regions. *Foresight* **2008**, *10*, 16–38. [CrossRef]
36. Dewar, J.; Builder, C.; Hix, W.; Levin, M. *Assumption-Based Planning: A Planning Tool for Very Uncertain Times*; RAND: Santa Monica, CA, USA, 1993.
37. Ecola, L.; Popper, S.; Silberglitt, R.; Fraade-Blanar, L. *The Road to Zero: A Vision for Achieving Zero Roadway Deaths by 2050*; RAND Corporation: Santa Monica, CA, USA, 2018.
38. Da Costa, O.; Warnke, P.; Cagnin, C.; Scapolo, F. The impact of foresight on policy-making: Insights from the FORLEAN mutual learning process. *Technol. Anal. Strateg. Manag.* **2008**, *20*, 369–387. [CrossRef]
39. Bishop, P.; Hines, A.; Collins, T. The current state of scenario development: An overview of techniques. *Foresight* **2007**, *9*, 5–25. [CrossRef]
40. Voros, J. A generic foresight process framework. *Foresight* **2003**, *5*, 10–21. [CrossRef]
41. Dator, J. Alternative futures at the Manoa School. *J. Futures Stud.* **2009**, *14*, 1–18.

42. Royal Dutch Shell. Scenarios: An Explorer's Guide. Available online: https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/new-lenses-on-the-future/earlier-scenarios/_jcr_content/par/expandablelist/expandablesection_842430368.stream/1519772592201/f5b043e97972e369db4382a38434d4dc2b1e8bc4/shell-scenarios-explorersguide.pdf (accessed on 21 March 2021).
43. Curry, A.; Hodgson, A. Seeing in multiple horizons: Connecting futures to strategy. *J. Futures Stud.* **2008**, *13*, 1–20.
44. International Labour Organization; ITC Limited Foresight Toolkit. Three Horizons Framework. Available online: http://training.itcilo.org/delta/Foresight/3-Horizons.pdf (accessed on 20 October 2020).
45. Rhydderch, A. Scenario Building: The 2 × 2 Matrix Technique. Prospective and Strategic Foresight Toolbox. Available online: https://www.futuribles.com/en/group/prospective-and-strategic-foresight-toolbox/document/scenario-building-the-2x2-matrix-technique/ (accessed on 23 March 2021).
46. Mietzner, D.; Reger, G. Advantages and disadvantages of scenario approaches for strategic foresight. *Int. J. Technol. Intell. Plan.* **2005**, *1*, 220–239. [CrossRef]
47. Popper, R. Mapping Foresight: Revealing how Europe and Other World Regions Navigate into the Future. European Foresight Monitoring Network Report EUR 24041 EN. Available online: https://rafaelpopper.files.wordpress.com/2010/04/efmn-mapping-foresight_en.pdf (accessed on 20 March 2021).
48. Amer, M.; Daim, T.; Jetter, A. A review of scenario planning. *Futures* **2013**, *46*, 23–40. [CrossRef]
49. Van Notten, P.; Rotmans, J.; van Asselt, M.; Rothma, D. An updated scenario typology. *Futures* **2003**, *35*, 423–443. [CrossRef]
50. Schoemaker, P. Scenario planning—A tool for strategic thinking. *Sloan Manag. Rev.* **1995**, *36*, 25–40.
51. Curry, A.; Schultz, W. Roads less travelled: Different methods, different futures. *J. Futures Stud.* **2009**, *13*, 35–60.
52. Sarpong, D.; Maclean, M.; Alexander, E. Organizing strategic foresight: A contextual practice of 'way finding'. *Futures* **2013**, *53*, 33–41. [CrossRef]
53. Wilkinson, A. Using strategic foresight methods to anticipate and prepare for the jobs-scarce economy. *Eur. J. Futures Res.* **2016**, *4*, 12. [CrossRef]
54. Kaplan, S.; Orlikowski, W. Beyond forecasting: Creating new strategic narratives. *MIT Sloan Manag. Rev.* **2014**, *56*, 23–28.
55. Fergnani, A. The future persona: A futures method to let your scenarios come to life. *Foresight* **2019**, *21*, 445–466. [CrossRef]
56. Bradfield, R.; Wright, G.; Burt, G.; Cairns, G.; Van Der Heijden, K. The origins and evolution of scenario techniques in long range business planning. *Futures* **2005**, *37*, 795–812. [CrossRef]
57. Rhisiart, M.; Miller, R.; Brooks, S. Learning to use the future: Developing foresight capabilities through scenario processes. *Technol. Forecast. Soc. Chang.* **2015**, *101*, 124–133. [CrossRef]
58. Rohrbeck, R.; Battistella, C.; Huizingh, E. Corporate foresight: An emerging field with a rich tradition. *Technol. Forecast. Soc. Chang.* **2015**, *101*, 1–9. [CrossRef]
59. Schoemaker, P. Multiple scenario development: Its conceptual and behavioral foundation. *Strateg. Manag. J.* **1993**, *14*, 193–213. [CrossRef]
60. Roubelat, F. Scenario planning as a networking process. *Technol. Forecast. Soc. Chang.* **2000**, *65*, 99–112. [CrossRef]
61. Wack, P. Scenarios: Unchartered waters ahead. *Harv. Bus. Rev.* **1985**, *63*, 72–89.
62. Schwartz, P. *The Art of the Long View: Planning for the Future in an Uncertain World*; Currency Doubleday: New York, NY, USA, 1996.
63. Dreyer, I.; Stang, G. *Foresight in Governments—Practices and Trends around the World*; European Union Institute for Security Studies: Paris, France, 2013; Available online: https://core.ac.uk/display/30676012?utm_source=pdf&utm_medium=banner&utm_campaign=pdf-decoration-v1 (accessed on 21 March 2021).
64. Hammoud, M.; Nash, D. What corporations do with foresight. *Eur. J. Futures Res.* **2014**, *2*, 42–62. [CrossRef]
65. Institute for Futures Research. NEDLAC Futures of Work in South Africa. Available online: http://www.foresightfordevelopment.org/library/54/1466-nedlac-future-of-work-in-south-africa (accessed on 16 April 2021).
66. Ajman Department of Economic Development (DED). Ajman DED Launches Future Foresight Initiatives. Available online: https://www.ajmanded.ae/en/30dec2020.aspx (accessed on 5 March 2021).
67. Loveridge, D. *Foresight: The Art and Science of Anticipating the Future*; Routledge: New York, NY, USA, 2009.
68. Schulte, P.; Streit, J.; Sheriff, F.; Delclos, G.; Felknor, S.; Tamers, S.; Fendinger, S.; Grosch, J.; Sala, R. Potential scenarios and hazards in the work of the future: A systematic review of the peer-reviewed and gray literatures. *Ann. Work Expo. Health* **2020**, *64*, 786–816. [CrossRef]
69. Millett, S. The future of scenarios: Challenges and opportunities. *Strategy Leadersh.* **2003**, *31*, 16–24. [CrossRef]
70. Stacey, N.; Ellwood, P.; Bradbrook, S.; Reynolds, J.; Williams, H.; Lye, D. Foresight on New and Emerging Occupational Safety and Health Risks Associated with Digitalization by 2025. Available online: https://osha.europa.eu/en/publications/foresight-new-and-emerging-occupational-safety-and-health-risks-associated/view (accessed on 6 November 2019).
71. Brown, J.; Gosling, T.; Sethi, B.; Sheppard, B.; Stubbings, C.; Sviokla, J.; Williams, J.; Zarubina, D.; Fisher, L. The Workforce of the Future: The Competing Forces Shaping 2030. Available online: https://www.pwc.com/gx/en/services/people-organisation/workforce-of-the-future/workforce-of-the-future-the-competing-forces-shaping-2030-pwc.pdf (accessed on 5 March 2021).
72. World Economic Forum (WEF). Eight Futures of Work: Scenarios and Their Implications. Available online: http://www3.weforum.org/docs/WEF_FOW_Eight_Futures.pdf (accessed on 5 March 2021).
73. Hines, A. Evolution of framework foresight. *Foresight* **2020**, *22*, 643–651. [CrossRef]

74. Dator, J. The futures of cultures and cultures of the future. In *Perspectives on Cross-Cultural Psychology*; Marsella, A., Ciborowski, T., Tharp, R., Eds.; Academic Press: New York, NY, USA, 1979.
75. Hines, A. Fun with scenario archetypes. Hinesight: For Foresight, Use Hinesight. 2014. Available online: https://www.andyhinesight.com/forecasting/fun-with-scenario-archetypes/ (accessed on 4 May 2021).
76. Institute for the Future (IFTF). *Foresight Essentials: IFTF Scenario Building Training Course*; Institute for the Future: Palo Alto, CA, USA, 2021.
77. Glenn, J. The Milliennium Project Team. Work/Technology 2050: Scenarios and Actions. Available online: http://www.millennium-project.org/projects/workshops-on-future-of-worktechnology-2050-scenarios/ (accessed on 5 March 2021).
78. Glenn, J.; Florescu, E. The Millennium Project Team. State of the Future v.19.1. Available online: http://www.millennium-project.org/publications-2-3/#sof2015-16 (accessed on 27 March 2021).
79. Tapinos, E. Perceived environmental uncertainty in scenario planning. *Futures* **2012**, *44*, 338–345. [CrossRef]
80. Institute for the Future (IFTF). *IFTF Alternative Futures Scenario Toolkit: Tools for Making Choices in Uncertain Times*; IFTF: Palo Alto, CA, USA, 2021.
81. Osoba, O.; Welser, W. The Risks of Artificial Intelligence to Security and the Future of Work. Available online: https://www.rand.org/content/dam/rand/pubs/perspectives/PE200/PE237/RAND_PE237.pdf (accessed on 23 February 2021).
82. Rhisiart, M.; Störmer, E.; Daheim, C. From foresight to impact? The 2030 Future of Work scenarios. *Technol. Forecast. Soc. Chang.* **2017**, *124*, 203–213. [CrossRef]
83. Abdychev, A.; Alonso, C.; Alper, E.; Desruelle, D.; Kothari, S.; Liu, Y.; Perinet, M.; Rehman, S.; Schimmelpfennig, A.; Sharma, P. The Future of Work in Sub-Saharan Africa. Available online: https://www.imf.org/en/Publications/Departmental-Papers-Policy-Papers/Issues/2018/12/14/The-Future-of-Work-in-Sub-Saharan-Africa-46333 (accessed on 30 January 2021).
84. Münch, C.; von der Gracht, H.A. A bibliometric review of scientific theory in futures and foresight: A commentary on Fergnani and Chermack 2021. *Futures Foresight Sci.* **2021**, 1–9. [CrossRef]
85. Hines, A.; Bishop, P. Framework foresight: Exploring futures the Houston way. *Futures* **2013**, *51*, 31–49. [CrossRef]
86. Hines, A. Strategic Foresight, Training seminar presented to the National Institute for Occupational Safety and Health. Online presentation, 14–18 September 2020.
87. Börjeson, L.; Höjer, M.; Dreborg, K.-H.; Ekvall, T.; Finnveden, G. Scenario types and techniques: Towards a user's guide. *Futures* **2006**, *38*, 723–739. [CrossRef]
88. Balliester, T.; Elsheikhi, A. The Future of Work: A Literature Review. Working Paper No. 29. Available online: https://www.ilo.org/global/research/publications/working-papers/WCMS_625866/lang--en/index.htm (accessed on 27 August 2019).
89. Rohrbeck, R.; Schwarz, J. The value contribution of strategic foresight: Insights from an empirical study of large European companies. *Technol. Forecast. Soc. Chang.* **2013**, *80*, 1593–1606. [CrossRef]
90. National Institute for Occupational Safety and Health (NIOSH). NIOSH Program Portfolio. Available online: https://www.cdc.gov/niosh/programs/default.html (accessed on 22 April 2021).
91. Hines, A.; Gary, J.; Daheim, C.; van Der Laan, L. Building foresight capacity: Toward a Foresight Competency Model. *World Futures Rev.* **2017**, *9*, 123–141. [CrossRef]
92. University of Houston. Professional Certificate in Foresight. Available online: https://www.uh.edu/technology/programs/professional/fore/ (accessed on 22 April 2021).
93. University of Oxford. Oxford Scenarios Programme. Available online: https://www.sbs.ox.ac.uk/programmes/executive-education/campus-open-programmes/oxford-scenarios-programme (accessed on 22 April 2021).
94. Copenhagen Institute for Futures Studies. Applied Strategic Foresight (Live-Online). Available online: https://cifs.dk/calendar/applied-strategic-foresight/ (accessed on 28 April 2021).
95. Federal Foresight Community of Interest (FFCOI). Presentations. Available online: https://www.ffcoi.org/presentations/ (accessed on 22 April 2021).
96. United Nations Development Programme. *Foresight Manual: Empowered Futures for the 2030 Agenda*. Available online: https://www.undp.org/content/dam/undp/library/capacity-development/English/Singapore%20Centre/UNDP_ForesightManual_2018.pdf (accessed on 22 April 2021).
97. Policy Horizons Canada. Foresight Training Modules. Available online: https://horizons.gc.ca/en/resources/ (accessed on 22 April 2021).
98. Federal Foresight Community of Interest (FFCOI). Federal Foresight Community of Interest. Available online: www.ffcoi.org/ (accessed on 31 January 2021).

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Article

Development and Implementation of a Total Worker Health® Mentoring Program in a Correctional Workforce

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Abstract: Correctional officers (COs) are exposed to a number of occupational stressors, and their health declines early in their job tenure. Interventions designed to prevent early decline in CO health are limited. This article describes the development, implementation, and evaluation of a one-year peer health mentoring program (HMP) guided by Total Worker Health® principles and using a participatory action research to collectively address worker safety, health, and well-being of newly hired COs. The HMP aimed to provide new COs with emotional and tangible forms of support during their first year of employment, including peer coaching to prevent early decline in physical fitness and health. The development and implementation of the HMP occurred across five main steps: (1) participatory design focus groups with key stakeholders; (2) adaptation of an existing mentoring handbook and training methods; (3) development of mentor–mentee recruitment criteria and assignment; (4) designing assessment tools; and (5) the initiation of a mentor oversight committee consisting of union leadership, corrections management, and research staff. Correctional employee engagement in the design and implementation process proved to be efficacious in the implementation and adaptation of the program by staff. Support for the HMP remained high as program evaluation efforts continued.

Keywords: total worker health; correctional workforce; health mentoring; workplace wellness; occupational safety

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1. Introduction

Correctional officers (COs) are front-line employees who work in prisons and jails and are exposed to many unique risks that can jeopardize their safety and well-being [1–3]. COs have one of the poorest health profiles of any public safety occupation, and their health declines early in their job tenure [1,4]. CO life expectancy is also affected by job-related stressors and is below the national average (59 versus 75, respectively) [5]. Working as a CO involves extended and irregular shift work [6,7], demanding interpersonal interactions, and repeated exposure to verbal and physical trauma [8,9]. Responses to stressors experienced by COs on the job can spill over to their lives outside of work and can be a source of work–family conflict [10,11]. If COs do not develop healthy coping behaviors early in their careers, the demands of their work can have long-term adverse effects on their health and overall well-being [12]. However, interventions designed to help protect and promote CO health and well-being in the early stages of COs' careers are scarce [1,13,14]. Furthermore, because the risks to COs are widespread and, therefore, systemic, an individualized psychological approach is likely to be incomplete in addressing the root causes of poor health [10].

Health Improvement Through Employee Control (HITEC) II, currently in its third phase, was a partnership with the Department of Correction (DOC) in a Northeastern state that was formed to develop, implement, and evaluate interventions intended to improve the health, safety, and well-being of correctional employees [1,4]. The Total Worker Health® initiative of the National Institute for Occupational Safety and Health (NIOSH) recognizes work as a social determinant of health and aims to protect the safety and health of workers, and advance their well-being by creating safer and healthier work [15]. HITEC II used a participatory action research (PAR) approach that engaged front-line workers in identifying and addressing health issues through their direct involvement in the design, implementation, and evaluation of interventions specific to their health and safety needs [13]. Further, the HITEC II approach is consistent with Total Worker Health principles and practices because interventions are designed to address risks arising from both the physical and psychosocial work environment, and risks from outside of the workplace [1,2].

In a preliminary study of 326 COs conducted in 2008, HITEC research staff found that CO health declines rapidly early in work tenure [1]. Despite being relatively young with a mean age of 41 (SD = 7.2) years, the population sampled was in relatively poor health. Eighty-five percent (85%) were overweight or obese (BMI of >30); 35% were pre-hypertensive and 56% were hypertensive, and 31% reported symptoms of clinical depression [1,2]. These observations emphasize the need for preventive workplace health practices to improve physical and psychosocial health of COs early in their career.

In the past decade, the public safety sector has applied and recommended peer mentoring to facilitate an easier transition for new recruits on the job [16,17]. Through peer mentoring, new COs can learn to anticipate, identify, and manage the health risks related to their jobs from experienced co-workers. Peer mentoring can also help these new recruits handle risks that arise from the physically dangerous aspects of corrections work, which can have long-term health consequences for employees [18]. Additionally, mentees with high-quality traditional mentoring relationships show a more favorable level of organizational commitment than mentees with poor or fair quality relationships [19–21]. However, there is a lack of evidence on health peer mentoring programs in general, and specifically within corrections.

Recognizing the potential decline of CO health during the first years of employment, HITEC II research staff partnered with union leadership, line-level staff, and managers in the DOC in the development, implementation, and initial assessment of a one-year peer-to-peer health mentoring program (HMP) for newly hired COs (newly hired COs who are receiving training are also known as cadets) using a Total Worker Health participatory approach. The idea of developing a HMP came directly from the three regional union leaders representing line-level staff. Union leaders were concerned about the health of their members and recognized that newly hired COs may be less resistant to on-the-job training and preventative health programs, compared to more tenured staff.

The HMP concept can be contrasted with traditional workplace mentoring programs that largely focus on supervisors guiding or enhancing junior employees' (mentees) personal and career development, where there is a large gap between short-term on-the-job mentoring and later selection for eventual promotion [22]. Despite these programmatic differences, there is ample evidence that employees who receive traditional supervisor or senior employee-centered workplace mentoring benefit in terms of confidence on the job, satisfaction with their jobs, higher incomes, and better job retention [23–25].

The main goals of the HMP were to help newly hired COs develop positive health behaviors, and to provide them with peer coaching on health topics to prevent early decline in physical fitness and promote healthy eating, stress management, and work–family balance. In this article, we describe the five steps that were used to design and implement the HMP.

2. Methods

The HMP was developed in five major steps (design, adaptation, recruitment, assessment, oversight), as detailed below. The overall process and design of the HMP is depicted in a logic model (Figure 1). The program was approved by the university institutional review board.

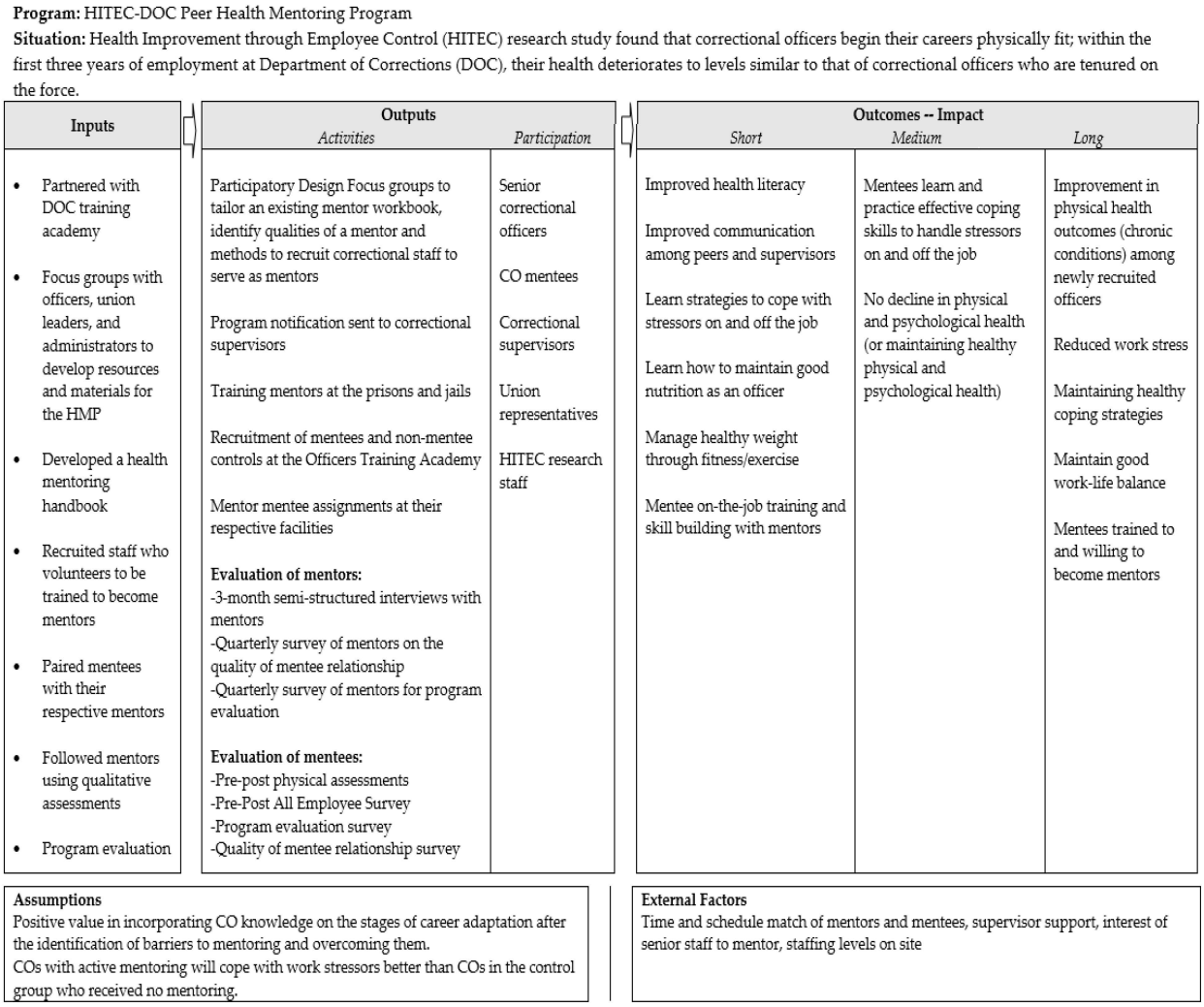


Figure 1. Logic model depicting the process of the Health Mentoring Program (HMP) for newly hired correctional officers (COs).

A core planning group met regularly during the development of the HMP (approximately a total of six meetings per month) and consisted of research staff and union presidents for line-level correctional staff and some of their designees. The meetings focused on the development of the mentoring program and review of draft materials. Additionally, a series of participatory design focus groups were organized with correctional officers who potentially could become mentors. The participatory design focus groups were conducted differently than conventional focus groups and were used to inform ongoing design and development of the HMP and associated materials. Summary findings of suggestions from these participatory focus groups were immediately reported back to the core planning group by research staff in order to inform ongoing program design efforts.

3. Results

The following results highlight the process of development and implementation of the HMP, which occurred across the following five main steps:

Step 1. Designing the HMP through Participatory Design Focus Groups.

In line with PAR techniques, the participatory design focus groups provided the means for engaging DOC staff as equal partners in all aspects of program design and implementation [13,26,27]. A guide to the participatory design focus groups was developed based on findings from our previous study of health issues and concerns among corrections workers at two prisons in the Northeast [2]. This guide was used as a reference point in the development of the HMP. More specifically, focus group participants were asked to provide input regarding the following aspects of HMP design: setting program goals; qualities of an effective mentor; salutogenic activities that would strengthen mentor participation [28]; adaptation of an existing mentor workbook and training program; creation of mentor recruitment criteria and a recruitment protocol; formulation of a data collection plan on mentoring activities and on mentee outcomes; and assignment of a mentor oversight committee.

Focus group participants were chosen based on their tenure and rank at DOC. Specifically, participants had to have at least 5 years on the force and prior experience in training newly hired officers on the job. One participatory design focus group consisted of members of the supervisory staff (captains and lieutenants) and two participatory design focus groups consisted of COs, representing two of the three union locals in the state. Participatory design focus groups met at local union offices; 23 officers and five captains and lieutenants participated.

Participatory Design Focus Group Findings: There were differences between the groups in their recommended weighting of experience and personal qualities of prospective mentors, but there were also noted differences of this weighting among members of each participatory design focus group. For example, some considered interpersonal qualities to be more important than technical skills in prospective mentors. The interpersonal skills identified as significant were as follows: *someone to whom one can speak freely, someone who sets a good example, and someone who demonstrates good work quality and good communication skills*. Confidence was expressed among all participatory design focus groups that a well-conceived mentor training program could be developed and sustained. They also felt that the training should be jointly designed with the research team, COs, and Training Academy personnel (the Training Academy has a dedicated site for training newly hired COs and also for providing ongoing training within the DOC).

Although all such ideas gathered in the participatory design focus groups were carefully considered, some of the ideas, although desirable, would have faced structural obstacles if implemented. For example, there was a strong desire for all mentor training to occur at the Training Academy, and for mentors to meet each other monthly in order to share the knowledge gained. However, these ideas proved infeasible due to the geographic dispersion of the correctional facilities and staffing limitations for coverage of those who would be meeting. The participatory design focus group members also recommended matching the gender of mentor and mentee because of the specific challenges to women in the male-dominated workforce but this was not always possible. One unforeseen barrier identified by the participatory design focus groups involved the tenure requirement for mentors and how this would affect shift alignment. In the participatory design focus groups, it was contended that to be a mentor, a CO needed at least 7 years of tenure and a disciplinary record that was currently clear. It was argued that mentor/mentee pairs would not need to be limited to working the same hours, and that they could instead work on adjacent shifts and meet at shift change. However, the arrival of the first mentees revealed this was an unworkable plan when it became apparent that most new officers worked the third shift whereas officers with 7 years of tenure worked the first shift. The SWSC offered a solution to this problem, which was to reduce the tenure requirement to 3 years, allowing for more within-shift mentoring to occur. One principle that could not be similarly compromised by the SWSC was the provision that mentor supervision would be handled by line-level COs, rather than supervisory staff. An important participatory design focus group recommendation was that, although supervisory staff could participate in establishing formal mentor selection criteria, the actual selection of mentors needed to fall

under the authority of the COs. One remaining concern that needed to be addressed was the possibility that a mentor might be contested by management because of an undisclosed disciplinary action that was pending, or investigation of potential criminal activity that was ongoing. As the program was further developed through participatory design over time, resolutions on such process issues were worked out within labor leadership meetings. A management oversight committee structure that was proposed and eventually adopted was found to be effectively preventive; it had yet to be convened to resolve a labor-management conflict at the time of this writing.

Step 2. Adaptation of an Existing Mentoring Handbook and Training.

Building on the information generated from the participatory design focus groups, the research team and frontline COs modified an existing career mentoring workbook from the Southern Region of the National Institute of Corrections Academy Division's Regionalization Project of 2002 [29]. The resulting new handbook, "Health Mentoring in the Correctional Workplace", consisted of eight sections, entitled: (1) What is Mentoring? (i.e., performance objectives, mentors vs. supervisors, resources, rules of mentoring); (2) Listening skills; (3) Basics of Mentoring (i.e., setting expectations, checking progress); (4) Giving Feedback (advice on ways to engage in regular exercise despite a challenging shift schedule, making healthy food choices at work and home, stress management, and addressing work-family issues); (5) Avoiding Pitfalls, such as conflict between individual health peer consultations and upper level administrative prerogatives; (6) Transitioning and Special Topics (i.e., mentoring and the generation gap; what mentors can do to prevent suicide; incivility); (7) Guidelines for Sessions; and (8) Forms.

The subsequent training of mentors by HITEC II research staff relied on several approaches tailored to adult learners. A presentation using Microsoft PowerPoint was developed that included both lessons from the Handbook and interactive scenarios and scripts. To accommodate agency stipulations on educational travel and release time, the training session was developed to last 1 to 1.5 h with provision for later in-person follow-up. Training delivery at a centralized facility was not feasible due to the geographic distribution of mentors across 18 facilities. Consequently, training sessions were scheduled at each correctional facility during normally assigned shifts. In addition to the Handbook, mentors received a binder that included the initial goal-setting contract, record keeping forms, and materials for quarterly evaluation of their mentee's personal development and career goals.

Step 3. Mentor–Mentee Recruitment Criteria and Assignment.

An important consensus recommendation from earlier participatory design focus groups was that supervisory staff could participate in establishing formal mentor selection criteria and in making mentor recommendations, but that the actual selection of mentors should fall under the authority of the COs. Focus group participants had also recommended that mentor supervision should not be handled by supervisory staff.

COs working in the cadets' destination facilities were first introduced to the HMP and the role of mentors at roll call, a regular event that is held at the start of all shifts. Research staff delivered a short presentation on the purpose of the HMP program, on the desired qualifications for mentorship, and on mentors' obligations and their expected time commitment. Interested prospective mentors signed up either with research staff, through a confidential channel at onsite locations, or via e-mail. Requirements to become a mentor included having worked as a CO for at least 5 years (later reduced to 3) and having remained in good disciplinary standing with the DOC. Because of the unexpectedly high level of interest on the part of mentor candidates, union leadership regularly reviewed individual qualifications, although rejection was uncommon.

To help avoid treatment bias and minimize the effects of a wide range of confounding variables, successive cadet classes were recruited into either the Personalized Follow-up Program (PFP) as the mentored group, or into the Standard Follow-up Program (SFP) as the non-mentored control group. Those in the SFP received conventional on-the-job training (OJT) that all new cadets receive upon transfer to a facility. In the project years 2013–2014, there were five classes matriculating at the Officers' Training Academy, the

inception point for new officers. Three of these classes were assigned to the PFP condition, and two were assigned to the SFP condition. All cadets in each class were invited to participate in the study, as either mentees or controls depending on the inception class, or to decline the invitation without consequence. Those choosing to participate were consented into the study.

Among 406 eligible cadets in the PFP classes, 183 (45.1%) elected to participate in the study. Thirteen corrections facilities within the state had mentors and mentees in the HMP (Table 1). Four facilities receiving the fewest number of mentees are combined in Table 1 because there were few mentor–mentee pairs (n = 11).

Table 1. Number and percent of mentees by location, and mentors who volunteered.

Location	Mentees		Mentors	
	Number	Percent	Number	Percent
A	30	16.4%	19	18.1%
B	17	9.3	10	9.5
C	14	7.6	7	6.7
D	23	12.5	14	13.3
E	19	10.4	12	11.4
F	18	9.8	12	11.4
G	7	3.8	2	1.9
H	24	13.1	10	9.5
I	20	10.9	8	7.6
All others (n = 4)	11	6.0	11	10.5
Total	183		105	

Participants completed the baseline survey and physical assessment. The ratio of mentors to mentees ranged between 1:1 and 1:3. The majority of mentees were male (76.4%), which was representative in this working population of officers. The results from the surveys and physical assessments at baseline and follow-ups are presented in a separate article reporting on the efficacy of the program [30].

Mentees were assigned to facilities after their academy-based orientation and training was completed. Their orientation and training included a brief internship placement at a facility that may have been different from their final (destination) facility. Research staff assigned mentors to each mentee following their graduation from the training academy and being posted at their destination facility. Mentors and mentees working the same shifts were paired to allow and optimize scheduled meetings. Supervisors at the designated facilities provided relief time for these on-site mentor–mentee meetings. Following mentor–mentee assignments, study staff conducted follow-ups, usually one week later, to ensure that initial contact between mentors and mentees had occurred successfully. These and subsequent follow-ups were initiated through reminder e-mails and phone calls with the mentors. Study staff also sent mentors a reminder e-mail that reiterated the importance of the record-keeping process for study integrity. Additionally, study staff visited each facility every three months to conduct a scheduled follow-up with the mentors that included refresher training with review of the existing materials from the initial training. To support further communications and provide technical assistance, there was also ongoing phone and internet access to the study team that was made available throughout this period.

Step 4. Health Mentor Program Assessment.

At intake and at one-year post-assignment, all participants in both the PFP arm (mentored group, n = 183) and in the conventional SFP arm (non-mentored group, n = 86) completed a survey and were offered a brief physical exam on a voluntary basis. Based on the initial follow-up results, and previously existing studies on declining health of COs,

it was evident and necessary to evaluate the mentee outcomes after around 3–5 years of employment [1,3]. Accordingly, a long-term evaluation of mentee health outcomes was planned at the end of 5 years of their employment by repeating the physical assessment and survey measures among participants. The physical assessment consisted of height, weight, blood pressure, and body fat percentage using the bioelectrical impedance method [11,31]. Participants completed HITEC's All-Employee Survey (AES) at baseline and after at least one year of receiving health mentoring. This comprehensive survey is a generic CPH-NEW instrument that can be modified to particular conditions of employment [31]. It assesses safety, physical and mental health, and well-being, in addition to several job design and workplace factors [2,11]. The AES had already been adapted in 2008 for the corrections workforce and its results, as noted earlier, were influential to the mentoring project [1]. Participants completed a modified and shortened version of the AES at baseline because many of the job-specific domains in the AES would have been muted by the absence of prior employment at the DOC. Baseline surveys and examinations were completed at a single site, the Officers Training Academy. The follow-up surveys and physical examinations were conducted a year later at the participants' assigned facilities. The follow-up survey differed from its baseline predecessor because it now included employment-related questions modified for corrections, with some specific additions. Both groups also had access to newsletters and a website with health information tailored to corrections work.

The research staff held onsite quarterly meetings with mentors which lasted about 20–30 min. Semi-structured interview guides created by HITEC II research staff and vetted by the participatory design focus group participants were used to assess the quality of the mentor–mentee relationship. These semi-structured interviews with mentors were designed to collect information on mentoring progress, frequency, type of meetings (formal or informal), topics discussed, health goals, perceptions of mentoring, and barriers and facilitators of peer health mentoring. The quality of the mentor–mentee relationship, and the frequency and quality of mentoring, was also assessed with a survey with mentees during their evaluation at the end of the one-year HMP. The aim of the process was to evaluate the quality of relationship overlaps and discrepancies with dual source data.

Step 5. Mentoring Oversight Committee.

Two different groups, separated by chronology, were charged with oversight of the HMP. In the first 2 years of the program, the major impetus came from regular meetings with the bargaining unit presidents and their representatives. The HMP was one of two major projects generated by HITEC II, and a Study Wide Steering Committee (SWSC) which was in place from 2007, beginning with HITEC I [1]. The SWSC consisted of key stakeholders, such as the HITEC II research team, union leaders, and DOC administration (Director of Human Resources, Deputy Commissioner, and Commissioner). Because the SWSC was developed as an oversight platform for all HITEC-related work, and given its labor and management representation, it assumed oversite of the HMP once the program was established. The SWSC maintained final authority over HMP practices, assisting in implementation by scheduling mentoring time into the workday through coordinating with facility supervisors, and by scheduling times for focus groups, evaluation, surveys, and testing. Consistent with PAR principles, research activities and program activities were discussed, approved, and reviewed at SWSC meetings, which have occurred every 2–3 months over the past 10 years. By agreement, all evaluation results, once stripped of potential personal identifiers, were made available to the SWSC and participants in the mentoring program. This open programmatic review was meant to be consistent with the program's PAR principles and to support participatory design efforts, which are the hallmark of all CPH-NEW programs.

4. Discussion

Programs supporting mentor–mentee relationships, based on consensual health-related goals, are relatively novel in the occupational health literature [32], and rarer still in corrections. In this paper, the process used to design and implement an HMP

for newly hired COs is described. The HMP is distinguished by its year-long duration and its Total Worker Health emphasis on work life and well-being, going beyond job task familiarization.

Key to the development of this HMP were the two concepts that define CPH-NEW. These two concepts are PAR methods, based around active participation at the line level in program design and implementation efforts, and adherence to Total Worker Health® principles, which requires an integration of individual health with working conditions and work organization. PAR methods were used to actively engage union leadership, COs, and managers in the design and implementation of Total Worker Health interventions. The presumptive value of incorporating bottom-up workforce knowledge of the stages of adaptation and of pitfalls and barriers was implicit. Another presumption, also consistent with PAR principles, was that correctional employee-driven design and involvement offered a heightened potential for participation, effectiveness, and sustainability [13]. Given its basis in PAR methods and Total Worker Health principles, the HMP is innovative and demonstrates feasibility in future applications in corrections. The future of work should involve careful intervention designs that are specific to unique job settings. Extensive application of both PAR methods and Total Worker Health principles in the design of the HMP enabled the effective development of an intervention that is likely to positively affect COs, whose jobs pose multiple obstacles to health and are resistant to change.

Support for organizational change was maintained through the SWSC. The SWSC provided ongoing program oversight pertaining to allocation of compensated time for training, mentoring, and evaluation, and instructed supervisory staff in program accommodation. As noted, the SWSC had a normalizing function. It assumed the ad hoc introductory work performed by the bargaining unit presidents, the study team, and DOC administration, when the start-up phase was complete. This two-part maturation process grew naturally as the bargaining units pursued initial dominance of design and implementation. It was found that many of the predictions of conflict did not arise, even though the developmental process of the program was largely exclusive of supervisory representation. Whether or not a more direct preliminary action phase is a necessity will likely depend on local, rather than elemental, conditions. However, it is clear that the autonomous contributions of the line workforce, even if temporarily in isolation, are elemental.

More than a decade before the HMP, the DOC had introduced a more traditional but concerted mentoring program which was principally top-down in its implementation. It proved to be unsustainable. The HMP offered a different level of engagement in which line-level staff, union leaders, and DOC management worked together in program design and took responsibility for its continuity. The HMP within HITEC II could not have been, however, a purely bottom-up creation. Bargaining unit leadership is largely consumed in contractual affairs, and program management is a learned and selective skill. Moreover, the constraints over aligned scheduling, coverage, and compensation fall outside of bargaining unit jurisdiction. A high level of programmatic autonomy had been negotiated and maintained through the SWSC. Thus, there was always an institutional readiness to address critical barriers and promote engaged activity. Conversely, a purely line officer program is likely to fail because officers change facilities and have insufficient administrative experience and authority to manage a complex program such as the HMP. The ability of administrators and supervisors to flexibly facilitate, rather than direct, within defined parameters, is essential to program success and has required a sophisticated SWSC.

Additionally, the HMP was part of a research study requiring the support of HITEC II research staff. HITEC II research staff presented a research design and created a battery of process assessment tools that were vetted through the participatory design focus groups and the SWSC, but which would not have evolved without academic engagement. The goal of the HMP program was to help COs develop and maintain positive health behaviors; to provide COs with peer coaching around physical fitness; to prevent early decline in fitness; and to improve stress management. HITEC II research staff also provided support with training mentors, and baseline and follow-up assessments. Further, research staff

created a website for COs with customized health information, in addition to a newsletter that was circulated to various facilities on a quarterly basis. The HITEC II research team has placed its methods in the public domain with the development of a toolkit to guide peer mentoring in correctional workforce [33], but it must be conceded that the particular combination of academic, labor union, and administrative interplay is unusual [34]. The HMP with a Total Worker Health approach addresses many components of organizational design at work and beyond for a healthy future of work in corrections by training mentees on outside work factors such as work-family balance.

Certain adaptations also occurred during program implementation. These included changes to mentor eligibility criteria and supervisor involvement. Initially, eligible mentors were required to have had five years of experience or more on the job. However, it become evident early in the program initiation that interested tenured staff at various facilities were in the process of retirement, which resulted in scheduling problems. To increase the pool of mentors interested in the HMP, the eligibility criteria changed from five to three years' experience, and even less in some cases. It became clear that highly motivated younger officers were capable of superior performance. As the selection process matured, a more personalized approach to admission replaced rigid guidelines, in some cases. Additionally, younger, less tenured COs were considered to suffer from less burnout and could be expected to provide a more positive and healthy perspective on the job. In later program review, there was a realization that the process of development from engaged mentor to health and well-being advocate and champion was continuous, and in the long run may be constructed along continuous improvement lines.

During program design, the supervisors' role in program implementation was secondary to that of CO leadership. However, during implementation, supervisors played a key role in relieving mentees and mentors from their shift assignments in order for them to meet during work hours. Supervisors also helped recruit mentors, and their possible role in training mentors was also discussed by the SWSC. Ultimately, the supervisors developed their own health promotion programs for supervisors. The traditional division between supervisory and CO staff softened on issues involving health and well-being. The need for changes in program design for continuous improvement played a key role in determining the important function that the SWSC played, especially during implementation of the HMP.

It is also important to highlight some of the barriers that were overcome in the process of developing the mentoring program. First, there was a lack of precedent materials for a CO mentoring program. As such, it was necessary to bring all levels of correctional staff to work together in creating and formatting the training materials. Second, COs have limited formal administrative and/or organizational experience in conducting and evaluating programs. This necessitated union leadership and SWSC engagement, in addition to engagement of study staff to design and conduct this participatory program. Third, problems of vetting and confidentiality during the recruitment of mentors were handled with an elaborate mitigation process that was acceptable to the administration and the union, which initially followed the formal administration-union grievance practices. Over time, actual working relations softened these restrictions. Finally, barriers around varying shift and work slots between mentors and mentees were identified and addressed early during the design and implementation of the mentoring program. Considerations over scheduling meeting time and shift alignments of mentors and mentees were discussed at labor management to maximize the amount of time available for mentors and mentees to meet.

The HMP benefited from being introduced in the context of the ongoing HITEC II study that included efforts to compare two different means of engaging employees in the participatory design of Total Worker Health interventions [1]. Separate employee "design teams" were tested, one consisting of front-line corrections staff only, whereas the other was multi-level and included supervisors and managers. Both design teams engaged in the design and implementation of interventions to address a set of preselected health and wellness

issues [1]. The SWSC was formed during the initial phase of the HITEC study to oversee the design teams. Thus, the HMP from its inception could rely on a functioning oversight committee that was well versed and skilled in PAR. Based on these study experiences, CPH-NEW has developed a new toolkit to guide organizations interested in establishing an HMP [33]. Additional guidance on forming and maintaining a dedicated steering committee is available in the CPH-NEW Healthy Workplace Participatory Program Toolkit [35]. Organizations seeking to expand employee involvement in designing Total Worker Health interventions, including implementation of a peer health mentoring program or a Healthy Workplace Participatory Program, are now able to assess key program facilitators and obstacles prior to implementation with an Organizational Readiness Tool survey [36]. The Organizational Readiness Tool assesses organizational readiness for participatory Total Worker Health programs in the following eight domains: (1) Current safety/health/well-being programs; (2) Current organizational approaches to safety/health/well-being; (3) Resources available for safety/health/well-being; (4) Resources and readiness for change initiatives to improve safety/health/well-being; (5) Resources and readiness for use of teams in programmatic initiatives; (6) Teamwork; (7) Resources and readiness for employee participation; and (8) Management communication about safety/health/well-being. In addition to being used for pre-implementation planning, the ORT can be administered multiple times during program implementation to track the extent to which barriers and obstacles to implementation are being fully addressed [37].

Promoting employee efficacy in the design of Total Worker Health interventions and programs such as peer health mentoring has important implications for the future of work. With so many internal and external factors impacting present-day workplaces in ways that critically affect health, including COVID-19 and the accelerating pace of technological change, work organizations must not only respond quickly but also in a manner that draws upon expertise from all levels of their organization. Peer-to-peer programs have gained recognition in addressing job satisfaction and worker health [23,24,38]. However, to our knowledge, this is the first mentoring program focused on health that has been designed for newly hired COs using participatory methods. The empowerment of COs offered through this participatory program to improve the health and safety of their peers is an important progression in creating a healthy correctional workforce, beginning a process of changing correctional culture. Using an approach based on continuous and documented improvement opened the HMP to a long-term view of interventions in which successes, failures, and ongoing operations can be accommodated.

5. Conclusions

In the first wave of practice, the preparation proved to be effective because of its reach; nearly 100 mentors were trained, and 269 participants (mentees and controls) signed up and completed baseline testing. Evaluation findings of the HMP are discussed in a separate article within this Special Issue [30].

CO involvement in participatory design efforts can serve to overcome widespread resistance and distrust by COs towards preventive health and work programs. CO involvement could also be effective in alleviating the culture of reluctance by COs to share health and well-being issues of a confidential and personal nature with their peers/DOC staff. In addition to initial planning efforts with union leaders and corrections management, support for the HMP remained high as program evaluation efforts continued, suggesting the likelihood of program sustainability. HMP has shown promise as an intervention within the correctional sector; further evaluation is needed to demonstrate generalizability and adaptability of such programs across state lines and specific correctional settings (such as jails).

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Abbreviations

CO	Correctional Officer
HMP	Health Mentoring Program
SFP	Standard Follow-up Program
PFP	Personalized Follow-up Program
NIOSH	National Institute for Occupational Safety and Health
HITEC	Health Improvement Through Employee Control
CPH-NEW	Center for the Promotion of Health in the New England Workplace
PAR	participatory action research
DOC	Department of Correction
SWSC	Study-wide Steering Committee
OJT	On the Job Training

References

1. Cherniack, M.; Dussetschleger, J.; Dugan, A.; Farr, D.; Namazi, S.; El Ghaziri, M.; Henning, R. Participatory action research in corrections: The HITEC 2 program. *Appl. Ergon.* **2016**, *53*, 169–180. [CrossRef]
2. Morse, T.; Dussetschleger, J.; Warren, N.; Cherniack, M. Talking about health: Correction employees' assessments of obstacles to healthy living. *J. Occup. Environ. Med.* **2011**, *53*, 1037–1045. [CrossRef]
3. Warren, N.; Dussetschleger, J.; Punnett, L.; Cherniack, M.G. Musculoskeletal disorder symptoms in correction officers: Why do they increase rapidly with job tenure? *Hum. Factors* **2015**, *57*, 262–275. [CrossRef]
4. El Ghaziri, M.; Jaegers, L.A.; Monteiro, C.E.; Grubb, P.L.; Cherniack, M.G. Progress in Corrections Worker Health: The National Corrections Collaborative Utilizing a Total Worker Health® Strategy. *J. Occup. Environ. Med.* **2020**, *62*, 965–972. [CrossRef]
5. Cheek, F.E.; Miller MD, S. The experience of stress for correction officers: A double-bind theory of correctional stress. *J. Crim. Justice* **1983**, *11*, 105–120. [CrossRef]
6. Namazi, S.; Dugan, A.G.; Fortinsky, R.H.; Barnes-Farrell, J.; Coman, E.; El Ghaziri, M.; Cherniack, M.G. Examining a comprehensive model of work and family demands, work–family conflict, and depressive symptoms in a sample of correctional supervisors. *J. Occup. Environ. Med.* **2019**, *61*, 818–828. [CrossRef] [PubMed]
7. Swenson, D.X.; Waseleski, D.; Hartl, R. Shift work and correctional officers: Effects and strategies for adjustment. *J. Correct. Health Care* **2008**, *14*, 299–310. [CrossRef]
8. Spinaris, C.G.; Denhof, M.D.; Kellaway, J.A. Posttraumatic Stress Disorder in United States Corrections Professionals: Prevalence and Impact on Health and Functioning. Desert Waters Correctional Outreach; 2012; pp. 1–32. Available online: https://www.ojp.gov/ncjrs/virtual-library/abstracts/posttraumatic-stress-disorder-united-states-corrections (accessed on 17 August 2021).

9. Spinaris, C.; Denhof, M.; Morton, G. Impact of Traumatic Exposure on Corrections Professionals. White Paper National Institute of Corrections; 2013. Available online: https://info.nicic.gov/virt/sites/info.nicic.gov.virt/files/06Impact_of_Traumatic_Exposure.pdf (accessed on 17 August 2021).
10. Brower, J. *Correctional Officer Wellness and Safety Literature Review*; Office of Justice Programs, US Department of Justice: Washington, DC, USA, 2013. Available online: https://nicic.gov/correctional-officer-wellness-and-safety-literature-review (accessed on 5 May 2021).
11. Obidoa, C.; Reeves, D.; Warren, N.; Reisine, S.; Cherniack, M. Depression and work family conflict among corrections officers. *J. Occup. Environ. Med.* **2011**, *53*, 1294–1301. [CrossRef] [PubMed]
12. Finn, P. *Addressing Correctional Officer Stress: Programs and Strategies. Issues and Practices*; NCJ 183474; National Institute of Justice: Washington, DC, USA, 2000. Available online: https://www.ojp.gov/pdffiles1/nij/183474.pdf (accessed on 17 August 2021).
13. Dugan, A.G.; Farr, D.A.; Namazi, S.; Henning, R.A.; Wallace, K.N.; El Ghaziri, M.; Cherniack, M.G. Process evaluation of two participatory approaches: Implementing total worker health® interventions in a correctional workforce. *Am. J. Ind. Med.* **2016**, *59*, 897–918. [CrossRef] [PubMed]
14. Ferdik, F.V.; Smith, H. *CSR Incorporated & United States of America*; Correctional Officer Safety and Wellness Literature Synthesis: Washington, DC, USA, 2017. Available online: https://www.ncjrs.gov/pdffiles1/nij/250484.pdf (accessed on 17 August 2021).
15. The National Institute for Occupational Safety and Health (NIOSH). What Is Total Worker Health? 2018. Available online: https://www.cdc.gov/niosh/twh/totalhealth.html (accessed on 17 August 2021).
16. Morrison, E. Mentoring in Law Enforcement. The Bill Blackwood Law Enforcement Management Institute of Texas. 2014. Available online: https://shsu-ir.tdl.org/bitstream/handle/20.500.11875/1909/1512.pdf?sequence=1 (accessed on 5 August 2021).
17. Griffin, M.L.; Hogan, N.L.; Lambert, E.G. Career stage theory and turnover intent among correctional officers. *Crim. Justice Behav.* **2014**, *41*, 4–19. [CrossRef]
18. Arredondo, R.; Shumway, S.T.; Kimball, T.G.; Dersch, C.A.; Morelock, C.N.; Bryan, L. *Law Enforcement and Corrections Family Support: Development and Evaluation of a Stress Management Program for Officers and Their Spouses, Final Report*; Office of Justice Programs, National Institute of Justice, US Department of Justice: Washington, DC, USA, 2002. Available online: https://www.ojp.gov/pdffiles1/nij/grants/197900.pdf (accessed on 17 August 2021).
19. Donaldson, S.I.; Ensher, E.A.; Grant-Vallone, E.J. Longitudinal examination of mentoring relationships on organizational commitment and citizenship behavior. *J. Career Dev.* **2000**, *26*, 233–249. [CrossRef]
20. Whitaker, S. Mentoring beginning special education teachers and the relationship to attrition. *Except. Child.* **2000**, *66*, 546–566. [CrossRef]
21. Payne, S.C.; Huffman, A.H. A longitudinal examination of the influence of mentoring on organizational commitment and turnover. *Acad. Manag. J.* **2005**, *48*, 158–168. [CrossRef]
22. Kram, K.E.; Isabella, L.A. Mentoring alternatives: The role of peer relationships in career development. *Acad. Manag. J.* **1985**, *28*, 110–132. [CrossRef]
23. Eby, L.T.; Lockwood, A. Protégés' and mentors' reactions to participating in formal mentoring programs: A qualitative investigation. *J. Vocat. Behav.* **2005**, *67*, 441–458. [CrossRef]
24. Allen, T.D.; Eby, L.T.; Poteet, M.L.; Lentz, E.; Lima, L. Career benefits associated with mentoring for protégés: A meta-analysis. *J. Appl. Psychol.* **2004**, *89*, 127. [CrossRef] [PubMed]
25. Horner, D.K. Mentoring: Positively influencing job satisfaction and retention of new hire nurse practitioners. *Plast. Surg. Nurs.* **2017**, *37*, 7–22. [CrossRef] [PubMed]
26. McVicar, A.; Munn-Giddings, C.; Seebohm, P. Workplace stress interventions using participatory action research designs. *Int. J. Workplace Health Manag.* **2013**, *6*, 18–37. [CrossRef]
27. Rosskam, E. Using participatory action research methodology to improve worker health. In *Unhealthy Work*; Routledge: London, UK, 2018. [CrossRef]
28. Henning, R.A.; Zweber, Z.M.; Bizarro, A.M.; Bauerle, T.; Tubbs, D.C.; Reeves, D. The Application of salutogenesis to correctional officers in corrections settings. In *The Handbook of Salutogenesis*; Mittelmark, M.B., Sagy, S., Eriksson, M., Bauer, G.F., Pelikan, J.M., Lindstrom, B., Espnes, G.A., Eds.; Springer: Berlin/Heidelberg, Germany, 2016. [CrossRef]
29. Fricker, M.; Brown, A.; Simmons, L. Mentoring in the Corrections Workplace, A Self-Paced Workbook. The Southern Region of the National Institute of Corrections Academy Division's Regionalization Project. 2002. Available online: https://s3.amazonaws.com/static.nicic.gov/Library/018196.pdf (accessed on 20 May 2021).
30. Kotejoshyer, R.; Gilmer, D.O.; Namazi, S.; Farr, D.; Henning, R.A.; Cherniack, M. Impact of a Total Worker Health® Mentoring Program in a Correctional Workforce. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8436. [CrossRef]
31. Center for the Promotion of Health in the New England Workplace. Healthy Workplace Participatory Program All Employee Survey User Manual. 2014. Available online: https://www.uml.edu/docs/AES_manual_4-17-14_tcm18-147260.pdf (accessed on 20 May 2021).
32. Delisle, A.T.; Delisle, A.L.; Chaney, B.H.; Stopka, C.B.; Northcutt, W. Methods for fostering a community academic partnership in a firefighter community. *Am. J. Health Behav.* **2013**, *37*, 721–733. [CrossRef]

33. Introduction to Total Worker Health Mentoring Toolkit for the Corrections Workforce. Center for the Promotion of Health in the New England Workplace (CPH-NEW). Available online: https://www.uml.edu/Research/CPH-NEW/Resources/Corrections-Officer-Health-Resources/TWH-Mentoring-Toolkit-Corrections.aspx (accessed on 11 August 2021).
34. Health Improvement through Employee Control II (HITEC II). Available online: https://health.uconn.edu/occupational-environmental/academics-and-research/cph-new/hitec-ii-project/ (accessed on 17 August 2021).
35. Healthy Workplace Participatory Program. Center for the Promotion of Health in the New England Workplace. Available online: https://www.uml.edu/Research/CPH-NEW/Healthy-Work-Participatory-Program/ (accessed on 17 August 2021).
36. Robertson, M.M.; Tubbs, D.; Henning, R.A.; Nobrega, S.; Calvo, A.; Murphy, L.A. Assessment of organizational readiness for participatory occupational safety, health and well-being programs. *Work* **2021**, *Pre-press*, 1–26. [CrossRef] [PubMed]
37. Nobrega, S.; Morocho, C.; Robertson, M.M.; Rice, S.; Kurowski, A.; Henning, R.A.; Punnett, L. A mixed method approach to tailor the implementation of a participatory Total Worker Health® program. *Int. J. Workplace Health Manag.* **2021**, *14*, 409–425. [CrossRef]
38. Fischer, J.A.; Sousa-Poza, A. Does job satisfaction improve the health of workers? New evidence using panel data and objective measures of health. *Health Econ.* **2009**, *18*, 71–89. [CrossRef] [PubMed]

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Using Total Worker Health® Implementation Guidelines to Design an Organizational Intervention for Low-Wage Food Service Workers: The Workplace Organizational Health Study

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Abstract: Total Worker Health® (TWH) interventions that utilize integrated approaches to advance worker safety, health, and well-being can be challenging to design and implement in practice. This may be especially true for the food service industry, characterized by high levels of injury and turnover. This paper illustrates how we used TWH Implementation Guidelines to develop and implement an organizational intervention to improve pain, injury, and well-being among low-wage food service workers. We used the Guidelines to develop the intervention in two main ways: first, we used the six key characteristics of an integrated approach (leadership commitment; participation; positive working conditions; collaborative strategies; adherence; data-driven change) to create the foundation of the intervention; second, we used the four stages to guide integrated intervention planning. For each stage (engaging collaborators; planning; implementing; evaluating for improvement), the Guidelines provided a flexible and iterative process to plan the intervention to improve safety and ergonomics, work intensity, and job enrichment. This paper provides a real-world example of how the Guidelines can be used to develop a complex TWH intervention for food service workers that is responsive to organizational context and addresses targeted working conditions. Application of the Guidelines is likely transferable to other industries.

Keywords: total worker health; intervention development; working conditions; occupational safety and health; food service workers; wellbeing; pain and injury; work environment

1. Introduction

Ensuring worker safety, health, and well-being is critical for employees and employers, since this can directly and indirectly contribute to enterprise outcomes, such as productivity and turnover [1]. Given the diversity of worksites, work arrangements, and challenges to worker well-being, the National Institute for Occupational Safety and Health developed Total Worker Health® (TWH) as a holistic approach to promoting and protecting worker safety, health, and well-being. TWH is defined as "policies, programs, and practices that integrate protection from work-related safety and health hazards with promotion of injury and illness-prevention efforts to advance worker well-being" [2]. Central to TWH is the idea that integrated interventions and approaches that address policies, programs, and practices within the work environment are critical to modifying the multifaceted and interwoven factors that affect worker safety, health, and well-being [1,3]. These approaches

are also important for identifying and improving working conditions and changes in work arrangements shaped by the future of work [4].

However, designing these approaches can be difficult in practice, especially since some employers perceive psychosocial working conditions to be more challenging to manage than physical health and safety risks [5–8]. To support the dissemination and utilization of TWH approaches, the Center for Work, Health, and Well-being at the Harvard T.H. Chan School of Public Health ("the Center") developed a set of TWH guidelines titled *Implementing an Integrated Approach: Weaving Worker Health, Safety, and Well-being into the Fabric of Your Organization* ("the Implementation Guidelines") [9]. The Implementation Guidelines were developed to help workplaces plan, implement, and evaluate integrated approaches that address working conditions to improve worker safety, health, and well-being. While the Implementation Guidelines can be utilized by individuals in diverse industry sectors, application of the Implementation Guidelines requires translation to specific organizational goals and contexts, as well as workplace needs and requirements. Our goal is to help practitioners and researchers successfully design and implement TWH interventions for their organizational contexts and workplace settings. To this end, this paper illustrates how we applied specific elements of the Implementation Guidelines to develop and implement an organizational TWH intervention to improve the safety and well-being of low-wage food service workers, a workforce that experiences high rates of injury and turnover [10]. Using this industry example, this paper aims to contribute to the body of TWH research-to-practice literature of how to develop interventions that address working conditions; it also provides transparency around the decision-making processes and methods used to guide the stages of intervention development, as called for by other researchers [11,12].

1.1. The Implementation Guidelines

The Implementation Guidelines are based on a rich foundation of research, practice, and a conceptual model developed earlier by our research team [1]. The model is grounded on several interdisciplinary theoretical perspectives, including the social ecological model [13,14], social contextual model of health behavior change [15,16], hierarchy of controls [17–19], and participatory frameworks [20]. At the core of the Implementation Guidelines is the use of policies and practices to improve working conditions to address underlying systemic issues that are often the root causes of worker health, safety, and well-being concerns [9]. Working conditions can include factors in the physical environment, such as the equipment used or how the built environment is laid out; job demands such as the pace and amount of work, which may be influenced by staffing levels; and psychosocial factors such as supervisor support, teamwork, and job stress [9].

The Implementation Guidelines outline four stages of an iterative and integrated process to (1) foster buy-in and collaboration among worksite stakeholders, and (2) plan, (3) implement, and (4) evaluate a TWH approach. At the center of this process are the six key characteristics of an integrated approach that are important to the success of a TWH initiative and guide decision-making at each stage: (1) leadership commitment; (2) participation; (3) policies, programs, and practices focused on positive working conditions; (4) comprehensive and collaborative strategies; (5) adherence; and (6) data-driven change [1,9]. We recently applied the Implementation Guidelines to develop and test an integrated, organizational intervention to improve worker safety, health, and well-being in a high-risk sector (low-wage food service) [21], a particularly challenging undertaking due to the hierarchical organizational structure and economic and social vulnerability of frontline staff in this setting [22–26].

1.2. Low-Wage Food Service Workers and the Workplace Organizational Health Study

Compared to other industries, work-related injury and illness among workers in the food service industry is among the highest in the United States [10,27,28]. Among the 12 million workers employed in the food service industry in 2019, the incidence of

occupational injuries requiring days missed from work was 1.9 per 100 workers employed in special food services such as contract work [10]. In comparison, workers employed in manufacturing and construction industries—industries known for their high rates of injury—had incidences of 2.0 and 1.7 per 100 workers, respectively, while business and professional service sectors reported 0.7 injuries per 100 workers [10].

The work environments found in the food service industry can affect the safety, health, and well-being of frontline staff. For example, employees may experience strains and sprains because of repetitive movements (e.g., chopping and mixing), pushing carts, or prolonged standing, such as for cashiers. Similarly, jobs can involve awkward postures, bending, and lifting heavy equipment or items. Workers can slip, trip, and fall because of slick floors and clutter. They also suffer cuts from sharp objects and burns from exposure to hot stoves, ovens, cooking oils, and steam [27–31]. In parallel, employees also face organizational conditions and high psychosocial demands from responding to a fast-paced work environment, time pressures, and limited rest breaks from producing meals (e.g., breakfast and lunch) on a tight schedule and responding to catering requests [27,30–34]. These conditions may contribute to the fact that job separation is 75% higher among food service workers compared to the 2019 cross-industry average [35].

While many of these worker safety, health, and well-being outcomes are rooted in the working conditions of the food service work environment, warranting interventions that focus on system-wide, organizational improvements, few have been tested and are available in the existing literature [36–40]. This need prompted a large, multinational company ("Company") that provides food services through contractual arrangements to approach the Center to develop and test approaches to improve the health, safety, and well-being of their frontline workers. This partnership resulted in the development of a TWH organizational intervention focused on improving working conditions related to decreasing pain and injury and increasing worker well-being. Because of the Implementation Guidelines' sharp focus on using policies and practices to improve working conditions, we used them as a framework to develop the intervention. The purpose of this paper is to illustrate the process of using the Implementation Guidelines to develop and implement a TWH intervention as part of The Workplace Organizational Health Study [21]. In doing so, we additionally aim to provide an approach to develop TWH interventions that can be used by practitioners and researchers in other industry sectors.

2. Materials and Methods

2.1. Study Setting and Population

The intervention was designed for five of the Company's food service worksites, located in corporate settings in the Greater Boston area. Each site had 7–22 frontline workers and a site manager who was responsible for operations and supervision of frontline workers. The Company's project champion, who was a member of the national leadership team, contacted the Center about initiating the study and provided corporate-level support throughout the project. Company leadership at the district and national levels also participated in intervention development at multiple stages in the process.

2.2. Design Team

To develop the intervention utilizing the Implementation Guidelines, we established a multi-disciplinary research team, comprised of Center social and behavioral scientists, occupational safety and health experts, and public health practitioners. To inform the intervention development process, we conducted formative research in five of the Company's worksites that were not part of the planned intervention study [41]. The research team met weekly and collaborated regularly with the company national project champion, which provided an opportunity for feedback and discussion reflecting diverse and extensive intervention expertise. Throughout intervention development, the team met with Company leaders at different levels to incorporate their expertise into the design of the intervention, learn about existing Company resources, and garner buy-in. We used an iterative process

in which we applied what we learned at each stage of intervention development to inform the next, a process we have used to successfully develop other interventions [42,43]. This allowed us to modify the intervention as needed based on experience and feedback and to ensure stronger organizational fit.

We also kept comprehensive intervention development and meeting notes, which allowed us to document key decisions and any adaptations made to the intervention as it was implemented. Intervention staff documented barriers and facilitators encountered after each intervention contact. These notes were securely stored in a shared folder, accessible to the team, allowing for review of decision points and easy access to information to share with the larger investigator team and project champion.

2.3. Using the Implementation Guidelines to Develop the Intervention

We used the Implementation Guidelines to develop the intervention in two main ways: first, we used the six key characteristics of an integrated approach to create the foundation of the intervention [44]; second, we used the four stages to guide iterative and integrated intervention planning.

2.3.1. Key Characteristics

The six key characteristics described in the Implementation Guidelines are indicators of best practices for protecting and promoting worker safety, health, and well-being, as defined in Table 1 [9]. We used the key characteristics to guide decision-making related to: (a) who to involve? Leadership commitment (key characteristic 1) and broad participation of stakeholders, especially workers, (key characteristic 2) are pivotal to intervention success; (b) what to change? Using policies and practices to improve working conditions (key characteristic 3) is fundamental to the TWH approach and formed the basis of our initiative; (c) how to design the intervention? Best practices, such as implementing comprehensive and collaborative strategies (key characteristic 4) to foster employee engagement; promoting adherence to federal and state regulations and ethical norms (key characteristic 5); employing data-driven change to guide decision-making and improve an initiative (key characteristic 6) were all considered in the design of the intervention to change working conditions.

Table 1. Six key characteristics of a TWH integrated approach [9].

Key Characteristic	Definition from the Implementation Guidelines
1. Leadership commitment	Leadership makes worker safety, health, and well-being a clear priority for the entire organization. They drive accountability and provide the necessary resources and environment to create positive working conditions.
2. Participation	Stakeholders at every level of an organization, including organized labor when applicable, help plan and carry out efforts to protect and promote worker safety, health, and well-being.
3. Policies, programs, and practices focused on positive working conditions	The organization enhances worker safety, health, and well-being with policies, programs and practices that improve working conditions.
4. Comprehensive and collaborative strategies	Employees from across the organization work together to develop comprehensive safety, health, and well-being initiatives.
5. Adherence	The organization adheres to federal and state regulations, as well as ethical norms, that advance worker safety, health, and well-being.
6. Data-driven change	Regular evaluation guides an organization's priority setting, decision making, and continuous improvement of worker safety, health, and well-being initiatives.

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2.3.2. Stages

The Implementation Guidelines, organized into four stages of an integrated approach, provide processes to plan an intervention and strategies to change working conditions (Table 2). For example, the Implementation Guidelines recommend having employee-manager teams work collaboratively to identify relevant working conditions and develop action plans.

Table 2. Four stages of an integrated TWH approach [9].

Stage	Description from the Implementation Guidelines
1. Engaging Leadership and Collaborators	Buy-in and collaboration from across the organization are important. Seek top leadership support early on, encourage collaboration, work closely with middle managers, and give workers clear opportunities to participate.
2. Planning	Successful initiatives start with a clear plan. Define the goal and choose SMART (Specific-Measurable-Achievable-Relevant-Time Bound) objectives. Define working conditions; gather and analyze worksite information; select tactics; create an action plan; identify required resources.
3. Implementation	Changes to policies, practices, and programs play out in the workplace. To facilitate implementation, start small, communicate about progress, and conduct training.
4. Evaluation and Improvement	Monitor and analyze data to measure success and improve an initiative. Use a variety of data collection methods, evaluate as needed, and communicate findings frequently.

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The application of the Implementation Guidelines to intervention planning is described in the Section 3.

Figure 1 illustrates the overall process used: the key characteristics helped us answer the three questions that created the foundation of the intervention; the questions guided decision-making at each of the four stages, leading to the design of the organizational intervention.

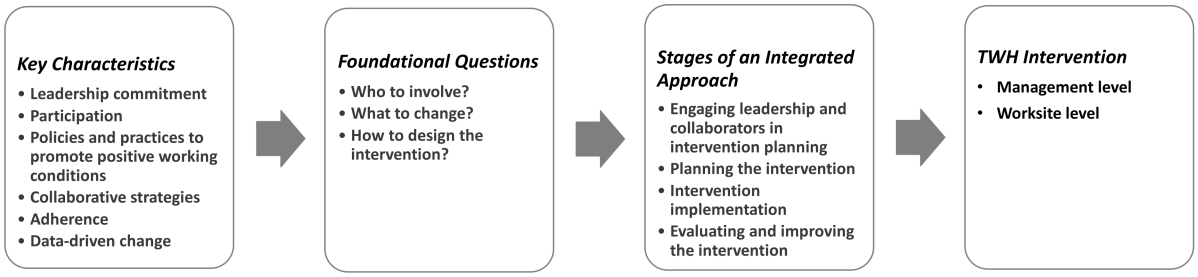


Figure 1. The Implementation Guideline's six key characteristics helped us answer the three questions that created the foundation of intervention. Those three questions informed our decision-making at each of the four stages from the Guidelines, leading to the design of a multilevel intervention.

3. Results

3.1. Applying the Key Characteristics

Who to involve? Using knowledge of the organizational setting and study outcomes determined based on our formative research [41], we collaborated with the Company to determine who to involve in the intervention. Specifically, we selected (1) site-level managers, since middle-managers are crucial to intervention success; (2) site-level frontline workers (chefs, cooks, food preparers, servers, dishwashers, and cashiers), given the importance of employee participation in all phases of planning and implementing an intervention;

(3) leadership, as different types and levels of leadership were needed to develop, implement, and support this intervention. For example, we collaborated with representatives of safety and health to ensure that our intervention aligned with approaches already being used within the Company. Similarly, we engaged human resources and operations leadership in order to build upon strategies already in place. Collaborating with the Company's project champion throughout the project was also crucial to maintain corporate support.

What to change? Based on a literature review of organizational interventions [45], formative research, including interviews with managers, focus groups with frontline workers, and a collaborative participatory process with the Company [41], we targeted three working conditions: (1) safety and ergonomics (equipment use, slips and falls, prolonged standing, and lifting and carrying demands); (2) work intensity (the pace of work and demands placed on employees); and (3) job enrichment (providing on-going job performance feedback and coaching and identifying opportunities for career advancement). Additionally, we identified four essential intervention elements (leadership commitment, participation of stakeholders at all levels of the Company, communication, and tailoring for fit), defined as mechanisms for achieving the intervention's intended effects that are well-aligned with our six key characteristics [41].

How to design the intervention? Given the targeted working conditions, essential elements, and knowledge of the context, we selected collaborative strategies (key characteristic 4) to enhance communication between employee levels, such as by promoting manager/worker action planning. We also decided to focus on data-driven change (key characteristic 6) to inform how we would tailor the intervention to "fit" the Company's organizational context. Because the Company was already adherent to federal and state regulations (key characteristic 5), we decided to build on the Company's strong safety program as we developed the intervention.

3.2. Applying the Stages

The following summary of our experience developing the intervention is organized based on the four stages outlined in the Implementation Guidelines. For each stage, we describe the Implementation Guidelines' recommendations, how these were applied to the development of our intervention, and considerations for others who may use the Implementation Guidelines to plan an intervention.

3.2.1. Stage 1: Engaging Leadership and Collaborators in Intervention Planning

a. What the Implementation Guidelines Recommend.

Having broad-based support—from top leadership and middle management to workers at all levels—is crucial to implementing an organizational intervention to create safer and healthier workplaces [9,46,47]. The Implementation Guidelines recommend working with multiple groups across sectors to achieve ongoing support. Leadership buy-in sets the stage for an intervention by engaging management at different hierarchical levels of the company, committing resources, and creating a supportive environment. Middle managers directly manage both the day-to-day workflow to ensure the company's work gets completed, and supervise employees, which entails creating working conditions and a work environment in which everyone can succeed. Soliciting and acting upon employees' input about working conditions through regular and continuous communication can improve the fit of strategies selected to address them and foster future participation. Employees may also feel more engaged, which contributes to their health, safety, and well-being [48]. Managers can also promote engagement by frequently communicating with employees, obtaining ongoing feedback, and "recognizing the value of [employees'] work" [9].

b. How we applied the Implementation Guidelines to engaging leadership and promoting collaboration.

From our literature review, interviews, focus groups, and collaboration with the Company, we learned several insights that influenced how we engaged leadership and

promoted broad-based collaboration in the intervention [41]. First, we learned that national leadership wanted more frequent communication between site managers and their frontline workers, above and beyond annual performance reviews. Specifically, they wanted a participatory process or tool that could be scaled across the organization.

Second, we learned that each level of Company management had different decision-making authority for how policies and practices were implemented at the national, district, and site levels. We also learned that the work environment and food service operations (e.g., size of the kitchen and number of catering requests) varied greatly from site to site within the Company. This informed our decision to work with each site to assess working conditions and plan for site-specific changes, given their unique contexts. In parallel, we recognized that intervention was needed at the leadership level to leverage the different management levels' abilities to change policies and practices to support site changes.

Third, we learned that different leadership groups (e.g., safety, human resources, and operations) had distinct priorities that we would need to build upon throughout intervention planning. Specifically, we decided to engage these groups in relevant parts of intervention development (e.g., safety and ergonomics) to learn how Company policies, practices, and resources could be leveraged, and to solicit their ideas for changing working conditions.

Given the key role of middle managers to intervention success, we also decided early on to work closely with the site managers to better understand working conditions from their perspective, tailoring the intervention to fit their context, and engaging them in participatory intervention delivery. We created tools, such as action planning forms, that were sensitive to their time and easy to complete.

To enhance collaboration and communication between site managers and frontline workers, we asked managers to work with their employees to assess working conditions and develop and implement plans to address these conditions. To facilitate this process, we developed a tip sheet for managers on how to engage workers at different stages. We also added discussion questions for managers to ask frontline workers during "huddles" (short team meetings) to continually engage them in the intervention.

c. Considerations for intervention developers.

It is important to take the time to understand who has decision-making authority that will influence the targeted changes and to align with their priorities early on. This will help ensure developers are engaging the appropriate individuals who can support the intervention process and changes in working conditions. Identifying and leveraging existing systems, processes, and resources can help embed the intervention into the way an organization does business. Additionally, it is important to obtain employee feedback in a way that makes the people involved in the intervention feel comfortable, such as soliciting anonymous comments or holding meetings with different stakeholder groups to allow people to speak candidly.

3.2.2. Stage 2: Planning the Intervention

a. What the Implementation Guidelines recommend.

Well-crafted plans are the backbone of successful workplace initiatives [4]. At this stage, the Implementation Guidelines recommend gathering information about working conditions, prioritizing actions, developing an action plan to address objectives, and evaluating and monitoring the plan [9]. This process can be an effective platform for implementing organizational interventions [49,50] by identifying "what works" in a company to align intervention approaches with organizational priorities and promote positive changes that build upon existing practices.

b. How we applied the Implementation Guidelines to intervention planning.

Using information learned in Stage 1, we planned the intervention with the following components. First, each working condition (safety and ergonomics, work intensity, and job enrichment) would be addressed in its own module, to be delivered sequentially. Because

the three working conditions were distinctly different, each required its own assessment and planned actions as recommended in the Implementation Guidelines. While all sites would address the same working conditions, the solutions implemented for each working condition would be site-specific. With frontline worker input, each site manager would assess needs and assets related to each working condition. A research team member would then interview the site manager and generate a report with recommendations to assist priority-setting. The safety and ergonomics assessment also included a walkthrough conducted by an industrial hygienist to identify site-specific areas of improvement.

Second, each site would develop and implement action plans based on their site-specific solutions, using the assessment report, planning tools, and consultation provided by a member of the research team. However, site managers would also be encouraged to share and learn from each other. For example, for the Work Intensity module, we convened site managers on a call to share experiences related to the pace of work and the demands placed on both managers and employees, discuss strategies to address challenges, and identify common themes that could be shared with district managers and senior leadership.

Third, training would be conducted to enhance employee engagement. For example, for the Job Enrichment module, we trained site managers on ways to provide coaching and feedback, and how to work with employees to improve performance and achieve career growth. Finally, leadership would be encouraged to support sites with system-level changes. National leadership and district-level managers would review aggregate findings from the site assessments for each working condition and determine what cross-site policies and practices could be improved to support site plans. They would also identify company resources to use during the intervention and address any challenges to intervention implementation. To build leadership buy-in and commitment, we engaged leaders in the planning and development of the intervention using the following strategies.

Building on existing practices and "what works": We worked with leadership to identify and tailor an existing company action planning form for sites to use during the intervention. The form had fields to record areas to improve, SMART (Specific, Measurable, Attainable, Relevant, and Time-bound) objectives, tactics, persons responsible, due dates, resources required, suggested policies to implement and plans for evaluation, and how to sustain each area of improvement. We utilized scripts for "huddles" between site managers and frontline workers (a commonly used Company communication tool used at sites), to support the site manager's leadership and communications with her/his team during the intervention. For the Job Enrichment module, we modified an existing tool—"2 + 2 Coaching and Feedback"—for site managers to use with frontline workers. Previously, this communication tool had been used for the site manager level and above.

Building on organizational priorities: Because leadership expressed pride in their Company's strong safety program, we started the intervention with the safety and ergonomics module to help build trust and establish early successes. This also reinforced the TWH approach to first prioritize a "hazard-free work environment" [2]. Knowing Company leadership wanted to enhance employee engagement, we sought ways to foster participation and communication between site managers and employees during planning. Specifically, we sought to make both the managers and employees "agents of change" by collaborating to identify how working conditions impacted their safety and well-being, brainstorm solutions, and develop and implement action plans to change working conditions that were tailored to fit their sites' assets and experiences.

Incorporating each of these components, we created a 13-month intervention with three modules, focused on two levels (management and site level), and with implementation of each module lasting approximately four months (Figure 2). Protocols, including objectives and supporting materials, were developed for each module, and delivered onsite by a research team member assigned to be the primary representative of the project within each worksite. Ongoing meetings and collaboration with district and national leaders occurred across the 13-month study period.

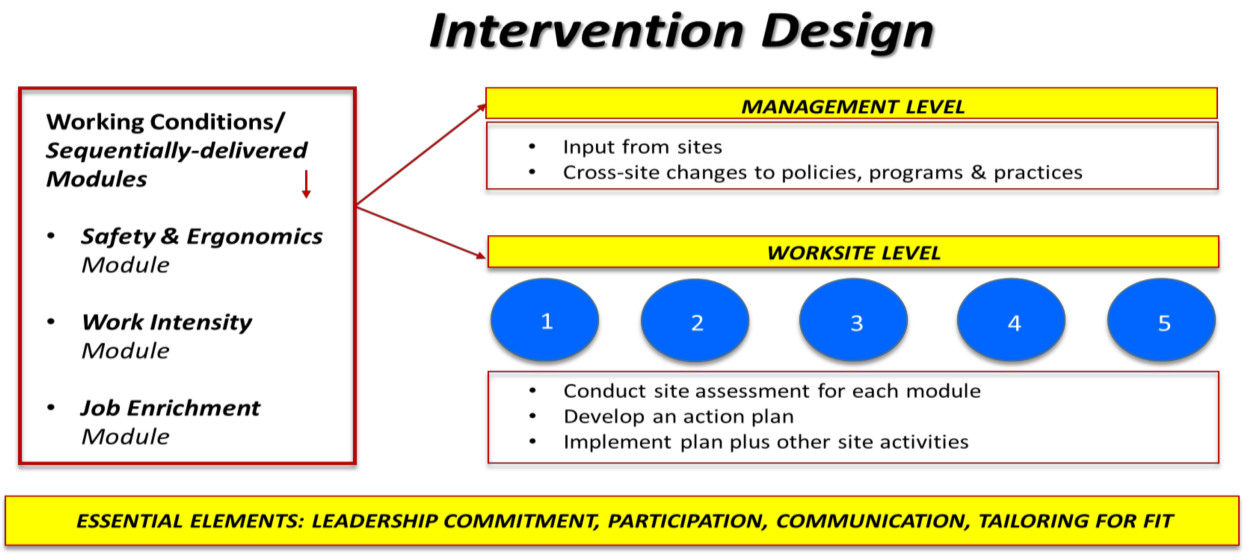


Figure 2. Organizational intervention for improving safety, health, and well-being of low-wage food service workers [26].

c. Considerations for intervention developers.

Intervention developers can build on existing practices and procedures to help make a "new" initiative feel familiar and embed the activities into the way a company does business. Focusing on organizational priorities during the planning stage, and engaging relevant policy makers in the process, can also help generate leadership support. Intervention developers might also consider conducting assessments to capture both strengths and challenges and help workplaces develop solutions that build upon existing organizational resources.

3.2.3. Stage 3: Planning for Implementation of the Intervention

a. What the Implementation Guidelines recommend.

Once an intervention is developed, the Implementation Guidelines offer suggestions to facilitate implementation, including starting small and communicating about intervention progress. Implementing one or a few simple tactics at a time allows worksites to build on incremental improvements, demonstrate progress, and learn from early wins, which can generate interest and potential sustainability [51]. Ongoing communication between organizational leadership, middle management, and workers helps maintain interest and support for the approach. For example, listening to and acting on employee input can help workers feel involved and part of the process, which can foster participation. Keeping leadership abreast of how the intervention is unfolding can also identify new solutions during implementation.

b. How we applied the Implementation Guidelines to planning intervention implementation.

To implement the intervention, the research team member would first visit the site to introduce the module and review the associated intervention materials with the site manager. They would also brainstorm with the site manager about developing and implementing site-specific action plans based on information gathered during the site assessment. The research team member would provide tools for developing the action plan and engage workers in the process, offer guidance to prioritize actions, and provide ongoing consultation and technical support to site managers during in-person and phone meetings. As an implementation strategy, this consultative approach has been shown to be critical to the uptake and quality of intervention implementation [52,53]. As recommended by the Implementation Guidelines, the research team member would encourage site managers to pick something from their action plan that they could feasibly implement at low or no

cost. This incremental strategy would allow sites to experience early successes and build momentum as they conduct assessments and develop action plans for subsequent modules.

At the leadership level, we designed the intervention to support ongoing communication about intervention progress though meetings with senior leadership and district managers. These meetings would also help identify existing resources and ensure the intervention aligned with the priorities of the different leadership groups. Summary reports of aggregate findings from the site assessments would facilitate leadership's implementation of policies and practices to address common challenges experienced by sites for each working condition.

To support leadership's indicated priority of enhancing employee engagement, we decided to conduct a training for all site managers during the Job Enrichment module. The training focused on how to provide coaching and feedback and work with employees to improve performance and identify opportunities for career growth. In discussions with Human Resources, we learned the Company had an existing 2 + 2 Coaching and Feedback tool that was already used to provide feedback to management-level employees, but there was no equivalent tool to provide feedback to frontline employees. The 2 + 2 model is based on a 15 min conversation, during which the manager and employee discuss two things the employee is doing well and two things the employee could be doing more or less of to enhance or improve performance or career growth. The conversation concludes with the manager and employee agreeing to specific actions and next steps, including a plan for follow-up. These 2 + 2 conversations had been effective at the management level of the Company, because they are short, simple, and scripted. This approach supported collaboration, communication, and participation by helping managers (a) incorporate concrete feedback into their coaching and (b) collaboratively work with their employees to develop next steps.

We decided to tailor the 2 + 2 Coaching and Feedback tool for use with frontline workers and created a 45 min, interactive webinar training for site managers, with Company leadership setting the expectation that managers would use this tool with their employees during their annual performance reviews and regularly during the year. Accordingly, this adapted Company tool promoted each of the four essential elements of our intervention: (1) leadership commitment: Human Resources leadership communicated their support and use of the modified 2 + 2 model with frontline employees, based on its previous use with managers. (2) participation: 2 + 2 Coaching and Feedback encouraged improved two-way discussions and invited employee participation and input. (3) communication: 2 + 2 Coaching and Feedback encouraged short, more frequent conversations between site managers and workers, which aligned with senior management's goal of enhanced communication. (4) tailoring for fit: 2 + 2 Coaching and Feedback had previously been used in other parts of the Company and at different levels, so it was already aligned with the organizational culture.

c. Considerations for intervention developers.

Providing hands-on and ongoing consultation can facilitate intervention implementation by helping organizations develop action plans, ensure organizational and site-specific priorities are clear, and decide which actions to initiate first. Intervention developers should also consider using multiple intervention strategies and communication modalities (e.g., in person visits, phone calls) to accommodate the pace of work and schedules of people implementing an intervention. Others may also find it beneficial to start small to build early success, and to identify existing resources that provide established platforms to further the intervention goals.

3.2.4. Stage 4: Planning for Evaluating and Improving the Intervention

a. What the Implementation Guidelines recommend.

Evaluation and continual improvement are fundamental to the successful implementation of integrated, organizational approaches and can have implications for long-term

success [54]. The Implementation Guidelines recommend using both quantitative (e.g., surveys) and qualitative (e.g., focus groups, interviews, or informal conversations with workers) data to understand what took place and why from the perspective of employees at all levels of an organization. Ongoing evaluation during implementation is key to provide data for making mid-course corrections, which can influence the intervention's ultimate success in improving outcomes [55,56]. Because implementation of an intervention may not go exactly as planned, the Implementation Guidelines help intervention developers identify where changes are needed and focus on incremental improvements. Additionally, monitoring the implementation process helps intervention developers learn not only what strategies are working, but also why, which gives essential insight to tailor the intervention to fit the context.

b. How we applied the Implementation Guidelines to plan for intervention improvement.

We planned for ongoing monitoring and using data to continually improve the intervention fit with the organizational context. At the site level, each module would begin with an assessment of a specific working condition. Site managers would be encouraged to use these data to tailor solutions to fit their site. To enhance employee participation, we encouraged discussions and devised alternative ways for employees to provide confidential feedback, such as using suggestion boxes. At the leadership level, we planned to keep district managers and senior leaders abreast of how the intervention was unfolding, the successes achieved, and any challenges to implementation. We also anticipated making data-driven modifications to the overall intervention as needed. To achieve this, we created a tracking system of the intervention process and to what degree the intervention was actually implemented [26] to help us develop a deeper understanding of intervention implementation at both the site and leadership levels. This system included observations and reflections from the research staff members who served as the primary contacts for the intervention at the five sites. Finally, through ongoing collaboration and listening to stakeholders at all levels, we would be able to learn what worked, what did not work, and why. As recommended by the Implementation Guidelines, collection of real-time data would facilitate continuous improvement of the intervention.

c. Considerations for intervention developers.

It is important to remember that intervention development and implementation is an iterative process. Interventions are frequently not implemented as planned, requiring flexibility to change and adapt the intervention as needed to accommodate the organizational or worksite context [57]. To achieve this, it is helpful to build opportunities for reflection on potential adaptations as part of the intervention plan. Building observations and dialogues into intervention monitoring can help intervention developers understand which intervention activities are going well and which ones are not. Data collection can also function as a useful communication tool so workers know what is happening, and leaders learn about successes and can identify where more resources could be helpful.

4. Discussion

Participatory TWH interventions can be challenging to design and implement in real-world settings, especially in low-wage, fast-paced, high-attrition industries such as food service [35]. While an integrated approach to improving the programs, policies, and practices which structure worker health outcomes is imperative, there are few examples accessible to researchers and practitioners, such as human resources personnel, occupational health professionals, and union representatives, to successfully plan and implement TWH interventions. The goal of this paper is to provide a pragmatic step-by-step example of how to use the Harvard T.H. Chan School of Public Health Center for Work, Health, and Well-being's TWH Implementation Guidelines to develop a complex TWH organizational intervention.

Using the Workplace Organizational Health Study as an illustrative example, the Implementation Guidelines helped us to design the intervention in two central ways. First,

the six key characteristics of an integrated approach guided decisions that laid the foundation for the intervention, including (a) who to involve, guided by the characteristics of leadership commitment and participation of stakeholders across the Company, especially frontline workers; (b) what to change, by identifying working conditions and related Company policies and practices through preliminary research and collaboration with the Company; (c) how to design the intervention to include collaboration across Company levels and ongoing monitoring to promote data-driven modifications to the intervention as needed. Second, the Implementation Guidelines—organized into four stages of an integrated approach—provided a process to plan the intervention using strategies to change working conditions. The planning process culminated in a 13-month intervention implemented at both leadership and site levels to change our three working conditions (safety and ergonomics, work intensity, and job enrichment), as described in detail elsewhere [26].

The Implementation Guidelines were designed for organizations to create TWH approaches. This research supports and advances the fundamentals of TWH in several important ways. First, it harmonizes with the TWH definition and key tenant of a TWH approach: "focusing on addressing system-level or environmental determinants of health before individual-level approaches" [58]. Second, it strengthens the five Defining Elements of TWH: (1) demonstrate leadership commitment to worker safety and well-being—we prioritized leadership engagement throughout all modules; (2) design work to reduce safety hazards—as in the safety and ergonomics module; (3) promote worker engagement—through assessments of working conditions, action planning, and training site managers to have ongoing conversations with their employees related to performance and career growth; (4) ensure confidentiality and privacy of workers—by using suggestion boxes for workers to provide confidential feedback and providing aggregate site assessments to leadership; (5) integrating relevant systems—by leveraging Company systems and resources, such as modifying existing planning forms and adapting the 2 + 2 Coaching and Feedback tool for use with frontline workers [59]. Finally, our selection of working conditions to address in the intervention supports issues NIOSH has identified as relevant to advancing worker well-being through TWH. Specifically, our approach to safety and ergonomics supports TWH issues related to "control of hazards and exposures," the work intensity focus aligns with "organization of work" issues, and the inclusion of job enrichment supports the issue of "career and skills development" [59].

In a field, such as food service, where there are few examples of successful participatory TWH organizational interventions, providing transparency around our process for developing a complex intervention at multiple levels and with different stakeholders provides a systematic process and structure that practitioners and researchers can use. In recent years, there has also been a call to publish intervention development studies—particularly complex interventions such as this one—and for transparency in reporting the decision-making processes, experiences, and methods used in the stages of intervention development [11,12]. This sharing can foster cross-disciplinary learning and help intervention developers replicate the processes and avoid recurring pitfalls [12]. We believe this paper makes an important contribution to this effort.

Related to the future of work, designing integrated approaches is especially important considering evolving changes to the work environment, employment relationships, and how work is performed [4,60,61]. The COVID-19 pandemic accelerated some future of work changes. The Implementation Guidelines can help organizations plan integrated approaches that evaluate and remedy emerging changes in working conditions that impact worker safety, health, and well-being, allowing them to be more agile and resilient in times of change, such as the pandemic. For example, communication mechanisms became very important so that new guidelines and changes to work could be communicated rapidly to workers; supervisors were essential to helping workers navigate these changes. Additionally, implementing remote work policies impacted onsite contractors, such as food service workers, resulting in decreased employment stability and job security for these workers.

The use of the Guidelines to inform intervention development, content and strategies is supported by other work conducted by the Center in different sectors. For instance, we recently used the Implementation Guidelines' six key characteristics to organize TWH recommendations for worksites on practical ways they could address worker safety, health, and well-being during the COVID-19 pandemic [62]. The Center's Implementation Guidelines were also used in conjunction with other theoretical models to design a participatory organizational intervention for subcontractors in the commercial construction industry [43]. Additionally, our decision to provide consultation and technical assistance to sites is supported by a recent study in which we tested the practical utility of a TWH capacity-building suite of services, including the Implementation Guidelines, to help worksites develop TWH action plans [63]. Outside of TWH, we have employed this strategy to help program implementers feel comfortable and confident in their roles [42,64].

4.1. Strengths and Limitations

This study has several strengths. To our knowledge, this is the first application of the Implementation Guidelines to create a TWH intervention for low-wage food service workers, focused on improving the conditions of work. It provides practitioners and researchers with a concrete example of how to develop a TWH organizational intervention in partnership with a multinational corporation. We kept comprehensive intervention development and meeting notes, which documented decisions and adaptations made to inform future interventions. This was not only helpful when iteratively developing the intervention during this study, but also to reflect on our process and to develop considerations for others who may use the Implementation Guidelines; these considerations are provided in this paper. We encourage other intervention developers to keep similar notes. Notably, we used the Implementation Guidelines as part of an academic research study. Given that the Implementation Guidelines were developed for use by workplaces, our experience speaks to their broad applicability in both research and practice settings.

Despite these strengths, there are limitations to this study. We designed the intervention for sites to assess working conditions, develop action plans, and implement changes for three working conditions over the course of 13 months. However, another recent study reported that it may take worksites approximately nine months to form an integrated team and craft a TWH action plan with on-going technical assistance [63], suggesting we may have been too ambitious in our intervention timeline [26]. We also realize the intervention development process, design, and choice of key characteristics may look different for organizations that are creating an intervention for one site verses tailoring the intervention for multiple sites. Since this was a research study, we selected, in advance, the working conditions that the sites would address. In practice, worksites might identify different sets of working conditions to target during the planning stage of the intervention. Application of the Implementation Guidelines may also look different when applied from within the organization rather than by researchers in collaboration with organization representatives.

4.2. Future Directions

While we have found the Implementation Guidelines to be transferable across industries, future efforts can be made to document how the Implementation Guidelines are used in other real-world settings and work contexts. For example, future research might compare the implications of these Implementation Guidelines for employers across different sectors, varying by size and with different readiness for change. Approaches to using a participatory process may also vary depending upon existing resources, leadership commitment, and levels of employee engagement. We believe the provision of concrete examples that transparently document the intervention development processes and decision-making, and provide considerations for future intervention developers can be a useful model to bridge research and practice gaps.

5. Conclusions

This translational research-to-practice paper demonstrates how we used the Harvard T.H. Chan School of Public Health Center for Work, Health, and Well-being's Implementation Guidelines to develop an organizational TWH intervention to improve the safety and well-being of low-wage food service workers. We used the Implementation Guidelines' key characteristics to establish who to involve, what to change, and how to design the intervention throughout a four-stage process. For each stage, the Implementation Guidelines provided suggestions and strategies to develop an evidence-informed intervention. The Implementation Guidelines can be used by both practitioners and researchers to develop interventions that are responsive to the organizational context and address targeted working conditions to improve worker safety, health, and well-being. Efforts such as this to translate theory-based Implementation Guidelines into pragmatic processes and considerations for both practitioners and researchers is an important step forward to develop TWH interventions across industry sectors.

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References

1. Sorensen, G.; McLellan, D.L.; Sabbath, E.L.; Dennerlein, J.T.; Nagler, E.M.; Hurtado, D.A.; Pronk, N.P.; Wagner, G.R. Integrating worksite health protection and health promotion: A conceptual model for intervention and research. *Prev. Med.* **2016**, *91*, 188–196. [CrossRef] [PubMed]
2. National Institute of Occupational Safety and Health. Total Worker Health. Available online: https://www.cdc.gov/niosh/twh/totalhealth.html (accessed on 16 May 2021).
3. Chari, R.; Chang, C.C.; Sauter, S.L.; Petrun Sayers, E.L.; Cerully, J.L.; Schulte, P.; Schill, A.L.; Uscher-Pines, L. Expanding the Paradigm of Occupational Safety and Health: A New Framework for Worker Well-Being. *J. Occup. Environ. Med.* **2018**, *60*, 589–593. [CrossRef] [PubMed]
4. Sorensen, G.; Dennerlein, J.T.; Peters, S.E.; Sabbath, E.L.; Kelly, E.L.; Wagner, G.R. The future of research on work, safety, health and wellbeing: A guiding conceptual framework. *Soc. Sci. Med. (1982)* **2021**, *269*, 113593. [CrossRef]
5. EU-OSHA (European Agency for Safety and Health at Work). Third European survey of enterprises on new and emerging risks (ESENER-3). First findings. *Publ. Off. Eur. Union* **2019**. [CrossRef]
6. Nytrø, K.; Saksvik, P.Ø.; Mikkelsen, A.; Bohle, P.; Quinlan, M. An appraisal of key factors in the implementation of occupational stress interventions. *Work Stress* **2000**, *14*, 213–225. [CrossRef]
7. Schuller, K. Interventions as the centrepiece of psychosocial risk assessment–why so difficult? *Int. J. Workplace Health Manag.* **2020**, *13*, 61–80. [CrossRef]
8. Langenhan, M.K.; Leka, S.; Jain, A. Psychosocial risks: Is risk management strategic enough in business and policy making? *Saf. Health Work* **2013**, *4*, 87–94. [CrossRef]
9. McLellan, D.; Moore, W.; Nagler, E.; Sorensen, G. *Implementing an Integrated Approach Weaving Worker Health, Safety, and Well-being into the Fabric of Your Organization*; Harvard, T.H., Ed.; Chan School of Public Health Center for Work, Health and Wellbeing: Boston, MA, USA, 2017.

10. U.S. Department of Labor; Bureau of Labor Statistics. Incidence Rates of Nonfatal Occupational Injuries and Illnesses by Industry and Case Types. Available online: https://www.bls.gov/iif/oshwc/osh/os/summ1_00_2019.htm (accessed on 8 August 2021).
11. Croot, L.; O'Cathain, A.; Sworn, K.; Yardley, L.; Turner, K.; Duncan, E.; Hoddinott, P. Developing interventions to improve health: A systematic mapping review of international practice between 2015 and 2016. *Pilot Feasibility Stud.* **2019**, *5*, 127. [CrossRef]
12. Hoddinott, P. A new era for intervention development studies. *Pilot Feasibility Stud.* **2015**, *1*, 36. [CrossRef]
13. McElroy, K.; Bibeau, D.; Steckler, A.; Glanz, K. An ecological perspective on health promotion programs. *Health Educ. Q.* **1988**, *15*, 351–377. [CrossRef]
14. Stokols, D. Translating social ecological theory into guidelines for community health promotion. *Am. J. Health Promot.* **1996**, *10*, 282–298. [CrossRef] [PubMed]
15. Sorensen, G.; Emmons, K.; Hunt, M.K.; Barbeau, E.; Goldman, R.; Peterson, K.; Kuntz, K.; Stoddard, A.; Berkman, L. Model for incorporating social context in health behavior interventions: Applications for cancer prevention for working-class, multiethnic populations. *Prev. Med.* **2003**, *37*, 188–197. [CrossRef]
16. Sorensen, G.; Barbeau, E.; Hunt, M.K.; Emmons, K. Reducing social disparities in tobacco use: A social contextual model for reducing tobacco use among blue-collar workers. *Am. J. Public Health* **2004**, *94*, 230–239. [CrossRef]
17. Levy, B.S.; Wegman, D.H.; Baron, S.L.; Sokas, R.K. *Occupational and Environmental Health: Recognizing and Preventing Disease and Injury*, 5th ed.; Levy, B.S., Wegman, D.H., Baron, S.L., Sokas, R.K., Eds.; Lippincott Williams & Wilkins: Philadelphia, PA, USA, 2006.
18. Office of Technology Assessment. *Preventing Illness and Injury in the Workplace*; Office of Technology Assessment, Congressional Board of the 99th Congress; US Government Printing Office: Washington, DC, USA, 1985.
19. Roelofs, C.; Barbeau, E.; Moure-Eraso, R.; Ellenbecker, M.J. Prevention strategies in industrial hygiene: A critical literature review. *Am. Ind. Hyg. Assoc. J.* **2003**, *64*, 62–67. [CrossRef]
20. Abildgaard, J.S.; Hasson, H.; von Thiele Schwarz, U.; Løvseth, L.T.; Ala-Laurinaho, A.; Nielsen, K. Forms of participation: The development and application of a conceptual model of participation in work environment interventions. *Econ. Ind. Democr.* **2018**, *41*, 746–769. [CrossRef]
21. Sorensen, G.; Peters, S.; Nielsen, K.; Nagler, E.; Karapanos, M.; Wallace, L.; Burke, L.; Dennerlein, J.T.; Wagner, G.R. Improving Working Conditions to Promote Worker Safety, Health, and Wellbeing for Low-Wage Workers: The Workplace Organizational Health Study. *Int. J. Environ. Res. Public Health* **2019**, *16*, 1449. [CrossRef]
22. Montano, D.; Hoven, H.; Siegrist, J. Effects of organisational-level interventions at work on employees' health: A systematic review. *BMC Public Health* **2014**, *14*, 135. [CrossRef] [PubMed]
23. Johnson, S.A.; Madera, J.M. Sexual harassment is pervasive in the restaurant industry. Here's what needs to change. *Harv. Bus. Rev.* **2018**, *20*, 2019.
24. Korczynski, M.; Evans, C. Customer abuse to service workers: An analysis of its social cretion within the service economy. *Work. Employ. Soc.* **2013**, *27*, 768–784. [CrossRef]
25. Williams, C.; Drago, R.; Miller, K. *44 Million, U.S. Workers Lacked Paid Sick Days in 2010: 77 Percent of Food Service Workers Lacked Access (IWPR #B293)*; Institute for Women's Policy Research: Washington, DC, USA, 2011.
26. Sorensen, G.; Peters, S.E.; Nielsen, K.; Stelson, E.; Wallace, L.M.; Burke, L.; Nagler, E.M.; Roodbari, H.; Karapanos, M.; Wagner, G.R. Implementation of an organizational intervention to improve low-wage woerkers' safety, health and wellbeing: Findings from the Workplace Organizational Health Study. *Under Rev.* **2021**. [CrossRef]
27. Alamgir, H.; Swinkels, H.; Yu, S.; Yassi, A. Occupational injury among cooks and food service workers in the healthcare sector. *Am. J. Ind. Med.* **2007**, *50*, 528–535. [CrossRef] [PubMed]
28. Cann, A.P.; Baker, A.M.; Hansen, A.; Massie, D.; Vandervoort, A.A. A five year retrospective analysis of occupational injuries and incidence reported at a research intensive Canadian university. *Work (Read. Mass)* **2008**, *30*, 171–184.
29. U.S. Department of Labor; Bureau of Labor Statistics. Injury and Illness Rates Higher in Special Food Services Than In Broader Food Services Industry. Available online: https://www.bls.gov/opub/ted/2019/injury-and-illness-rates-higher-in-special-food-services-than-in-broader-food-services-industry.htm (accessed on 28 October 2020).
30. Cocci, S.J.; Namasivayam, K.; Bordi, P. An investigation of ergonomic design and productivity improvements in foodservice production tables. *Foodserv. Res. Int.* **2005**, *16*, 53–59. [CrossRef]
31. Filiaggi, A.J.; Courtney, T.K. Restaurant hazards: Practice-based approaches to disabling occupational injuries. *Prof. Saf.* **2003**, *48*, 18–23.
32. Stephenson, J. Determining optimal work surface height for Surrey Memorial Hospital food service workers. *J. Can. Diet. Assoc.* **1994**, *55*, 39–41. [PubMed]
33. Andersen, J.H.; Kaergaard, A.; Mikkelsen, S.; Jensen, U.F.; Frost, P.; Bonde, J.P.; Fallentin, N.; Thomsen, J.F. Risk factors in the onset of neck/shoulder pain in a prospective study of workers in industrial and service companies. *Occup. Environ. Med.* **2003**, *60*, 649–654. [CrossRef]
34. Verma, S.K.; Chang, W.R.; Courtney, T.K.; Lombardi, D.A.; Huang, Y.H.; Brennan, M.J.; Mittleman, M.A.; Perry, M.J. Workers' experience of slipping in U.S. limited-service restaurants. *J. Occup. Environ. Hyg.* **2010**, *7*, 491–500. [CrossRef]
35. U.S. Department of Labor; Bureau of Labor Statistics. Annual Total Separations Rates by Industry and Region, Not Seasonally Adjusted, 2016–2020. Available online: https://www.bls.gov/news.release/jolts.t16.htm (accessed on 10 August 2021).

36. Busch, C.; Koch, T.; Clasen, J.; Winkler, E.; Vowinkel, J. Evaluation of an organizational health intervention for low-skilled workers and immigrants. *Hum. Relat.* **2017**, *70*, 994–1016. [CrossRef]
37. Haukka, E.; Leino-Arjas, P.; Viikari-Juntura, E.; Takala, E.P.; Malmivaara, A.; Hopsu, L.; Mutanen, P.; Ketola, R.; Virtanen, T.; Pehkonen, I.; et al. A randomized controlled trial on whether a participatory ergonomics intervention could prevent musculoskeletal disorders. *Occup. Environ. Med.* **2008**, *65*, 849–856. [CrossRef]
38. Haukka, E.; Pehkonen, I.; Leino-Arjas, P.; Viikari-Juntura, E.; Takala, E.P.; Malmivaara, A.; Hopsu, L.; Mutanen, P.; Ketola, R.; Virtanen, T.; et al. Effect of a participatory ergonomics intervention on psychosocial factors at work in a randomized controlled trial. *Occup. Environ. Med.* **2010**, *67*, 170–177. [CrossRef]
39. Siukola, A.; Virtanen, P.; Huhtala, H.; Nygård, C.-H. Absenteeism following a workplace intervention for older food industry workers. *Occup. Med.* **2011**, *61*, 583–585. [CrossRef] [PubMed]
40. Nielsen, K.; Fredslund, H.; Christensen, K.B.; Albertsen, K. Success or failure? Interpreting and understanding the impact of interventions in four similar worksites. *Work Stress* **2006**, *20*, 272–287. [CrossRef]
41. Peters, S.E.; Nielsen, K.M.; Nagler, E.M.; Revette, A.C.; Madden, J.; Sorensen, G. Ensuring Organization-Intervention Fit for a Participatory Organizational Intervention to Improve Food Service Workers' Health and Wellbeing: Workplace Organizational Health Study. *J. Occup. Environ. Med.* **2020**, *62*, e33–e45. [CrossRef]
42. Nagler, E.M.; Pednekar, M.S.; Viswanath, K.; Sinha, D.N.; Aghi, M.B.; Pischke, C.R.; Ebbeling, C.B.; Lando, H.A.; Gupta, P.C.; Sorensen, G.C. Designing in the social context: Using the social contextual model of health behavior change to develop a tobacco control intervention for teachers in India. *Health Educ. Res.* **2013**, *28*, 113–129. [CrossRef] [PubMed]
43. Peters, S.E.; Trieu, H.D.; Manjourides, J.; Katz, J.N.; Dennerlein, J.T. Designing a Participatory Total Worker Health(®) Organizational Intervention for Commercial Construction Subcontractors to Improve Worker Safety, Health, and Well-Being: The "ARM for Subs" Trial. *Int. J. Environ. Res. Public Health* **2020**, *17*, 5093. [CrossRef] [PubMed]
44. Vella, J. *Learning to Listen Learning to Teach: The Power of Dialogue in Educating Adults*; Josey-Bass: San Francisco, CA, USA, 2002.
45. Nielsen, K.; Noblet, A. Organizational interventions: Where are we, where do we go from here? In *Organizational Interventions for Health and Well-Being: A Handbook for Evidence-Based Practice*; Nielsen, K., Noblet, A., Eds.; Routledge: Oxford, UK, 2018; pp. 1–23.
46. McLellan, D.L.; Cabán-Martinez, A.J.; Nelson, C.C.; Pronk, N.P.; Katz, J.N.; Allen, J.D.; Davis, K.L.; Wagner, G.R.; Sorensen, G. Organizational Characteristics Influence Implementation of Worksite Health Protection and Promotion Pro-grams: Evidence From Smaller Businesses. *J. Occup. Environ. Med.* **2015**, *57*, 1009–1016. [CrossRef]
47. Cherniack, M.; Morse, T.; Henning, R.; Seidner, A.; Punnett, L. Health promotion site selection blues: Barriers to participation and implementation. *J. Occup. Environ. Med.* **2010**, *52*, 626–634. [CrossRef]
48. Hunt, M.K.; Lederman, R.; Stoddard, A.M.; LaMontagne, A.D.; McLellan, D.; Combe, C.; Barbeau, E.; Sorensen, G. Process evaluation of an integrated health promotion/occupational health model in WellWorks-2. *Health Educ. Behav.* **2005**, *32*, 10–26. [CrossRef]
49. Pronk, N.P.; Katz, A.S.; Lowry, M.; Payfer, J.R. Reducing occupational sitting time and improving worker health: The Take-a-Stand Project, 2011. *Prev. Chronic Dis.* **2012**, *9*, E154. [CrossRef]
50. von Thiele Schwarz, U.; Augustsson, H.; Hasson, H.; Stenfors-Hayes, T. Promoting employee health by integrating health protection, health promotion, and continuous improvement: A longitudinal quasi-experimental intervention study. *J. Occup. Environ. Med.* **2015**, *57*, 217–225. [CrossRef]
51. Amabile, T.; Kramer, S.J. The Power of Small Wins. *Harv. Bus. Rev.* **2011**, *89*, 70–80.
52. Lewis, C.; Darnell, D.; Kerns, S.; Monroe-DeVita, M.; Landes, S.J.; Lyon, A.R.; Stanick, C.; Dorsey, S.; Locke, J.; Marriott, B.; et al. Advancing efficient methodologies through community partnerships and team science. In *Implementation Science, Proceedings of the 3rd Biennial Conference of the Society for Implementation Research Collaboration (SIRC) 2015, Seattle, WA, USA, 24–26 September 2015*; BioMed Central Ltd: London, UK, 2016; Volume 11, (Suppl. 1), p. 85. [CrossRef]
53. Nadeem, E.; Gleacher, A.; Beidas, R.S. Consultation as an implementation strategy for evidence-based practices across multiple contexts: Unpacking the black box. *Adm. Policy Ment. Health* **2013**, *40*, 439–450. [CrossRef]
54. Quelch, J.; Boudreau, E.C. *Building a Culture of Health: A New Imperative for Business*; Springer International Publishing: Cham, Switzerland, 2016.
55. Institute of Medicine. *Integrating Employee Health: A Model Program for NASA*; National Academy Press: Washington, DC, USA, 2005.
56. Hunnicutt, D. Evaluation: Why, what, how, and when you should evaluate your wellness program. *Absol. Advant.* **2007**, *6*, 12–19.
57. Escoffery, C.; Lebow-Skelley, E.; Haardoerfer, R.; Boing, E.; Udelson, H.; Wood, R.; Hartman, M.; Fernandez, M.E.; Mullen, P.D. A systematic review of adaptations of evidence-based public health interventions globally. *Implement. Sci.* **2018**, *13*, 1–21. [CrossRef]
58. Tamers, S.L.; Chosewood, L.C.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.C. Total Worker Health® 2014–2018: The Novel Approach to Worker Safety, Health, and Well-Being Evolves. *Int. J. Environ. Res. Public Health* **2019**, *16*, 321. [CrossRef]
59. National Institute of Occupational Safety and Health. *Fundamentals of Total Worker Health Approaches: Essential Elements for Advancing Worker Safety, Health, and Well-Being*; US Department of Health and Human Services; Centers for Disease Control and Prevention; National Institute for Occupational Safety and Health: Cincinnati, OH, USA, 2016.
60. Hudson, H.L.; Nigam, J.A.S.; Sauter, S.L.; Chosewood, L.C.; Schill, A.L.; Howard, J. *Total Worker Health*; American Psychological Association: Washington, DC, USA, 2019.

61. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef] [PubMed]
62. Dennerlein, J.T.; Burke, L.; Sabbath, E.L.; Williams, J.A.R.; Peters, S.E.; Wallace, L.; Karapanos, M.; Sorensen, G. An Integrative Total Worker Health Framework for Keeping Workers Safe and Healthy During the COVID-19 Pandemic. *Hum. Factors* **2020**, *62*, 689–696. [CrossRef] [PubMed]
63. Pronk, N.P.; McLellan, D.L.; Dennerlein, J.T.; Anderson, P.; Karapanos, M.; Nagler, E.; Schmidt, D.; Spoonheim, J.; Wallace, L.M.; Sorensen, G. Building Capacity for Integrated Occupational Safety, Health, and Well-Being Initiatives Using Guidelines for Total Worker Health®Approaches. *J. Occup. Environ. Med.* **2021**, *63*, 411–421. [CrossRef]
64. Sorensen, G.; Pednekar, M.; Cordeira, L.S.; Pawar, P.; Nagler, E.M.; Stoddard, A.M.; Kim, H.Y.; Gupta, P.C. Effects of a worksite tobacco control intervention in India: The Mumbai worksite tobacco control study, a cluster-randomised trial. *Tob. Control* **2017**, *26*, 210–216. [CrossRef] [PubMed]

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Evaluation of the HearWell Pilot Program: A Participatory *Total Worker Health*® Approach to Hearing Conservation

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Abstract: Our objective was to pilot test HearWell, an intervention created to preserve hearing among highway maintainers, by using a participatory *Total Worker Health*® (TWH) approach to designing, implementing and evaluating interventions. Regional maintenance garages were randomized to control (n = 6); HearWell (n = 4) or HearWell Design Team (n = 2) arms. Maintainer representatives from the HearWell Design Team garages identified barriers to hearing health and collaborated to design interventions including a safety leadership training for managers, a noise hazard management scheme to identify noise levels and indicate the hearing protection device (HPD) needed, and a comprehensive HearWell training video and protocol. These worker-designed interventions, after manager input, were delivered to the HearWell Design Team and the HearWell garages. Control garages received standard industry hearing conservation training. Periodic surveys of workers in all 12 garages collected information on the frequency of HPD use and a new hearing climate measure to evaluate changes in behaviors and attitudes over the study period and following interventions. An intention-to-treat approach was utilized; differences and trends in group HPD use and hearing climate were analyzed using a mixed-effects model to account for repeated measures from individual participants. The HearWell Design Team maintainers reported the highest frequency of HPD use. Hearing climate improved in each group 6 months following intervention implementation, with the largest increase and highest value for the HearWell Design Team workers. The HearWell pilot intervention showed promising results in improving HPD use through a participatory TWH approach to hearing conservation. Furthermore, results suggest that employee participation in hearing conservation programs may be necessary for maximal effectiveness.

Keywords: *Total Worker Health*; hearing conservation; hearing protection device; safety climate

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1. Introduction

Despite over 30 years of occupational noise regulation in the United States (US), noise-induced hearing loss (NIHL) remains one of the most common self-reported occupational illnesses or injuries [1]. While identifying the exact number of noise-exposed workers in the US is difficult, it is estimated that approximately 22 million workers are exposed to high levels of noise at work with approximately 25% of all workers reporting hazardous workplace noise exposure at some point in their career [2,3]. Among workers with a history of noise exposure, approximately one-third have NIHL documented through

audiometric evaluation and 16% have hearing impairment [4]. In addition to NIHL, high noise exposures are associated with myriad health effects including tinnitus, cardiovascular disease, and sleep disturbances [4]. At the workplace, high noise levels and hearing loss contribute to communication difficulties, safety concerns, and poor job performance [4]. Diminished ability to hear is a disability in itself; hearing loss also greatly impacts quality of life and is strongly associated with depression [5].

While noise exposures were recognized as an occupational hazard for centuries, in 1983 the US—through the Occupational Safety and Health Administration (OSHA) Hearing Conservation Amendment–required hearing conservation programs (HCP) for worksites where noise exposures meet or exceed 85 dBA over an 8-h time-weighted average (TWA) [6]. The OSHA Hearing Conservation Amendment mandates five key components of an HCP: annual audiometry, noise monitoring and exposure control, employee training, provision of hearing protection devices (HPD), and recordkeeping. However, a systematic review indicates a paucity of rigorous research demonstrating the effectiveness of HCP on reducing NIHL [7]. Thus, it remains unclear whether the current burden of NIHL is a reflection of the lack of HCP among noise-exposed workers or the ineffectiveness of HCP in preventing NIHL. Research suggests that certain elements of an HCP appear to be key factors in achieving or failing to achieve program effectiveness, such as management commitment and counseling of workers about NIHL [8].

OSHA's Hearing Conservation amendment is a performance standard, where the content of the HCP is prescribed, and workplaces may use methods of their choosing to implement their HCP. One approach to addressing worker health is through active employee engagement, a cornerstone of participatory ergonomics and the *Total Worker Health*® (TWH) approach, where workers use their expertise to design or change their workplace, work organization and/or jobs to improve physical and psychosocial working conditions [9,10]. In fact, many argue that employee engagement is a core component of an integrated TWH program [11]. Furthermore, an integrated approach to address worker health, safety and well-being, consistent with the TWH approach, was suggested by the National Institute for Occupational Safety and Health (NIOSH) as paramount in addressing the challenges put forth by future work issues [12].

The Center for the Promotion of Health in the New England Workplace (CPH-NEW), a NIOSH TWH Center of Excellence, has designed the Healthy Workplace Participatory Program (HWPP) as a TWH approach for addressing worker health, safety and well-being issues and concerns in which employee engagement is a cornerstone. At the core of the HWPP is the active participation of employees through worker teams and a structured root-cause analysis approach using the Intervention Design and Analysis Scorecard (IDEAS) Tool [13]. The IDEAS approach builds interventions along with a business case for the importance of the worker health, safety and well-being issues that are being addressed. This approach was used in a variety of workplace settings including corrections [14], real estate management [15], state agencies [15], healthcare [16], and retail workplaces [17] to address a variety of health, safety and well-being concerns: burnout [15], blood pressure [17], healthy weight [17,18], work overload [19], sleep [20], and indoor air quality [11].

Our objective was to design, implement and evaluate elements of an HCP, called "HearWell," using a participatory TWH approach based on CPH-NEW's HWPP. While the IDEAS process can be used to address any well-being issue, for the purpose of this study workers were asked to focus exclusively on hearing health. We hypothesized that, compared to a standard HCP, a participatory program would improve hearing-related attitudes and behaviors. Furthermore, we expected that workgroups with a higher level of participation would show the greatest improvements in attitudes and behaviors related to hearing loss prevention which would represent a more lasting solution.

2. Materials and Methods

2.1. Study Design and Population

We used a cluster randomized control design (Figure 1) to test study hypotheses. We engaged workers within a New England state's Department of Transportation (DOT), specifically highway "maintainers" who are involved in road construction and maintenance activities and are regularly exposed to high noise levels. For example, during the routine task of cutting brush, we observed a mean (standard deviation) noise exposure of 86.2 (2.6) dBA TWA_{8hr} over the work shift and 92.1 (7.6) dBA L_{eq} while using the chainsaw [21]. Maintainers work out of regionally located maintenance garages. Garages were randomized as either control that received elements of the standard HCP, or HearWell that received HCP elements selected and re-designed using the HWPP. HearWell garages were further differentiated based on the presence of worker Design Teams that created interventions. Garages, rather than individuals, were assessed at each phase of enrollment and allocation.

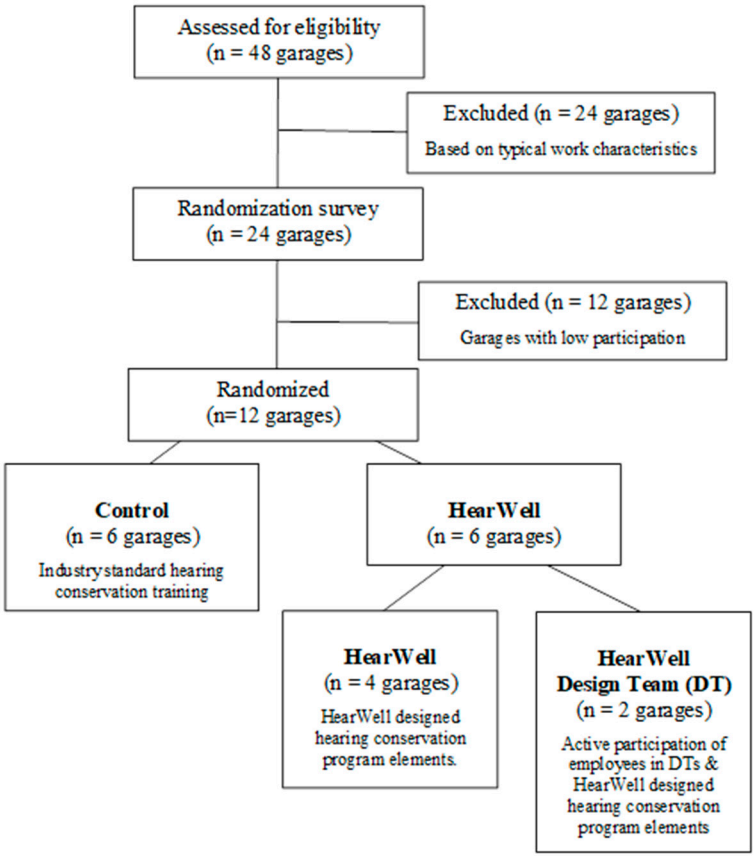


Figure 1. Flow diagram of the allocation of Department of Transportation maintenance garages into study arms.

The HearWell intervention was developed using the HWPP with a focus on hearing health. While traditional HCPs required by OSHA require several elements, given the limited scope of this project (budget and timeline) and with the direction of the Design Team, HearWell focused on the training and hearing protection components of the HCP. The other components of an HCP including audiometry, noise monitoring and control, and record-keeping, were already being addressed by the DOT's Health and Safety Department. With respect to policy, at the time of the study, the DOT had a general policy requiring ear protection when working in an environment with sound levels that exceed 85 dB. Ear protection in the form of muffs and earplugs was issued to all maintainers. Yet, clarification on when worker noise exposures exceeded this level as well as the specific hearing pro-

tection required was at the discretion of the supervisors. The HearWell study period was from February 2016 through August 2019 (Table 1). The UConn Health Center Institutional Review Board reviewed and approved all research activities, and all participants provided informed consent.

Table 1. HearWell Study period timeline and major activities.

Year (s)	Month (s)	Participants	Activities
2016	Feb	SC	HearWell start-up
2016	Apr–May	Full Workforce [1]	Eligibility assessment, randomization survey
2017	Mar–May	DT [2]	Team formation and training
2017	May–Oct	DT [2]	IDEAS Steps 1–5
2017/2018	Dec–Jan	Workforce [3]	Pre-intervention survey
2018	Apr–Nov	SC, DT [2]	Intervention development, IDEAS Steps 5–7
2018	Oct	Supervisors [4]	Supervisor training
2019	Jan–Feb	Workforce [3]	HearWell or control training; Pre- and post-training surveys
2019	Jun–Aug	Workforce [3]	Post-intervention survey

SC, Steering Committee; DT, Design Team; IDEAS, Intervention Design and Analysis Scorecard. [1] N = 24 garages. [2] N = 2 HearWell garages. [3] N = 12 garages (control, HearWell, HearWell Design Team); [4] N = 6 garages (HearWell, HearWell Design Team).

2.2. Randomization of Study Sites

Maintainers worked out of 48 garage facilities spread evenly across the state. The 48 garages are classified into 8 sections or groupings based on geography. In consultation with management and for the purpose of this study, 24 garages in 4 sections were chosen based on similarity of work tasks after considering the types of roadways and typical weather events within each section (Figure 1). For randomization, researchers conducted a survey at each of these 24 garages. In light of the participatory foundations of the HWPP, the 12 garages with the highest participation in the survey (84 to 100% of on-site workers participating) were selected for randomization among the study arms (Figure 1). A random number generator was used to assign the 12 garages into groups: control, which received the standard DOT HCP elements, and HearWell, which received the HearWell HCP elements. Among the HearWell garages, the first two garages selected via random number were designated to host worker Design Teams and were classified as HearWell Design Team (Figure 1).

2.3. Implementation of the Healthy Workplace Participatory Program (HWPP)

Using the participatory methodology outlined by CPH-NEW [11,17], we implemented key components of the HWPP. Program elements included a 2-committee structure with a worker Design Team in two garages and a state-wide Steering Committee of representatives from Health and Safety, Operations, and Finance. Importantly, Steering Committee members supported the project by allocating paid work time for Design Team members to meet regularly and authorizing the workforce surveys at all 12 garages. Research staff served as the program facilitators, and an internal health and safety manager served as the program champion. Throughout the study period, the program champion updated the Steering Committee of the Design Team regarding activities. In addition to the study start-up, the Steering Committee was actively engaged during the design and implementation of the HearWell interventions (Table 1).

Supervisors at the two HearWell Design Team garages were each asked to recruit five workers to form the worker Design Teams. The Steering Committee and Design Teams worked together through the 7-step IDEAS process. The Design Teams each held 20 1-h meetings, beginning in March 2017 and ending in November 2018 (Table 1). In meetings 1–4, occurring every two weeks, Design Team members were trained and participated in a focus group assessing their beliefs, attitudes and opinions about hearing and noise exposure. In meetings 5–12, approximately monthly, Design Team members went through

Steps 1–5 of the IDEAS process [13]. Briefly, Step 1 of the IDEAS process used a structured root-cause analysis approach to identify the factors contributing to hearing loss. Step 2 developed intervention objectives and activities to address the contributing factors. Steps 3 and 4 set and applied selection criteria to compare the strengths and weaknesses of interventions being considered by the Design Team.

The development, selection, implementation and evaluation of interventions occurred in IDEAS Steps 5–7. In collaboration with the Steering Committee, the Design Team and research staff developed interventions across four months and five Design Team meetings. The intervention included multiple components including supervisor training, a noise hazard management scheme, and a HearWell training video and presentation. Design Team members from both garages were actively engaged in drafting each intervention component. The noise hazard scheme was reviewed and adapted based on members' suggestions. Workers suggested and edited a maintainer-specific scenario within the supervisor safety training materials to emphasize HPD use. To create the HearWell training, Design Team members reviewed numerous industry videos and presentations and assessed which elements and content they found most effective. They also discussed the relative merits of different methods to deliver the training (i.e., in-person, video, toolbox talk, and workbook).

The supervisor training was implemented in October 2018 at the 6 HearWell garages (those with and without Design Teams). Supervisors in the control garages received no additional training. In January through February of 2019, the HearWell worker training and HearWell noise hazard scheme interventions were both implemented among HearWell garages (Table 1). Workers within control garages received a standard hearing conservation training video at this time.

2.4. Data Collection

Survey data collection occurred at four time points across the study period: randomization, pre-intervention, training and post-intervention (Table 1). Surveys were prepared in Qualtrics™ and administered on electronic tablets. All surveys were completed during work time at the beginning or end of the work shift. A convenience sample of workers present on the day of the survey was collected at each time point. The number of garages surveyed varied by study period. In Spring 2016, the randomization survey was distributed to workers in 24 garages. In Winter 2018, the pre-intervention survey was administered among the 6 control, 4 HearWell, and 2 HearWell Design Team garages. In Winter 2019, the same 12 garages were surveyed pre- and post-training. In Summer 2019, 5 control, 4 HearWell, and 2 HearWell Design Team garages were surveyed with the 6-month post-intervention survey. One control garage was not surveyed due to staffing and work project constraints.

Each survey included items to assess demographics and job history, as well as the frequency of HPD use [21]. Workers were asked "If you use noisy tools or are in noisy areas, do you use hearing protectors (e.g., earplugs or earmuffs)?" rated on a 6–point frequency scale from rarely or never (1) to always (6).

The Design Team suggested additional survey items for the pre-intervention, training, and post-intervention surveys. A new hearing climate scale was modeled on the concept of safety climate as a way to capture attitudes about noise and hearing prevention within the workgroup. The hearing climate scale was validated prior to its use [22].

In order to address the bias inherent with asking workers to report on their own HPD use frequency, the Design Team included a question on frequency of HPD use by co-workers: "How often do your co-workers wear hearing protectors (e.g., earplugs or earmuffs) when they use noisy tools or are in noisy areas?" This used the same 6–point frequency scale as the self-assessment, from rarely or never (1) to always (6). On the pre- and post-intervention surveys, workers were also asked how often they used HPD during specific home or leisure tasks and activities. Workers used the same 6–point frequency scale or indicated that they did not perform such tasks or activities. Attitudes, beliefs, and

behaviors about hearing protection were measured pre- and post-training using the NIOSH Hearing Protection Beliefs, Attitudes and Behaviors Items and Scales (BAPHLS) [23,24] with each item coded on a 5-point Likert scale from 1 (totally disagree) to 5 (totally agree). BAPHLS outcomes were summarized into 7 subscales (see results).

2.5. Data Analysis

An intent-to-treat approach was used in evaluating differences between control, HearWell, and HearWell-Design Team arms. The following hypotheses were tested:

Hypothesis 1 (H1). *HearWell and HearWell Design Team garage workers will show changes in HPD beliefs, attitudes and behaviors following the HearWell training.*

Hypothesis 2 (H2). *Compared to the control group at randomization, workers in the HearWell and HearWell Design Team garages will report an increase in HPD use frequency following supervisory training (pre-training) and 6 months following the HearWell training (post-training).*

Hypothesis 3 (H3). *Compared to the control group at pre-training, workers in the HearWell and HearWell Design Team garages will show an increase in hearing climate (attitudes about noise and hearing prevention) 6 months following the HearWell training (post-training).*

Hypothesis 4 (H4). *Compared to the control group at pre-intervention, workers in the HearWell and HearWell Design Team garages will show an increase in at-home HPD use (post-intervention).*

We assessed changes in HPD beliefs, attitudes and behaviors following the training by performing paired t-tests on pre- and post- values for each subscale by each independent intervention scenario group. We assessed the impact of the HearWell intervention using mixed linear modeling while accounting for repeated measures among participants. Analyses were conducted in SAS 9.4 using PROC MIXED with a REPEATED statement. A categorical variable for the survey period (randomization, pre-intervention, pre-training and post-intervention) was included in the model along with a variable to indicate intervention scenario (control, HearWell, HearWell Design Team). For each analysis, the control group at the earliest survey period served as the reference. Reported *p*-values represent the comparison of the selected survey period and intervention arm to the control group at the earliest survey period. In sensitivity analyses, stratified analyses were performed by the intervention group, with the earliest survey period serving as the reference. In addition to the main outcome variables of interest (HPD use frequency and hearing climate), a sensitivity analysis was performed by examining the difference in reported frequency of HPD use among co-workers. All analyses were conducted in SAS 9.4.

3. Results

3.1. The IDEAS Process

The two HearWell Design Teams completed the IDEAS process Steps 1 through 5 in parallel through seven meetings each. The major results are presented in Table 2. Briefly, in Step 1, Design Team members identified root causes of poor hearing health: high noise exposures due to noisy equipment and long shifts; not knowing when to wear HPD given the varying tasks and equipment used, and inconsistent supervisor policy enforcement and support for wearing HPD and reducing noise exposures (Table 2).

In Step 2, Design Team members strategized a full range of solutions without the consideration of feasibility. Solutions fell within the areas of noise reduction, policy, noise awareness, hearing culture, HPD, training, and work practices (Table 2). Researchers served as subject matter experts in hearing conservation, providing background information regarding hearing or intervention options when asked. In Steps 3 and 4, the Design Team members set and applied selection criteria to the proposed solutions to narrow and further refine the solutions under consideration. They sought solutions that were accessible to all maintainers and were also effective in protecting long-term hearing. They recognized the

limited budget for the solutions as well as potential resources including trainers as well as the knowledge of the Design Team members themselves. In the end, Design Team members had crafted a set of solutions for the Steering Committee to consider implementing.

Table 2. Summary of selected IDEAS Toolkit Step results from HearWell Design Teams addressing hearing health at two transportation maintenance garages.

Activity	Outcome
Identify Health and Safety Problems; Contributing Factors Attributed to Hearing Loss (IDEAS Step 1)	
	High noise exposures from loud equipment. Extended noise exposures due to long shifts and specialization of tasks requiring no variation in noise exposures. HPD: hot, uncomfortable, limited options, unsure of proper use/replacement. Knowledge gap: unsure of when to use HPD, noise levels of equipment. Safety climate: lack of supervisor and coworker support for wearing HPD and reducing noise exposures.
Brainstorm Solution Activities (IDEAS Step 2)	
Noise reduction	Buy less noisy equipment. Retrofit mowers and vehicles to reduce in-cab noise exposures.
Policy	Upgraded, written policy specific to hearing protection, with detail on equipment/situations that require HPD. Enforcement for policy should including escalation of consequences (e.g., verbal warning for 1st offense, then written warning) and a transition period to counsel workers.
Noise Awareness	Color-coded system to easily identify noise levels. Stickers on equipment to identify noise levels.
Hearing Culture	Increase coworker HPD use support and awareness of bystander noise exposures. Support of HPD use to create consistency in hearing culture across garages. Hearing and noise awareness campaign (e.g., HearWell week/day/month) with hearing/noise theme tailgate talks and training.
HPD	Posters, information on hearing, HPD use and dangerous noise levels. More HPD options to increase comfort and fit. HPD allows for communication and warning signal awareness.
Training	Supervisor training on HPD policy and enforcement. All worker in-depth training with Design Team recommended content. Add training on noise and HPD use to existing tailgates (e.g., a tailgate on chainsaw blade safety should include HPD use). Design Team members can serve as hearing ambassadors to assist in training and best practice demonstration.
Work practices	Use a safety spotter to relay warning signals when over protection from HPD may diminish ability to hear critical noises. Daily work orders should specify noise level and HPD required based on equipment or task assigned.
HearWell Intervention Components (IDEAS Step 5)	
Supervisor Training	Supervisor training on safety leadership skills including HPD use support.
Noise Hazard Scheme	Color-coded system to identify noise level and required HPD based on task or equipment.
HearWell Training	A 30-min video with OSHA-required and HearWell Design Team identified topics, including job-specific scenarios and context delivered in-person with a hands-on demonstration of PPE use.

3.2. HearWell Intervention Components

In IDEAS Step 5, the Steering Committee and Design Team worked together to select, adapt and create three main HearWell intervention components; supervisor training, a noise hazard management scheme, and the HearWell training (Table 2).

The goal of the supervisor training was to increase leadership support of hearing and HPD use and ultimately create a safe and consistent environment supportive of hearing health. The Foundations for Safety Leadership (FSL) Training was identified as a relevant component as its goal is to teach construction supervisors leadership skills to strengthen

workplace safety climate and reduce adverse safety outcomes [25]. With permission from FSL creators, the program materials were adapted with formatting and minor content editing for garage supervisors and crew leaders. In addition, we created and implemented a scenario specific to transportation maintenance noise hazards during brush cutting. The FSL training was a 2.5 h, instructor-led training that included videos along with a workbook for participants.

The goal of the noise hazard management scheme was to easily identify noise levels of individual equipment models and indicate the required HPD for each. The Design Team, Steering Committee and researchers developed a color-coded noise hazard scheme that allows workers to recognize equipment and task noise levels and choose the appropriate HPD [21]. Briefly, the noise hazard scheme identified noise level ranges (red, above 105 dBA; orange, 90–105 dBA; and yellow, 85–90 dBA) and the corresponding HPD required (red, muffs and plugs; orange, muffs or plugs; yellow, muffs or plugs or ear caps). The noise hazard scheme was developed using a participatory and iterative process. Ultimately, the workers opted for a scheme that incorporated the noise levels of each piece of equipment, regardless of exposure time and the selection of HPD based on what was already available to them [20]. The scheme complemented and further clarified the existing noise policy, requiring HPD use when noise exposures exceeded 85 dB.

The goal of the HearWell training was to educate workers (maintainers and supervisors) on the noise hazard scheme as well as the content required by OSHA and other information suggested by Design Team members. Topics required by OSHA (CFR 1910.95) were incorporated into the training including: (a) the effects of noise on hearing; (b) the purpose of hearing protectors, the advantages, disadvantages, and attenuation of various types and instructions on hearing protectors selection, fit, use, and care; and (c) the purpose of audiometric testing, and an explanation of the test procedures. In addition to training on the noise hazard scheme, Design Team additions included: (a) ways to reduce noise exposure (optimizing distance from noise source, trading off noisy jobs); (b) assessing noise levels (a noise thermometer mapping noise levels of common tools/equipment; the "shouting test" to assess if noise levels are beyond 85 dBA; and (c) ways that co-workers can support HPD use and practices to reduce noise exposures. The Design Teams chose a video format to provide a consistent experience and allow for easier rollout. Following the video, workers suggested a demonstration of proper HPD use including earplug insertion and muff adjustment as well as time for questions and answers.

3.3. Survey Results

A total of 271, 163, 140 and 95 workers were surveyed at randomization, pre-intervention, pre-training, and post-intervention, respectively. Survey participation at randomization averaged 81% among the 12 garages. Among the randomized control and HearWell garages, high participation was maintained for the pre-intervention, pre-training, and post-intervention surveys (means 94%, 96%, 86%, respectively). A total of 288 participants were surveyed with 131 (46%) providing one survey, 78 (27%) providing 2 surveys, 52 (18%) providing 3 surveys and 27 (9%) providing 4 surveys. Survey respondents were predominantly male, White, and maintainers, with a mean age of 44 years and a mean of 11 years in the current job (Table 3). All characteristics remained similar across surveys (Table 3). Among surveyed workers, 20 changed garages across the study period; 11 workers moved from the excluded garages to the intervention garages, 4 workers had no change in the intervention arm, 2 workers changed from control to HearWell, 2 workers changed from HearWell Design Team to control, and 1 worker changed from HearWell to control.

Table 3. Population characteristics across survey periods at 12 Department of Transportation garages: Data from worker surveys.

	Randomization	Pre-Intervention	Pre-Training	Post-Intervention
	n (%) or Mean (SD)	*n* (%) or Mean (SD)	*n* (%) or Mean (SD)	*n* (%) or Mean (SD)
Male	254 (97)	156 (97)	136 (99)	91 (96)
Racial category				
White	194 (74)	113 (69)	97 (70)	67 (70)
Black	34 (13)	19 (11)	19 (14)	14 (15)
American Indian/Alaska Native; Asian; multiple or unknown races	34 (13)	26 (16)	22 (16)	14 (15)
Age (years)	44 (11)	44 (10)	44 (10)	44 (10)
Job tenure (years)	11 (6)	12 (11)	10 (9)	11 (10)
Job Title				
Maintainer	227 (87)	135 (85)	110 (84)	77 (84)
Supervisor	36 (13)	24 (15)	21 (16)	15 (16)

Eighteen supervisors and crew leaders attended the supervisors' training. In total 73 workers received the HearWell training, and 72 workers received the control training. Participation in the pre-training survey was high: 99% (n = 72) of HearWell garage workers and 94% (n = 68) of control garage workers. The majority (84%) of workers who received the training were maintainers; three workers did not indicate a job title (Table 3).

Table 4 indicates the pre- and post-training beliefs, attitudes and values for workers by intervention arm (Hypothesis 1). There were significant changes in some, but not all of the BAPHLS subscales for the HearWell trained workers in both the HearWell and HearWell Design Team arms. Specifically, maintainers who had received the HearWell training perceived lower barriers to HPD use afterward (Table 4). Workers in the HearWell intervention garages also reported increased self-efficacy in HPD use and increased social norms around hearing protection (Table 4). Workers receiving the control training did not have meaningful changes in beliefs or attitudes about hearing protection, hearing and noise (Table 4).

Table 4. Hearing protection belief, attitudes and behaviors (BAPHLS) sub-scales pre- and post-training by intervention arm. Mean (standard deviation) of values from 5-point Likert scale from totally disagree (1) to totally agree (5). Values are bolded to indicate statistically significant differences. p-values are from paired t-test between pre- and post-values.

	Control			HearWell			HearWell Design Team		
	Pre	Post	p-Value	Pre	Post	p-Value	Pre	Post	p-Value
Barriers to preventive action (reverse coded)	3.33 (0.65)	3.32 (0.63)	0.89	**3.38 (0.60)**	**3.63 (0.79)**	**0.01**	**3.36 (0.63)**	**3.65 (0.65)**	**<0.0001**
Self-efficacy	4.00 (0.56)	4.10 (0.54)	0.12	**3.89 (0.70)**	**4.13 (0.69)**	**0.04**	4.06 (0.52)	4.17 (0.54)	0.16
HPD behavior intent	4.07 (0.67)	4.12 (0.65)	0.29	3.93 (0.71)	4.01 (0.65)	0.43	4.33 (0.52)	4.27 (0.42)	0.33
Social norms	3.89 (0.52)	3.87 (0.52)	0.66	**3.64 (0.63)**	**3.84 (0.65)**	**0.001**	4.06 (0.36)	4.07 (0.38)	0.87
Susceptibility to hearing loss	4.13 (0.54)	4.13 (0.55)	0.89	4.13 (0.52)	4.19 (0.61)	0.39	**4.14 (0.51)**	**4.27 (0.41)**	0.04
Benefits of protective action	4.35 (0.53)	4.46 (0.57)	0.12	4.30 (0.61)	4.39 (0.58)	0.39	4.34 (0.51)	4.39 (0.53)	0.64
Severity of hearing loss consequences	4.51 (0.62)	4.42 (0.65)	0.24	4.46 (0.69)	4.35 (0.66)	0.27	4.23 (0.68)	4.27 (0.71)	0.73

To assess intervention impact, we evaluated the frequency of HPD use for each survey by intervention arm (Hypothesis 2) using a mixed-effects model to account for repeated measures of participants across surveys. Figure 2 presents the reported frequency of HPD use by maintainers for each survey by control, HearWell and HearWell Design Team

intervention arms. Following randomization, the HearWell Design Team garage workers reported meaningful increased HPD use frequency after the Design Teams were formed (pre-intervention) with a continued increase in HPD use up to 6-months post-intervention. Although the HearWell garages workers also reported an increase in HPD use frequency, there was no significant statistical difference as compared to the control except for at randomization where workers in the HearWell garages reported a significantly lower frequency of HPD use as compared to the control. In sensitivity analyses, the scale point increase in HPD use frequency by intervention arm, from randomization to 6-months post-intervention, was calculated as 0.98 (95% CI: 0.30 to 1.67) for HearWell; 0.92 (95% CI: −0.10 to 1.93) for HearWell Design Team; and 0.43 (95% CI: −0.10 to 0.96) for control garage workers.

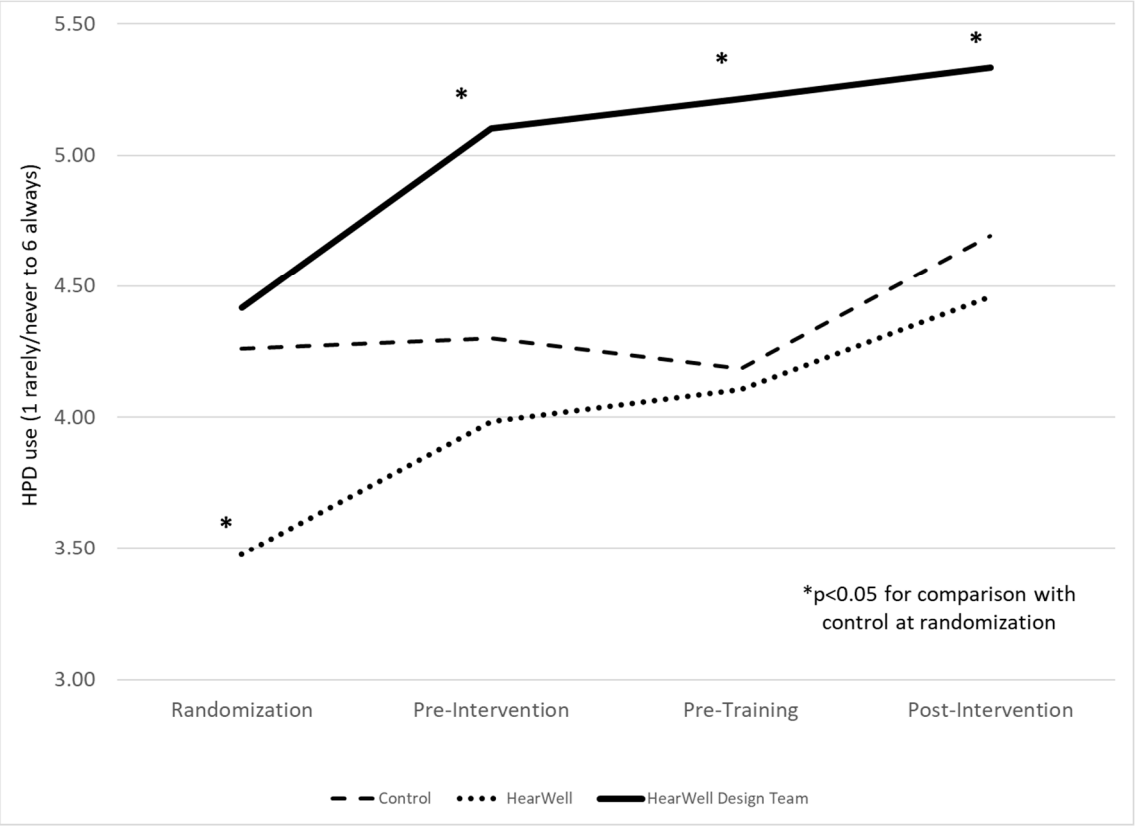


Figure 2. Reported frequency of HPD use across surveys by intervention arm among transportation maintainers. Mixed linear models accounting for repeated measures were used to evaluate difference between survey periods and intervention arms. Statistical significance ($p < 0.05$) is presented for the comparison between each time period, by intervention arm with respect to the control values at randomization.

In a sensitivity analysis, HPD use frequency by co-workers was examined as an alternative to self-report (data not shown). Co-worker HPD use frequency was consistently lower than self-reported HPD use frequency, with a mean (SD) of 4.13 (1.19); 4.37 (1.46); and 5.0 (0.94) for control, HearWell and HearWell Design Team garage workers, respectively at post-intervention. Yet, similar trends were observed over time and by the intervention arm. The scale point increase in HPD use frequency by intervention arm from pre-intervention (when the co-worker HPD use frequency variable was first introduced) to 6-months post-intervention was calculated as 0.74 (95% CI: 0.12 to 1.29) for HearWell, 0.75 (95% CI: −0.01 to 1.50) for HearWell Design Team, and 0.55 (95% CI: 0.03 to 1.06) for control garage workers.

We also assessed hearing climate at pre-training and post-intervention by intervention arm (Hypothesis 3). Using linear mixed models with the control at pre-training as a reference, we found no meaningful difference in hearing climate by intervention arm

at pre-training (Table 5). However, as compared to control at pre-training, meaningful improvements in hearing climate were observed across all intervention arms at 6-months post-intervention. Furthermore, the HearWell Design Team garages showed the largest improvement, up 24% from pre-training to post-intervention, and the highest value at the end of the study (Table 5).

Table 5. Hearing climate by intervention arm pre-training and post-intervention. *p*-values represent the statistical significance as compared to the control at pre-training using a mixed linear model.

	Pre-Training		Post-Intervention	
	Mean (SD)	*p*-Value	Mean (SD)	*p*-Value
Control	3.26 (0.76)	Reference	3.89 (0.79)	0.0003
HearWell	3.07 (0.77)	0.24	3.74 (0.92)	0.005
HearWell Design Team	3.18 (0.65)	0.65	3.94 (0.77)	0.001

For Hypothesis 4, with the exception of one activity (snow blowing), there were no meaningful differences in at-home HPD use among study arms, at pre-intervention (Table 6). The frequency of at-home HPD use increased for each intervention arm at 6-months post-intervention with the exception of chainsaw use and leaf blowing, which had the highest frequency of use at pre-intervention.

Table 6. Self-reported at-home hearing protection device use frequency (1 rarely/never to 6 always) by task and intervention arm. *p*-values represent the statistical significance as compared to the control at pre-intervention using a mixed linear model.

	Pre-Intervention				Post-Intervention			
	n	Mean	(SD)	*p*-Value	*n*	Mean	(SD)	*p*-Value
Mowing								
Control	67	2.52	(1.99)	Ref	32	4.06	(1.29)	0.0004
HearWell	55	2.80	(1.98)	0.41	26	3.96	(1.66)	0.002
HearWell Design Team	29	2.93	(2.02)	0.33	17	3.82	(1.70)	0.01
Chainsaw								
Control	66	3.41	(2.10)	Ref	25	3.64	(1.66)	0.62
HearWell	58	3.36	(2.05)	0.90	24	3.38	(1.88)	0.94
HearWell Design Team	27	4.04	(1.97)	0.18	14	3.57	(1.79)	0.78
Power tools								
Control	69	2.87	(1.87)	Ref	28	3.89	(1.17)	0.01
HearWell	57	3.04	(1.79)	0.59	30	3.57	(1.61)	0.07
HearWell Design Team	28	3.54	(1.86)	0.09	17	3.88	(1.32)	0.04
Leaf blowing								
Control	68	3.18	(2.09)	Ref	28	4.00	(1.41)	0.07
HearWell	58	3.26	(1.99)	0.81	27	3.70	(1.77)	0.24
HearWell Design Team	28	3.75	(2.01)	0.23	16	3.69	(1.85)	0.35
Plowing								
Control	52	1.37	(1.07)	Ref	34	5.09	(0.87)	<0.0001
HearWell	48	1.38	(1.14)	0.97	34	4.71	(1.47)	<0.0001
HearWell Design Team	23	1.39	(1.12)	0.93	19	4.84	(1.21)	<0.0001

Table 6. *Cont.*

	Pre-Intervention				Post-Intervention			
	n	Mean	(SD)	*p*-Value	*n*	Mean	(SD)	*p*-Value
Snow blowing								
Control	56	1.75	(1.48)	Ref	30	4.83	(1.29)	<0.0001
HearWell	49	2.24	(1.81)	0.12	30	4.87	(1.46)	<0.0001
HearWell Design Team	26	2.73	(2.07)	0.02	18	4.89	(1.13)	<0.0001
Motorized recreational vehicles								
Control	55	1.62	(1.30)	Ref	35	5.14	(0.60)	<0.0001
HearWell	52	1.42	(0.98)	0.42	33	4.48	(1.48)	<0.0001
HearWell Design Team	25	2.08	(1.87)	0.13	18	5.00	(0.84)	<0.0001
Music concerts and racetracks								
Control	54	1.78	(1.57)	Ref	35	4.74	(1.01)	<0.0001
HearWell	52	1.77	(1.46)	0.98	34	4.50	(1.01)	<0.0001
HearWell Design Team	24	2.29	(1.94)	0.17	18	4.33	(1.41)	<0.0001

4. Discussion

The HearWell intervention created by the worker Design Teams and Steering Committee was comprised of multiple components including supervisor leadership training, noise hazard management scheme, and customized hearing prevention training. These intervention components built upon an existing policy that directed workers when to wear HPD, yet offered little guidance on identifying high noise levels or selecting the correct HPD. The goals of the intervention were to increase HPD use; improve the hearing climate in the workplace, including supervisor and co-worker support for HPD use; and reduce ambient noise levels. While all three intervention arms (control, HearWell, HearWell Design Team) showed increases in HPD use over the study period, the only statistically significant increase was in the HearWell Design Team garage workers, who also reported the highest HPD use frequency 6 months after the intervention. Both HearWell and HearWell Design Team workers reported statistically significant increases in some beliefs and attitudes about hearing loss and hearing protection following the HearWell training. Interestingly, all three intervention arms showed an improvement in hearing climate as well as increases in at-home HPD use.

The training was shown to be an effective means of improving HPD use [26–28]. As was observed in HearWell, tailored training appears to be most effective in increasing HPD use [28]. Among construction workers, both train-the-trainer and expert-based 1-hour oral presentations with physical demonstration increased knowledge and self-efficacy and decreased barriers with respect to hearing and HPD [26]. Multi-component approaches, including hearing loss prevention training, refresher training along with noise-level indicators have been successful in increasing HPD use among construction workers [29].

4.1. Defining Integration for Total Worker Health

In addition to its ability to improve hearing-related outcomes, the success of HearWell can also be assessed in its ability to achieve a TWH approach. TWH is defined by the NIOSH as "policies, programs and practices that integrate protection from work-related safety and health hazards with promotion of injury and illness prevention efforts to advance worker well-being" [30]. While the fundamental approach in TWH programs is to adopt integrated approaches for promoting worker health and well-being, there remain different perspectives on what defining elements should be included [9,11,31,32]. As practiced in the HWPP introduced by CPH-NEW, there are four criteria that define the content and process of integrated TWH interventions: (i) emphasis on work interventions that prioritize

workplace contributors to poor well-being; (ii) assessment of both work and non-work risk factors; (iii) participatory engagement of workers; (iv) coordination of goals and activities across programs that support worker well-being [11]. These four criteria provide a useful context to assess the HearWell intervention in terms of its TWH approach.

4.1.1. Interventions That Prioritize Workplace Contributors to Poor Well-Being

A comprehensive TWH approach would prioritize workplace changes to promote well-being and can be expected to be consistent with the industrial hygiene hierarchy of controls with respect to noise exposure. This prioritizes eliminating noise exposure followed by buying quiet equipment [33] and tools, controlling the sources of noise, shortening workers' noise exposure time, and as a last resort use of HPD [34]. Although both the Design Teams and Steering Committee discussed initiatives that consider noise level when purchasing equipment, this was not prioritized due to cost and complexities in state purchasing cited as a large barrier. Rather, the HearWell program focused on reducing noise exposures through increased HPD use and education. This approach was desirable due to the low cost, available training resources and ability to impact all workers.

A TWH approach to hearing preservation also considers workplace policies, programs, and work organizations as well. HearWell addressed workplace hearing health and noise culture through the supervisor training in safety leadership, adapted from the FSL training for construction leaders [25]. The FSL training was shown to increase supervisor leadership skills, yet to date, changes in safety climate and reported supervisor practices by the crew have not been observed in prior evaluations of the training [35].

Additional facets of work organization addressed through the HearWell training included co-workers' support for reducing noise exposures. Design Team member suggestions for increasing co-worker support for HPD use included (a) keeping extra plugs in the truck for co-workers who forget them; (b) reminding and encouraging co-workers to use HPD, especially those new to the job; and (c) before starting up a noisy piece of equipment, warning co-workers to check that they are wearing HPD.

Administrative controls to reduce noise exposure were also part of HearWell interventions. Job rotation or switching off on noisy equipment such as the chainsaw was emphasized within the HearWell training. In addition, within Design Team garages, the noise hazard color scheme was used when assigning morning work orders. Supervisors and crew leaders added the color code corresponding to the noise level and required HPD to be added to the work order as a way to emphasize that HPD was required.

Overall, HearWell addressed workplace contributors to hearing health, yet the approaches that were adopted could have been further improved by prioritizing the hierarchy of controls with respect to noise exposure; namely noise exposure elimination or reduction at the sources over the use of HPD. Perhaps after a longer period of collaboration, members of the Design Team would no longer rule out the selection of quiet equipment due to feasibility concerns. Nonetheless, the reliance on HPD use to control noise exposure, while less desirable than engineering controls, is relatively commonplace and has been implicated as a driver of the high burden of hearing loss among noise-exposed workers [4]. HPD use can be improved upon by performing fit-testing or by choosing HPD that incorporates advanced attenuation technologies and/or features that promote communication between coworkers.

4.1.2. Assessment of Both Work and Non-Work Factors

A comprehensive TWH approach to promoting hearing health would also consider work and non-work risk factors for hearing loss. In addition to workplace noise exposures, non-work exposure to noise at home and in the community can also put workers at risk for hearing loss. Among maintainers within this study, noisy tasks such as lawn mowing or leaf blowing may occur concurrently at work and home increasing daily noise exposure levels. As part of the HearWell program, workers addressed at-home noise exposure by encouraging protective behavior outside of work and surveying at-home HPD use.

Interestingly, we observed an increase in at-home HPD use for the majority of tasks over time regardless of study arms. At-home HPD use for chainsaw use was high at pre-intervention and changed little post-intervention. However, prior to the pre-intervention survey, researchers conducted in-depth noise survey monitoring during tree removal [21], which includes chainsaw use, which may have contributed to the increase in at-home HPD use during this task at this time. Nevertheless, it is unclear why all arms showed an increase in at-home HPD use. It is possible that given the low frequency of at-home HPD use at pre-intervention, raising worker awareness about the benefits of hearing protection in general may have helped workers to reconsider HPD use at both work and home.

A comprehensive, TWH approach to hearing health considers work and non-work exposure to ototoxic chemicals promotes healthful living and monitoring activities including regular audiometric exams [36]. HearWell can be improved through a broader recognition of hearing health risk factors.

4.1.3. Participatory Engagement

Participatory engagement is the cornerstone of a TWH approach [11]. A participatory TWH approach is at the forefront of the HWPP and the IDEAS process, and therefore participatory engagement was central to the development, implementation and assessment of HearWell. The participatory process of HearWell was achieved through the direct engagement of maintainer representatives in the HearWell Design Team garages as well as the key decision-makers that made up the Steering Committee.

Participatory engagement appeared to have played a key role in the success of HearWell. HPD use frequency was highest across time and showed a statistically significant improvement for the HearWell Design teams compared to the control garages. The benefits of employing a participatory process when designing interventions are known to be multifold [10] and provide insights into the success of HearWell. Employee engagement in problem identification and solution development can help to identify issues that are most relevant to the workers, create interventions that are contextually appropriate, and identify a broader range of contributing factors such as work organization that can significantly affect workers [10]. This was definitely the case for HearWell where the Design Teams' intervention approach was multi-faceted. The intervention incorporated knowledge and behavior changes as well as work organization factors and was inclusive of supervisors as well as line workers. Training elements were tailored to the maintainers' job with realistic scenarios and tasks and also included videos in which peers described hearing loss consequences and HPD use challenges. Furthermore, the training purposefully addressed the noise and hearing concepts identified by the Design Team members as most relevant, including ways to reduce and assess noise exposure as well as the importance of co-worker support for noise reduction.

While both HearWell and HearWell Design Team garage members benefited from the HearWell interventions, direct employee engagement in TWH efforts promotes employee self-efficacy [10] which may have impacted HearWell garages with Design Teams more so than those garages without Design Teams. In fact, the HearWell Design Team members considered themselves "hearing ambassadors" and resources to their garages, which likely influenced co-worker HPD use frequency. The success of employee engagement is consistent with best practices for HCP where it was suggested that employee education and motivation are the keys to a successful HCP [37,38]. Employee engagement also benefits program sustainability [10]. While the long-term effects of HearWell are unknown, increased HPD use 6-months post-intervention is a promising indicator of program longevity. In addition to identifying barriers and risk factors for hearing health and crafting solutions, employee engagement should be a key component in continued program evaluation and improvement for increased program sustainability.

4.1.4. Coordination of Programs and Activities

A TWH approach involves the coordination of programs and activities that support worker well-being which can occur across a spectrum ranging from parallel programs with cross-promotion of specific activities to programs that are integrated through the common goal of promoting hearing health. Therefore, coordination to support hearing health may encompass a broad range of programs, policies and departments that support the reduction of noise exposure as well as the promotion of behaviors supporting hearing health.

Through the Steering Committee, the HearWell program advanced coordination of noise reduction strategies with other ongoing initiatives. The Steering Committee included representatives from finance as well as operations, and meetings focused on topics that included the importance of considering noise levels when buying new equipment, the need for a variety of HPDs for workforce fit and comfort, staffing needs, and best practices for limiting noise exposures. Notably, the HearWell interventions were limited by the small budget provided by the research staff for materials that included worksheets, posters, video production software and sample HPD. Higher expenditures for training and HPD fit-testing have been associated with reduced hearing loss documented through standard threshold shifts [39] and might have increased program effectiveness here. An integrated TWH approach to hearing health would also include coordination with health promotion and medical screening.

4.2. Limitations

The HearWell study had a number of noteworthy limitations. Ideally, the goal of an HCP is to preserve hearing health and reduce noise exposures. Yet, for the purpose of the HearWell pilot program, we did not have access to audiometry nor comprehensive noise exposure data for either motivating workers or evaluating HearWell effectiveness. Rather, HearWell relied on self-report measures, namely frequency of HPD use as well as hearing climate, to assess intervention effectiveness. While there is an inherent bias in self-report measures, in a sensitivity analysis we observed similar trends when workers were asked to report on co-workers HPD use frequency. Furthermore, small sample sizes may have limited our ability to detect differences in the groups. While garages were randomized at the study start, small sample sizes may have contributed to the unequal distribution of HPD use frequency, with the HearWell garages with the lowest HPD use at randomization. Some workers also switched between garages over the course of the study. Those transfers might have led to misclassification with regard to the intervention dose actually received. While the intention-to-treat analytic approach is appropriate for control of selection bias, misclassification could have biased these findings towards the null value, further limiting our ability to observe statistically significant associations. Yet despite these limitations, the HearWell pilot intervention showed promising results in improving HPD use through a participatory TWH approach to hearing conservation.

4.3. Implications for the Future of Work

The work performed by maintainers has and can be expected to change in the future due to myriad factors linked to climate change. In addition to increased outdoor heat exposures due to climate change-related heat increases, maintainers are also affected by the increasing frequency, duration and severity of extreme weather events caused by climate change [40]. With respect to HearWell, maintainers recognized that long shifts with extended noise exposure often resulting from storm work are a root cause of hearing loss. This suggests that regular involvement by the maintainer workforce in designing interventions as part of a TWH program will be necessary to address changes in their future work that can impact their health and well-being.

Consistent with the future of work trends across the workforce in general, maintainers are a multi-generational and aging workforce. The participatory methods employed in HearWell allowed for a range of worker attitudes, beliefs and needs to be heard and addressed. When the Design Team engaged in the IDEAS processes including root causes

analysis, this consensus-building process was able to incorporate the diversity of concerns present across the entire workforce. Importantly, the participatory design process and Design Team experience overall promoted skill development in the areas of interpersonal communication and group problem-solving, both of which are recognized as core competencies required for a successful future workforce [12].

5. Conclusions

The results of the present study indicate that the well-established occupational safety and health area of noise and hearing conservation can benefit from adopting a TWH approach. Employee engagement in hearing health promotion efforts was found to be an effective way of promoting behaviors that support hearing protection and instituting organizational changes in support of hearing conservation. Although employees benefitted from receiving the same interventions that were developed by employees elsewhere, maximum program impact was found at those sites in which employee design teams actively engaged in intervention design efforts. Thus, the present findings suggest that future hearing conservation programs should leverage employee participation for maximal effectiveness.

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References

1. Masterson, E.A.; Bushnell, P.T.; Themann, C.L.; Morata, T.C. Hearing Impairment Among Noise-Exposed Workers—United States, 2003–2012. *MMWR Morb. Mortal Wkly. Rep.* **2016**, *65*, 389–394. [CrossRef]
2. Kerns, E.; Masterson, E.A.; Themann, C.L.; Calvert, G.M. Cardiovascular conditions, hearing difficulty, and occupational noise exposure within US industries and occupations. *Am. J. Ind. Med.* **2018**, *61*, 477–491. [CrossRef]
3. Tak, S.; Davis, R.R.; Calvert, G.M. Exposure to hazardous workplace noise and use of hearing protection devices among US workers—NHANES, 1999–2004. *Am. J. Ind. Med.* **2009**, *52*, 358–371. [CrossRef] [PubMed]
4. Themann, C.L.; Masterson, E.A. Occupational noise exposure: A review of its effects, epidemiology, and impact with recommendations for reducing its burden. *J. Acoust. Soc. Am.* **2019**, *146*, 3879. [CrossRef]
5. Cosh, S.; Helmer, C.; Delcourt, C.; Robins, T.G.; Tully, P.J. Depression in elderly patients with hearing loss: Current perspectives. *Clin. Interv. Aging* **2019**, *14*, 1471–1480. [CrossRef] [PubMed]
6. Occupational Safety and Health Administration. Occupational Noise Exposure: Hearing Conservation Amendment. Final Rule. *Fed. Reg.* **1983**, *48*, 9738–9785.
7. Verbeek, J.H.; Kateman, E.; Morata, T.C.; Dreschler, W.A.; Mischke, C. Interventions to prevent occupational noise-induced hearing loss: A Cochrane systematic review. *Int. J. Audiol.* **2014**, *53*, S84–S96. [CrossRef]

8. Rabinowitz, P.; Cantley, L.F.; Galusha, D.; Trufan, S.; Swersey, A.; Dixon-Ernst, C.; Ramirez, V.; Neitzel, R. Assessing Hearing Conservation Program Effectiveness: Results of a Multisite Assessment. *J. Occup. Environ. Med.* **2018**, *60*, 29–35. [CrossRef] [PubMed]
9. Lee, M.P.; Hudson, H.; Richards, R.; Chang, C.-C.; Chosewood, L.C.; Schill, A.L. *Fundamentals of Total Worker Health Approaches: Essential Elements for Advancing Worker Safety, Health, and Well-Being*; Centers for Disease Control and Prevention: Cincinnati, OH, USA, 2016.
10. Henning, R.; Warren, N.; Robertson, M.; Faghri, P.; Cherniack, M.; CPH-NEW Research Team. Workplace health protection and promotion through participatory ergonomics: An integrated approach. *Public Health Rep.* **2009**, *124*, 26–35. [CrossRef]
11. Punnett, L.; Cavallari, J.M.; Henning, R.A.; Nobrega, S.; Dugan, A.G.; Cherniack, M.G. Defining 'Integration' for Total Worker Health(R): A New Proposal. *Ann. Work Expo. Health* **2020**, *64*, 223–235. [CrossRef]
12. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
13. Robertson, M.; Henning, R.; Warren, N.; Nobrega, S.; Dove-Steinkamp, M.; Tibirica, L.; Bizarro, A.; The CPH-NEW Research Team. The Intervention Design and Analysis Scorecard: A planning tool for participatory design of integrated health and safety interventions in the workplace. *J. Occup. Environ. Med.* **2013**, *55*, S86–S88. [CrossRef] [PubMed]
14. Cherniack, M.; Dussetschleger, J.; Dugan, A.; Farr, D.; Namazi, S.; El Ghaziri, M.; Henning, R. Participatory action research in corrections: The HITEC 2 program. *Appl. Ergon.* **2016**, *53*, 169–180. [CrossRef]
15. Nobrega, S.; Kernan, L.; Plaku-Alakbarova, B.; Robertson, M.; Warren, N.; Henning, R.; The CPH-NEW Research Team. Field tests of a participatory ergonomics toolkit for Total Worker Health. *Appl. Ergon.* **2017**, *60*, 366–379. [CrossRef] [PubMed]
16. Punnett, L.; Nobrega, S.; Zhang, Y.; Rice, S.; Gore, R.; Kurowski, A.; SHIFT Project Research Team. Safety and Health through Integrated, Facilitated Teams (SHIFT): Stepped-wedge protocol for prospective, mixed-methods evaluation of the Healthy Workplace Participatory Program. *BMC Public Health* **2020**, *20*, 1463. [CrossRef] [PubMed]
17. Strickland, J.R.; Kinghorn, A.M.; Evanoff, B.A.; Dale, A.M. Implementation of the Healthy Workplace Participatory Program in a Retail Setting: A Feasibility Study and Framework for Evaluation. *Int. J. Environ. Res. Public Health* **2019**, *16*, 590. [CrossRef] [PubMed]
18. Miranda, H.; Gore, R.J.; Boyer, J.; Nobrega, S.; Punnett, L. Health Behaviors and Overweight in Nursing Home Employees: Contribution of Workplace Stressors and Implications for Worksite Health Promotion. *Sci. World J.* **2015**, *2015*, 915359. [CrossRef]
19. Robertson, M.M.; Henning, R.A.; Warren, N.; Nobrega, S.; Dove-Steinkamp, M.; Tibiriçá, L.; Bizarro, A. Participatory design of integrated safety and health interventions in the workplace: A case study using the Intervention Design and Analysis Scorecard (IDEAS) Tool. *Int. J. Hum. Factors Ergon.* **2015**, *3*, 303–326. [CrossRef]
20. Dugan, A.G.; Namazi, S.; Cavallari, J.M.; Rinker, R.D.; Preston, J.C.; Steele, V.L.; Cherniack, M.G. Participatory survey design of a workforce health needs assessment for correctional supervisors. *Am. J. Ind. Med.* **2021**, *64*, 414–430. [CrossRef]
21. Cavallari, J.M.; Garza, J.L.; DiFrancesco, J.; Dugan, A.G.; Walker, E.D. Development and application of a noise-hazard scheme for road maintainers. *Am. J. Ind. Med.* **2020**, *63*, 429–434. [CrossRef]
22. Cavallari, J.M.; Burch, K.A.; Hanrahan, J.; Garza, J.L.; Dugan, A.G. Safety climate, hearing climate and hearing protection device use among transportation road maintainers. *Am. J. Ind. Med.* **2019**, *62*, 590–599. [CrossRef]
23. National Institute for Occupational Safety and Health (NIOSH). *Criteria for a Recommended Standard. Occupational Exposure to Noise. Revised Criteria*; Centers for Disease Control and Prevention: Cincinnati, OH, USA, 1998.
24. Svensson, E.B.; Morata, T.C.; Nylén, P.; Krieg, E.F.; Johnson, A.-C. Beliefs and attitudes among Swedish workers regarding the risk of hearing loss. *Int. J. Audiol.* **2004**, *43*, 585–593. [CrossRef]
25. Goldenhar, L.M.; Schwatka, N.; Johnson, S.K. Leadership skills for strengthening jobsite safety climate. *J. Saf. Res.* **2019**, *70*, 263–271. [CrossRef] [PubMed]
26. Trabeau, M.; Neitzel, R.; Meischke, H.; Daniell, W.E.; Seixas, N.S. A comparison of "Train-the-Trainer" and expert training modalities for hearing protection use in construction. *Am. J. Ind. Med.* **2008**, *51*, 130–137. [CrossRef] [PubMed]
27. Neitzel, R.; Meischke, H.; Daniell, W.E.; Trabeau, M.; Somers, S.; Seixas, N.S. Development and pilot test of hearing conservation training for construction workers. *Am. J. Ind. Med.* **2008**, *51*, 120–129. [CrossRef] [PubMed]
28. El Dib, R.P.; Mathew, J.L.; Martins, R.H. Interventions to promote the wearing of hearing protection. *Cochrane Database Syst. Rev.* **2012**. [CrossRef]
29. Seixas, N.S.; Neitzel, R.; Stover, B.; Sheppard, L.; Daniell, B.; Edelson, J.; Meischke, H. A multi-component intervention to promote hearing protector use among construction workers. *Int. J. Audiol.* **2011**, *50*, S46–S56. [CrossRef]
30. Tamers, S.L.; Chosewood, L.C.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.C. Total Worker Health® 2014–2018: The Novel Approach to Worker Safety, Health, and Well-Being Evolves. *Int. J. Environ. Res. Public Health* **2019**, *16*, 321. [CrossRef]
31. Sorensen, G.; McLellan, D.; Dennerlein, J.T.; Pronk, N.P.; Allen, J.D.; Boden, L.I.; Okechukwu, C.A.; Hashimoto, D.; Stoddard, A.; Wagner, G.R. Integration of health protection and health promotion: Rationale, indicators, and metrics. *J. Occup. Environ. Med. Am. Coll. Occup. Environ. Med.* **2013**, *55*, S12–S18. [CrossRef]
32. Anger, W.K.; Elliot, D.L.; Bodner, T.; Olson, R.; Rohlman, D.S.; Truxillo, D.M.; Kuehl, K.S.; Hammer, L.B.; Montgomery, D. Effectiveness of total worker health interventions. *J. Occup. Health Psychol.* **2015**, *20*, 226–247. [CrossRef]
33. Beamer, B.; McCleery, T.; Hayden, C. Buy Quiet Initiative in the USA. *Acoust. Aust.* **2016**, *44*, 51–54. [CrossRef]

34. Morata, T.C.; Meinke, D. Uncovering effective strategies for hearing loss prevention. *Acoust. Aust.* **2016**, *44*, 67–75. [CrossRef] [PubMed]
35. Schwatka, N.V.; Goldenhar, L.M.; Johnson, S.K.; Beldon, M.A.; Tessler, J.; Dennerlein, J.T.; Fullen, M.; Trieu, H. A training intervention to improve frontline construction leaders' safety leadership practices and overall jobsite safety climate. *J. Saf. Res.* **2019**, *70*, 253–262. [CrossRef]
36. Themann, C.L.; Morata, T.C.; Afanuh, S. *Using Total Worker Health(R) Concepts to Address Hearing Health*; U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Eds.; DHHS (NIOSH): Cincinnati, OH, USA, 2019.
37. Rogers, B.; Meyer, D.; Summey, C.; Scheessele, D.; Atwell, T.; Ostendorf, J.; Randolph, S.A.; Buckheit, K.; Berryman, P.; Lukes, E. What makes a successful hearing conservation program? *Aaohn J.* **2009**, *57*, 321–337. [CrossRef] [PubMed]
38. Berger, E.H. *The Noise Manual*, 6th ed.; American Industrial Hygiene Association: Fairfax, VA, USA, 2003.
39. Sayler, S.K.; Rabinowitz, P.M.; Cantley, L.F.; Galusha, D.; Neitzel, R.L. Costs and effectiveness of hearing conservation programs at 14 US metal manufacturing facilities. *Int. J. Audiol.* **2018**, *57*, S3–S11. [CrossRef]
40. Levy, B.S.; Roelofs, C. Impacts of Climate Change on Workers' Health and Safety. In *Oxford Research Encyclopedia of Global Public Health*; Oxford University Press: Oxford, UK, 2019.

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Total Worker Health® and Small Business Employee Perceptions of Health Climate, Safety Climate, and Well-Being during COVID-19

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Abstract: The COVID-19 pandemic created workplace challenges for employee safety and health, especially in small enterprises. We used linear mixed-effects regression to examine changes in health climate, safety climate, and worker well-being, prior to the pandemic and at two timepoints during it. We also examined whether employees at organizations that had received a TWH leadership development intervention prior to COVID-19 would better maintain pre-pandemic perceptions of climates and well-being. The final study cohort consisted of 261 employees from 31 organizations. No differences were observed in mean outcome scores between the leadership intervention groups at any of the survey timepoints. We combined intervention groups to examine the difference across timepoints. Perceptions of health and safety climates remained stable across all timepoints. However, employee well-being scores declined between the pre-pandemic period and subsequent COVID-19 timepoints. These findings suggest that while small organizations continued to be viewed as supporting employees' health and safety over the course of the pandemic, well-being scores declined, indicating that other factors contributed to decreased well-being. The findings from this study have implications for small business leaders as they navigate the impact of the COVID-19 pandemic on the health, safety, and well-being on their organizations and employees.

Keywords: Total Worker Health; leadership; health climate; safety climate; well-being; COVID-19

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1. Introduction

There has been a fundamental shift in working environments because of the global coronavirus pandemic (COVID-19). Research examining the impact of COVID-19 on the workplace is coming from a number of distinct fields—occupational safety and health [1–4], public health [5,6], psychology/psychiatry [7–10], business/management [11–13], and others [14,15]—demonstrating the multidisciplinary interest in understanding the impact of the pandemic on issues relevant to the workplace. Workplace challenges due to COVID-19 have been highlighted in the recent literature—fear of infection or disease transmission [6],

job insecurity [4–6], struggles to maintain work–life balance [1,5,6], and mental health challenges [3,7,8,16], among others [9,12,13].

Small businesses, in particular, have faced challenges including mass layoffs, closures, and lack of cash on hand [14]. Results from an April 2020 analysis of nationally representative data showed the immediate impact of COVID-19 on small businesses, with the number of active small businesses falling by 3.3 million businesses (a 22% decrease) from February 2020 to April 2020 [12]. Losses were across almost all industries and felt most profoundly in those considered "non-essential". Further, the losses disproportionately affected business owners who were Black, Latino, Asian, immigrant, and female [12]. Small businesses that were still operating faced additional challenges [14]. Even prior to the onset of the pandemic, smaller businesses faced higher rates of occupational injuries and illnesses [17]. They also tended to offer fewer health and safety programs, fewer benefits for workers, and had less ability to identify and mitigate workplace hazards [18].

1.1. Total Worker Health and Leadership

The Total Worker Health® (TWH) approach, developed by the National Institute of Occupational Safety and Health (NIOSH) [19], is one framework used to address the safety, health, and well-being challenges of workers and workplaces in the time of COVID-19 [2,20]. Dennerlein and colleagues [2] outlined six characteristics that are considered best practices for the protection and promotion of worker safety, health, and well-being, the first of which is particularly relevant for the current study—leadership commitment. Leadership commitment helped foster the policies, programs, and practices that organizations put into place to address the COVID-19 pandemic [20]. Others also noted the importance of leadership to mitigate the negative effects that resulted from the uncertainty and fear surrounding COVID-19. During the pandemic, the ways in which leaders communicated changes, motivated employees, and showed empathy were associated with employee well-being [1,11]. The importance of leadership in creating a climate where employee safety and health is valued has similarly been highlighted in small businesses [21–23]. Our past research demonstrates a positive relationship between leadership commitment to safety and health and employees' perceptions of safety and health climates [24] and safety and health behaviors [22].

Organizational climate is experienced by employees within an organization based on their collective perceptions of the environment, based on organizational policies, practices, and procedures [25]. Research in health climate and safety climate has consistently demonstrated the relationship between both types of climates and a number of relevant outcomes including better safety practices, increased motivation, knowledge, and fewer accidents on the safety side [26–29] and better physical health and health behaviors on the health side [30–32]. As outlined by Zohar, there is a demonstrated relationship between leadership and safety climate [33]. The reasons behind this relationship stem from the fact that leadership and supervisor behaviors are easy to see. When it is repeatedly observed that leaders value safety, employees report more positive perceptions of safety climate. Far less research has been conducted examining the relationship between leadership and health climate, though researchers found that leaders in organizations with high health climates were more likely to engage in health promoting leadership behaviors [34]. The TWH approach offers many ways in which workplaces impact the safety, health, and well-being of employees. A main assumption is that applying TWH in workplaces will lead to improved safety, health, and well-being outcomes. Further, if leaders are trained to apply principals of TWH leadership in the workplace, it should lead to improved safety, health, and well-being outcomes [35].

1.2. Study Purpose

The COVID-19 pandemic has presented researchers with an opportunity to examine what happens to health and safety climates and employee well-being during a global emergency and how TWH leadership may help leaders navigate the workplace challenges

they faced starting in 2020. COVID-19 upended workplaces, creating both challenges and opportunities for occupational safety and health. During the spring of 2020, we were completing a longitudinal study examining TWH in small businesses, called the Small + Safe + Well (SSWell) Study [36]. As described below, some participating businesses were randomized to receive a TWH leadership development program intervention. Once the pandemic hit, we examined how the pandemic impacted perceptions of safety and health climates and employee well-being in the SSWell cohort of small businesses at two timepoints: during the early wave of COVID in May 2020 and in September 2020 as rates of illness in the U.S. began to rise again. In the present study, we aimed to extend our prior leadership and climate and climate research in small business [22–24].

First, we aimed to observe how the pandemic affected small businesses over time. A recent analysis of the state of workplace climate research has outlined the need to define the context in which climate is examined, as well as investigate multiple types of climate, and understand how climate changes over time, both naturally and through intentional attempts to modify climates [25]. While there is evidence that health and safety climates remain stable over time [33], we are unaware of evidence that examines these climates during a global emergency. We hypothesized (H1) that employees at organizations with higher safety and health climate scores and well-being scores pre-pandemic would maintain safety and health climates and well-being during the pandemic.

Second, given the evidence for the importance of leadership for workforce health, we tested the hypothesis (H2) that employees at organizations that received our TWH leadership development program prior to the pandemic would better maintain their pre-pandemic perceptions of safety climate and health climate, as well as maintain their well-being scores during the pandemic.

2. Materials and Methods

2.1. Small + Safe + Well Study (SSWell)

The SSWell parent study was a randomized, longitudinal intervention study of small businesses (<500 employees) located in the state of Colorado. The study began in April 2017, concluded in March 2020, and was housed within the Center for Health, Work and Environment (CHWE), a NIOSH Total Worker Health Center of Excellence. The SSWell study focused on the protection and promotion of worker health, safety and well-being, utilizing the TWH approach developed by NIOSH [19]. Complete details of the SSWell study have been previously described [36]. Enrolled organizations participated in Health Links™, a TWH initiative that includes assessment, certification and advising [37]. Each year of the study, a representative from each organization completed the Healthy Workplace Assessment (HWA), an organization-level survey that captures the core elements of TWH in 6 distinct realms of workplace safety and health. Following assessment, organizations were offered advising sessions to review the HWA score and to set workplace health, safety, and well-being goals for the coming year.

An additional component of the SSWell study was randomization of organizations to participate in a TWH leadership development program. The non-intervention included the HWA and advising, as described, whereas the intervention included the HWA, advising, plus participation in the TWH leadership development program. A complete description of this intervention can be found in a previous publication [38]. To briefly summarize, the TWH leadership development program included a full-day in-person training for a senior leader, who was invited to bring one additional key staff person from within the organization. Program participants completed a pre-workshop evaluation describing their TWH practices for their organization, as well as their individual personal health/wellness practices. Upon completion of the in-person training, leaders created three goals for further development over the subsequent three-month period. Leaders were also invited to participate in up to three, 30 min, individual post-training coaching sessions and to participate in an online goal setting and tracking platform.

2.2. Health and Safety Culture Survey

Within approximately six weeks of completion of the annual HWA, all employees at SSWell organizations were invited to complete the Employee Health and Safety Culture (HSC) Survey during each year of study enrollment. This survey included 108 items that asked employees to report on their perceptions of leadership within their organization, health and safety climates, workplace health and safety, individual well-being, as well as demographic information.

2.3. COVID-19 Employee Impact Surveys

We distributed a modified HSC survey to employees at active SSWell organizations at two occasions during the coronavirus pandemic. The COVID-19 Employee Impact Survey included a subset of items from the HSC survey that targeted the constructs of health climate, safety climate and employee well-being, with additional work/life questions that addressed changes that employees may have experienced because of the pandemic. Employees completed the first COVID-19 Employee Impact Survey (COVID I) in May 2020 and the second COVID-19 Employee Impact Survey (COVID II) in September 2020.

2.4. Health Climate, Safety Climate, and Well-Being Constructs

The health climate and safety climate constructs were developed to elicit feedback on employee perceptions of their organization's commitment to health and safety. The health climate construct utilized items from the assessment of Zweber, Henning and Magley [30]. An example item from this four-question construct is, "My organization is committed to employee health and well-being". Safety climate is based upon six questions from the work of Lee and colleagues [39]. An example item is, "My organization uses any available information to improve existing safety rules". These constructs were measured using five-point Likert-type scales and were scored on a continuum of "strongly disagree" to "strongly agree" with a mean response calculated for each construct. The well-being construct included five questions from the WHO-5 Well-Being Index [40]. An example item is "I have felt cheerful and in good spirits". This construct utilized a five-point Likert-type scale with responses ranging from "at no time" to "most of the time". Higher mean scores on each of these constructs represent better employee perceptions of organizational health climate, safety climate, and individual well-being. All questions used in the COVID-19 Employee Impact Survey added the phrasing, "over/in the past 30 days", in order to elicit responses specific to the pandemic timeframes that were being measured.

The HSC and COVID I and COVID II surveys were administered via email using the REDCap electronic data capture tool [41,42]. To maintain anonymity, no identifying information was collected from employees and employers were not provided employee-level response data. To incentivize participation for each survey, employees were offered the opportunity to enter random drawings for one of 15 $100 gift cards for completing surveys at each of the survey occasions. The study protocol was approved by the Colorado Multiple Institutional Review Board (COMIRB).

2.5. Participants

The study design, including number of businesses and participating employees, is displayed in Figure 1. Seventy-four of the initial 143 organizations enrolled in the SSWell study were eligible for participation in the COVID I survey in early May 2020. This included only those organizations that were considered active and had not dropped out of the study. We sent survey links to our points of contact at each site and requested that they disseminate the survey to all employees via email invitation. For the COVID I survey, we received 491 responses from employees in 30 organizations (40.5% organizational response rate). Between May and September 2020, an additional 4 organizations dropped out of the SSWell study. In early September 2020, we requested that our point of contacts at the 70 remaining active organizations send employees the COVID II survey. For the COVID II survey we received 442 responses from employees in 29 organizations (41.4%

organizational response rate). We estimate that 2211 employees received the COVID I survey (22% response rate), whereas an estimated 2768 employees received the COVID II survey (16% response rate).

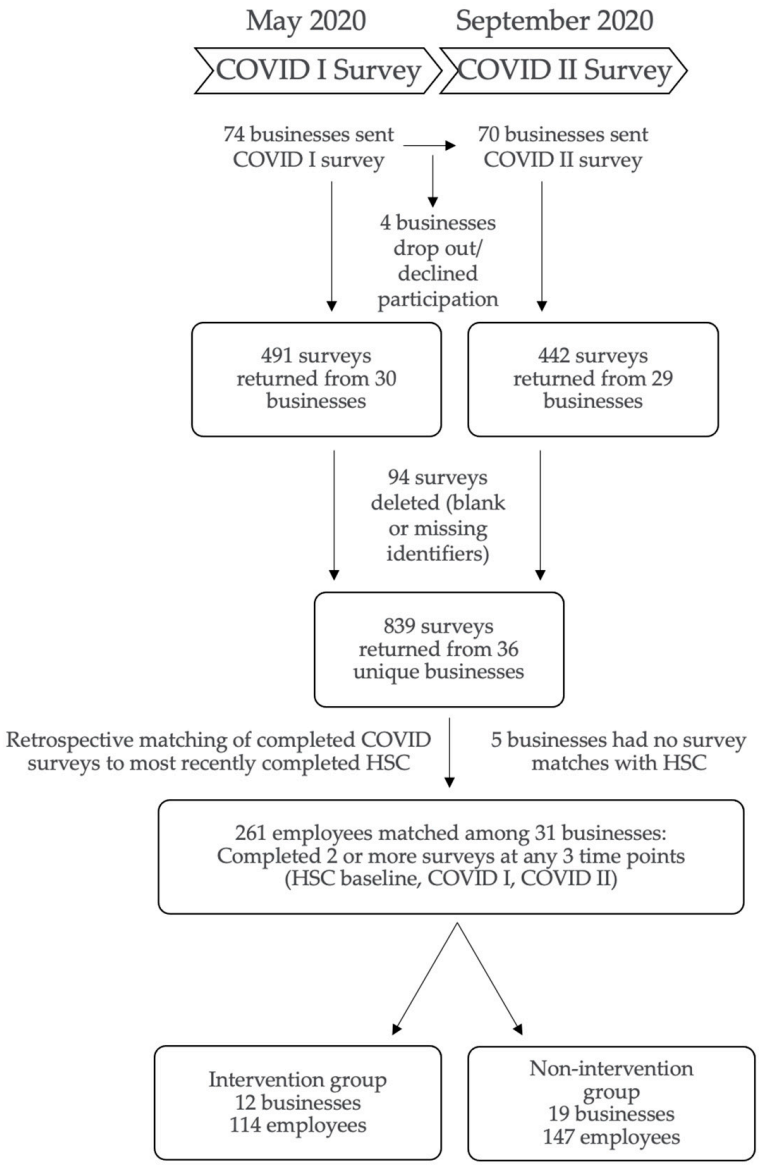


Figure 1. Design for the SSWell COVID-19 longitudinal study representing 31 unique businesses and 261 employees.

Across the two COVID surveys, 39 unique organizations responded. However, after deleting blank surveys, those missing unique identifiers, or responses from organizations with only a single response, the total number of responses equated to 839 employee surveys, with 36 unique organizations remaining in the study cohort. We then retrospectively matched via unique identifiers participating employees from the each COVID-19 Employee Impact Survey with their HSC responses from their most recent survey prior to the pandemic. To be included in the present study, employees must have completed any 2 of the 3 surveys from the HSC, COVID I and COVID II surveys. The final matched business cohort included 31 organizations with two or more employees completing at least two of the three surveys. We were able to match 261 employees in these organizations who had completed at least two of the three surveys. In the final cohort of 31 organizations and 261 individuals, 12 organizations with 114 matched employees previously received the

leadership development program (intervention) prior to the pandemic and 19 organizations with 147 matched employees did not receive the leadership development program (non-intervention).

2.6. Statistical Analysis

Demographic data at the business level were collected from the most recently completed HWA, the organization-level survey competed prior to distribution of the annual HSC. Employee demographic data were collected at each of the three survey occasions and thus we present employee level demographics from first completed surveys evaluated in this study. Chi-square or Fisher exact tests were used to test for differences between categorical variables and *t*-tests with Satterthwaite corrections for unequal variances were used for continuous variables. The main outcomes of interest were changes in employees' perceptions of health climate, safety climate and well-being across the three survey occasions. Normality of outcome variables was visually assessed.

We used linear mixed-effects regression to examine the change in the three primary outcomes over time. Random intercepts for employees nested within organization were included. Models for health climate, safety climate and well-being were assessed independently. All models were adjusted for employee age and gender. Potential confounding effects of timing of survey completion were addressed by adding a covariate for time between baseline HSC survey and first completed COVID survey. To determine if there were differences in the outcomes across survey timepoints between intervention groups, an interaction term for intervention group and time was included. Data were analyzed with SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

3. Results

Descriptive statistics for participating organizations and employees included in the analysis are presented in Table 1. Organizations had an average number of 84 employees (SD = 106) and 13 of 31 (41.9%) had 11–50 employees. While a range of industries were represented, the greatest proportion of organizations were from the health care and social assistance sector (n = 9, 29.0%) and 22 organizations (71.0%) were based in urban areas of Colorado. No demographic differences were observed for those in the intervention versus non-intervention group at the organization level.

Individual demographic data for the 261 participants indicated that employees in the intervention group were significantly younger than those in non-intervention organizations with mean ages of 34.1 years (SD = 12.7) versus 41.9 years (SD = 11.5), respectively. Most employees were white, non-Hispanic (n = 220, 84.3%) and female (n = 206, 78.9%), with no significant race/ethnicity or gender differences between intervention groups. Baseline outcome measures are presented for the 206 participants for whom we had HSC data. Results for these variables were not significantly different between the intervention groups, with mean health climate score of 4.1 (SD = 0.8), mean safety climate score of 3.9 (SD = 0.8), and mean well-being score equal to 3.6 (SD = 0.7).

Mean time from baseline HSC to first completed COVID survey differed between the groups, with the intervention group averaging 281 days (SD = 98) and 370 days (SD = 101) in the non-intervention group ($p < 0.0001$). Mean number of days from the TWH leadership development program to first completed COVID survey was 406 days (SD = 143) for those organizations in the intervention group.

Mixed-Effects Linear Regression Analysis

Table 2 presents least squares means for health climate, safety climate and well-being by intervention group at each survey timepoint. No differences were observed in mean outcome scores between the intervention and non-intervention groups at any of the survey timepoints shown. Figure 2 presents the least squares mean estimation and 95% CI for health climate, safety climate and well-being at each survey timepoint for intervention groups combined.

Table 1. Business characteristics and employee demographics by intervention group.

Business Characteristics	Combined (n = 31)	Intervention (n = 12)	Non-Intervention (n = 19)	p-Value
	N (%)/Mean (SD)	N (%)/Mean (SD)	N (%)/Mean (SD)	
Number of Employees, Mean (SD)	84 (106)	87 (87)	83 (119)	0.92
Business Size				0.17
Micro (2–10 employees)	6 (19.4%)	0 (0.0%)	6 (31.6%)	
Small (11–50 employees)	13 (41.9%)	7 (58.3%)	6 (31.6%)	
Medium (51–200 employees)	6 (19.4%)	3 (25.0%)	3 (15.8%)	
Large (>200 employees)	6 (19.4%)	2 (16.7%)	4 (21.1%)	
Industry				0.54
Health Care and Social Assistance	9 (29.0%)	6 (50.0%)	3 (15.8%)	
Non-Profit	5 (16.1%)	1 (8.3%)	4 (21.1%)	
Educational Services	4 (12.9%)	1 (8.3%)	3 (15.8%)	
Public Administration	4 (12.9%)	1 (8.3%)	3 (15.8%)	
Arts, Entertainment and Recreation	2 (6.5%)	1 (8.3%)	1 (5.3%)	
Construction	2 (6.5%)	1 (8.3%)	1 (5.3%)	
Real Estate and Rental and Leasing	2 (6.5%)	0 (0.0%)	2 (10.5%)	
Accommodation and Food Service	1 (3.2%)	1 (8.3%)	0 (0.0%)	
Services	1 (3.2%)	0 (0.0%)	1 (5.3%)	
Other	1 (3.2%)	0 (0.0%)	1 (5.3%)	
Region				0.42
Urban	22 (71.0%)	10 (83.3%)	12 (63.2%)	
Rural	9 (29.0%)	2 (16.7%)	7 (36.8%)	
Employee Demographics	**Combined (n = 261)**	**Intervention (n = 114)**	**Non-Intervention (n = 147)**	**p-Value**
Age (years)	38.5 (12.6)	34.1 (12.7)	41.9 (11.5)	<0.0001
Race/Ethnicity				0.32
White, non-Hispanic	220 (84.3%)	93 (81.6%)	127 (86.4%)	
Black or African American	5 (1.9%)	4 (3.5%)	1 (0.7%)	
Hispanic, Latino, Spanish Origin	26 (10.0%)	11 (9.7%)	15 (10.2%)	
Asian	2 (0.8%)	1 (0.9%)	1 (0.7%)	
Other/Multiracial	5 (1.9%)	4 (3.5%)	1 (0.7%)	
Did not provide	3 (1.2%)	1 (0.7%)	2 (1.4%)	
Gender				0.39
Male	54 (20.7%)	21 (18.4%)	33 (22.5%)	
Female	206 (78.9%)	92 (80.7%)	114 (77.6%)	
Other	1 (0.4%)	1 (0.9%)	0 (0.0%)	
Baseline HSC Study Measures, N = 206	**Mean (SD)**	**Intervention (n = 88)**	**Non-Intervention (n = 118)**	**p-Value**
Health climate	4.1 (0.8)	4.1 (0.8)	4.0 (0.8)	0.37
Safety climate (n = 202)	3.9 (0.8)	3.8 (0.8)	3.9 (0.8)	0.55
Well-being (n = 199)	3.6 (0.7)	3.7 (0.7)	3.5 (0.7)	0.09
Time from baseline HSC to first completed COVID survey, mean number of days (SD)	332 (109)	281 (98)	370 (101)	<0.0001
Time from TWH intervention to first completed COVID survey, mean number of days (SD)	NA	406 (143)	NA	NA

Table 3 presents the change in outcomes across the three timepoints, for the two intervention groups combined. Health climate and safety climate remained stable across the three timepoints. However, well-being scores declined between the baseline HSC survey and the COVID I and the COVID II surveys. From the HSC survey to the first COVID survey, well-being scores (out of 5 points) declined by −0.41 points ($p < 0.0001$, 95% CI = −0.558, −0.253). From the baseline HSC survey to the COVID II survey, mean well-being scores decreased by −0.29 points ($p < 0.001$, 95% CI = −0.435, −0.137).

Table 2. Least squares mean estimation of health climate, safety climate, and well-being at each survey occasion stratified by intervention group.

		Intervention	Non-Intervention		
Variable	**Time**	**Mean (95% CI)**	**Mean (95% CI)**	**Difference**	***p*-Value**
Health Climate	Baseline	4.05 (3.734, 4.358)	4.18 (3.949, 4.416)	−0.14	0.58
	COVID I	4.07 (3.748, 4.393)	4.24 (3.980, 4.500)	−0.17	0.50
	COVID II	3.93 (3.590, 4.261)	4.13 (3.884, 4.378)	−0.21	0.42
Safety Climate	Baseline	3.68 (3.371, 3.981)	4.09 (3.863, 4.322)	−0.42	0.08
	COVID I	3.86 (3.546, 4.180)	3.99 (3.728, 4.243)	−0.12	0.62
	COVID II	3.76 (3.430, 4.090)	4.02 (3.780, 4.267)	−0.26	0.30
Well-Being	Baseline	3.70 (3.422, 3.981)	3.57 (3.355, 3.783)	0.13	0.54
	COVID I	3.19 (2.902, 3.488)	3.26 (3.012, 3.504)	−0.06	0.78
	COVID II	3.32 (3.014, 3.632)	3.35 (3.115, 3.574)	−0.02	0.92

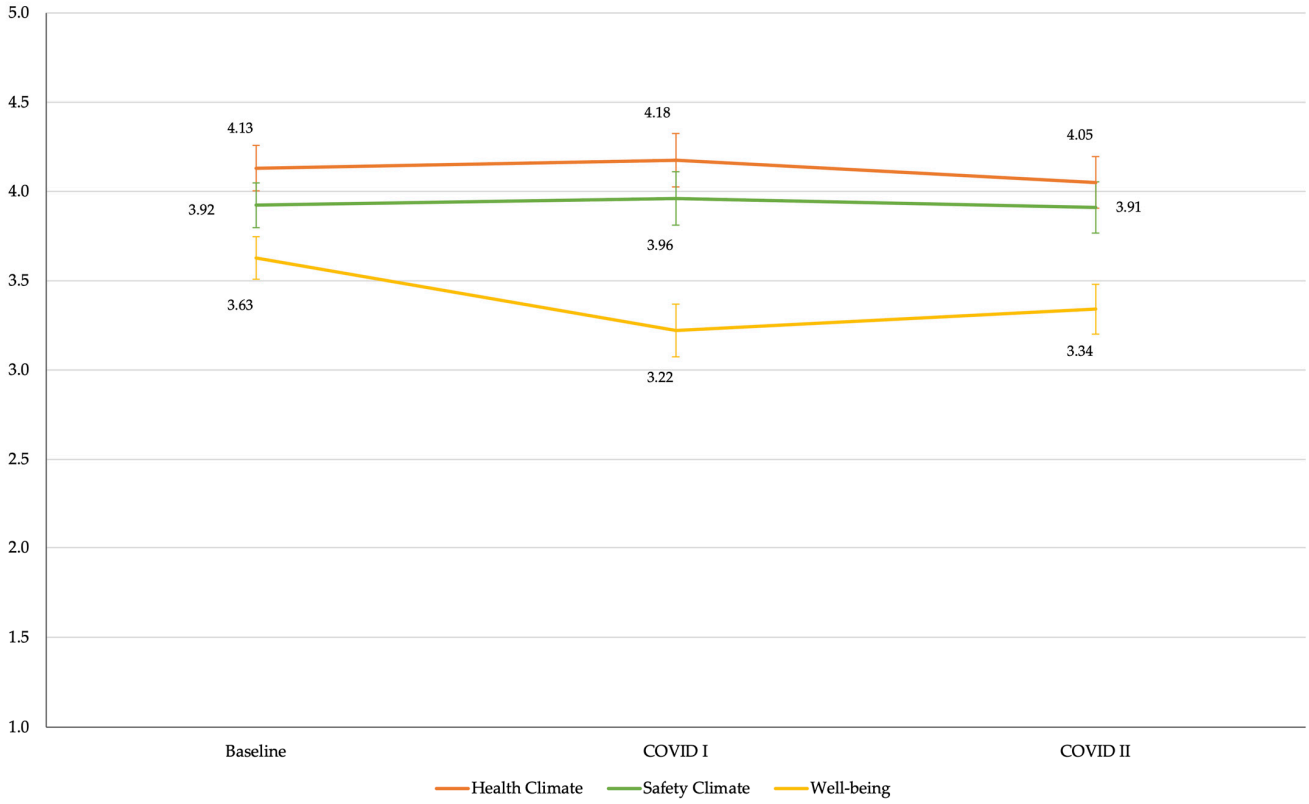


Figure 2. Least squares mean estimation of health climate, safety climate, and employee well-being at each timepoint.

Table 3. Mixed-effects linear regression analyses showing change in health climate, safety climate and well-being scores at three survey occasions, $N = 261$.

	Baseline HSC to COVID I		COVID I to COVID II		Baseline to COVID II	
Variable	**Estimate (95% CI)**	***p*-Value**	**Estimate (95% CI)**	***p*-Value**	**Estimate (95% CI)**	***p*-Value**
Health Climate	0.05 (−0.091, 0.181)	0.52	−0.12 (−0.285, 0.035)	0.13	−0.08 (−0.213, 0.053)	0.24
Safety Climate	0.04 (−0.102, 0.179)	0.59	−0.05 (−0.216, 0.114)	0.54	−0.01 (−0.150, 0.125)	0.86
Well-Being	−0.41 (−0.558, −0.253)	<0.0001 *	0.12 (−0.056, 0.295)	0.18	−0.29 (−0.435, −0.137)	0.0002 **

Note. Models controlled for age, gender, and time from baseline HSC to first completed COVID-19 Employee Impact Survey. * Significant at $p < 0.0001$. ** Significant at $p < 0.001$.

To test for introduction of potential bias between included and excluded organizations, we assessed organization level differences in demographics of employee participants from the 31 participating versus 43 non-participating organizations. There were no significant differences in mean number of employees, business size, industry, or region among the 74 eligible SSWell organizations comparing the 31 organizations that were included in this analysis with the 43 excluded organizations (Supplementary Table S1).

We included in the analyses the 261 employees at the 31 organizations who had completed at least two of the three surveys. This resulted in missing data across surveys (Supplementary Table S2). To evaluate the effect of missing data, we compared our outcome variables for the respondents completing all three surveys (n = 54) to the respondents completing any of two of the surveys (n = 207). No significant differences were observed in mean health climate, safety climate or well-being for those with only two completed surveys compared to employees who completed all three surveys (Supplementary Table S3).

4. Discussion

In the first year of COVID-19, small businesses demonstrated the ability to sustain employee perceptions of health and safety climates at pre-COVID-19 levels. Health climate and safety climate scores remained stable across both groups and all three timepoints. Nonetheless, employees reported worsening of well-being, suggesting that factors other than health and safety climate likely contributed to their perceptions of well-being during the pandemic. Our hypothesis that TWH leadership training would enable businesses to better maintain their pre-pandemic perceptions of safety climate and health climate, and for their employees to maintain their well-being scores during the pandemic was not supported by the results. Self-reported employee well-being scores declined in both the TWH leadership program intervention group and in the non-intervention group between baseline and COVID I and COVID II timepoints.

4.1. Theoretical Contributions

The stability in health climate and safety climate over time is consistent with previous literature in the safety climate field. As safety climate builds through social interactions over time, it stands that it would be somewhat stable and not easily changed [33,43]. There is an identified need to more closely examine the stability of health and safety climates over time and in relation to external factors [25] and the current study adds to this evidence base.

The decline in worker well-being scores is consistent with other recent findings. One study, conducted at an academic institution, found 58.3% of respondents reported worsened well-being related to COVID-19 work and non-work changes [3]. Multiple other studies conducted over the course of the pandemic have reported worsened mental health outcomes because of COVID-19. For example, a narrative review that included 35 studies examining psychological problems related to the workplace during COVID-19 reported high rates of depression, anxiety, and stress among workers from a wide range of occupations and from multiple countries [16].

The present study offers a unique look into climate perceptions during COVID-19. Historically, climate researchers have been focused on survey development [44] and relating climate perceptions to important antecedents and outcomes [45]. If changes in climate perceptions have been assessed, it has been because researchers were testing interventions. This may be due, in part, to differences in research traditions where culture researchers tend to examine the evolution of systems over time whereas climate researchers tend to focus on the impact of social systems [46]. In the present study, we begin to close this gap. Our study demonstrates that over a period of about one year, safety and health climates are relatively stable. To our surprise, their stability over time occurred even in the face of a global pandemic. This effect may be due, in part, to a selection bias whereby our sample included small businesses still in operation and willing to continue in a research study during a pandemic. Such businesses may be in a better position to maintain their health and safety practices in general.

Prior research suggests that climate perceptions change when leadership and communication practices are instituted [35]. As such, we had hypothesized that a TWH leadership development program would help small businesses maintain their climates and for employees to maintain their well-being. Health and safety climates during COVID-19 continue to be important, as organizations and leaders aim to promote the new health and safety procedures that have resulted from COVID-19 [10]. The results from our initial, cross-sectional study demonstrated that employees in small businesses reported better well-being during the initial wave of COVID-19 when they worked for an organization that they perceived had strong health and safety climates [47]. In fact, no other work or life factors, such as changes to childcare or limiting social contacts, were significant after accounting for perceptions of health and safety climates. We can only speculate as to why TWH leadership training failed to impact well-being. For example, the "dose" of leadership training may have been insufficient [35,48], training transfer may not have occurred [35], the size of our study may have been too small to detect a benefit, the multiple ways in which the pandemic affected well-being may have neutralized any leadership effect, or TWH leadership training does not contribute to worker well-being.

4.2. Practical Applications

The TWH leadership development program that served as the intervention for this study was not designed to address the health and safety needs of workers during a global pandemic. However, many of the concepts of the training were relevant to supporting the health and safety climates of organizations that could serve as a foundation in the event of an emergency. There are lessons we can take from the current study and other recent findings to adapt the TWH leadership development program. The literature from the fields of management and psychology focuses on communication by leaders as a key area that will help support employees during COVID-19 [1,11]. Specifically, regular communication, transparency, leading by example, and empathy are identified as specific leader behaviors that are especially important during this time. Other researchers have highlighted the key role that supervisory support plays [1,3]. Since leadership is one key area that is related to improved health and safety climates [33,34], we need to continue to develop the TWH leadership skills for small business leaders. One practical challenge is that the "dose" of leadership training that may be needed to change behavior may not match the time and effort that small business leaders are willing to commit to TWH.

Taken together, the findings from this study have real-world implications for small business leaders who continue to navigate the impact of the COVID-19 pandemic on the health, safety, and well-being on their organizations and their employees. One such implication is the need to focus on employee well-being more holistically. It is possible that even when workplace health and safety climates are generally positive, employee well-being may worsen due to other work and non-work factors. Already, research has demonstrated that caregivers of young children are experiencing high levels of pandemic stress which is related to worse mental health symptoms [49]. Our study cannot point to the specific factors that may have influenced the observed decline in well-being. However, our study does suggest that organizations and leaders have an opportunity to learn about and address employee needs to better understand the decline in well-being.

4.3. Future of Work

COVID-19 brought to the forefront several priority topics previously highlighted by NIOSH in putting forth a vision of the future of work and improving workforce safety, health, and well-being [50]. The COVID-19 pandemic led to an increase in changes to organizational design, including increased numbers of remote workers; need for work–life fit; changes to the physical work environment; and a re-examination of benefits, especially leave and bereavement benefits. As noted in their foundational paper, Tamers and colleagues state that as workplaces, work, and workforces change, organizational leadership has an important role to play in protecting and promoting the safety, health, and well-being

of workers [50]. While the results from this study did not find a significant relationship between prior participation in TWH leadership development and employee perceptions of health climate, safety climate, and well-being, we did find that worker well-being decreased over time through the pandemic and that both work and non-work factors are likely contributors to this decline. Further, the demographics of the workforce are continuing to change. Workers from racial and ethnic minorities already faced increased work-related health disparities, vulnerabilities, and stress [51]. COVID-19 has disproportionately impacted workers of color [12,52]. It was beyond the scope of this study to examine differences in perceived climates and well-being, based on respondents' race and ethnicity. However, this will continue to be an important focus for future studies.

4.4. Future Research Directions

The COVID-19 pandemic response has accelerated changes in the nature of work and is likely to continue to impact workforce health, safety and well-being for the foreseeable future. Multiple researchers have highlighted the role occupational safety and health professionals will continue to have as we emerge from the pandemic and work to create healthy and safe workplaces [10,13,53]. There will be a need to study the impact of COVID-19 on workplace climate and its relationship to worker well-being. Researchers should continue to study how the different phases of the pandemic impact employee health, safety, and well-being and the impact of the new policies, programs, and practices that are put into place to address workplace and employee needs [3,5]. Chang and colleagues [10] outline eight areas for designing workplace interventions that leaders can implement to help employees cope with COVID-19, including physical health and safety; work–life balance; job security; well-being; training and skill development; virtual work and alternate work arrangements; recognition; and involvement. These areas overlap with many of the relevant issues that the TWH approach outlined to advance worker well-being [54] as well as priorities highlighted in the NIOSH future of work initiative [50].

4.5. Strengths and Limitations

Due to the ongoing SSWell study, we were able to quickly develop and deploy the COVID-19 Employee Impact Survey that built upon our previous study materials and distribute it to our participating study organizations, increasing the speed by which we could collect data. The longitudinal nature of this study allowed us to assess health and safety climates and well-being at three timepoints, before and during the COVID-19 pandemic. The employees in the study represented organizations of various small business sizes, industries, and regions of the state, increasing the generalizability of our findings. Limitations must also be noted and include the nature of the organizations that were still operating and the employees who were able to complete the surveys. Organizations that may have shut down and employees who were furloughed or no longer working would not have been represented in this study. Based on the nature of the organizations enrolled in the study and the data collection methods, it is likely that employees surveyed were more likely to represent white collar workers. A sample that specifically examined differences by industry and/or included more frontline workers may have led to different results. The data collected were self-reported and though our questions asked participants to limit their responses to the previous 30 days, the heightened stress and time of great change may have affected participant recall.

5. Conclusions

Employee perceptions of health and safety climates remained relatively stable from the pre-COVID-19 baseline period to May and September of 2020. This, in part, demonstrates that organizations, even in the face of upheaval caused by the COVID-19 pandemic, maintained stable environments for their employees. In other words, the pandemic did not appear to change employees' perceptions of health climate or safety climate. However, the lower employee well-being scores indicate that work and other non-work factors are

likely contributing to diminished employee well-being. As of September 2020, COVID-19 was still having a major impact on small businesses. Organizations have a real opportunity to develop and implement innovative supports for employees in the changing nature of the workplace.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph18189702/s1. Table S1. Demographic data comparing organizations meeting study inclusion criteria compared to excluded organizations. Table S2. Distribution of completed surveys among 261 unique respondents. Table S3. Comparison of mean health climate, safety climate and well-being scores for employees completing two surveys versus employees completing three surveys.

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References

1. Sinclair, R.R.; Allen, T.; Barber, L.; Bergman, M.; Britt, T.; Butler, A.; Ford, M.; Hammer, L.; Kath, L.; Probst, T.; et al. Occupational Health Science in the Time of COVID-19: Now more than ever. *Occup. Health Sci.* **2020**, *4*, 1–22. [CrossRef] [PubMed]
2. Dennerlein, J.T.; Burke, L.; Sabbath, E.L.; Williams, J.A.R.; Peters, S.E.; Wallace, L.; Karapanos, M.; Sorensen, G. An integrative Total Worker Health framework for keeping workers safe and healthy during the COVID-19 pandemic. *Hum. Factors* **2020**, *62*, 689–696. [CrossRef] [PubMed]
3. Evanoff, B.A.; Strickland, J.R.; Dale, A.M.; Hayibor, L.; Page, E.; Duncan, J.G.; Kannampallil, T.; Gray, D.L. Work-related and personal factors associated with mental well-being during the COVID-19 response: Survey of health care and other workers. *J. Med. Internet Res.* **2020**, *22*, e21366. [CrossRef] [PubMed]
4. Kinman, G.; Grant, C. Presenteeism during the COVID-19 pandemic: Risks and solutions. *Occup. Med.* **2020**. [CrossRef]
5. Bakkeli, N.Z. Health, work, and contributing factors on life satisfaction: A study in Norway before and during the COVID-19 pandemic. *SSM Popul. Health* **2021**, *14*, 100804. [CrossRef]
6. Faghri, P.D.; Dobson, M.; Landsbergis, P.; Schnall, P.L. COVID-19 pandemic: What has work got to do with it? *J. Occup. Environ. Med.* **2021**, *63*, e245–e249. [CrossRef] [PubMed]
7. Van Der Feltz-Cornelis, C.M.; Varley, D.; Allgar, V.L.; de Beurs, E. Workplace stress, presenteeism, absenteeism, and resilience amongst university staff and students in the COVID-19 lockdown. *Front. Psychiatry* **2020**, *11*, 1284. [CrossRef] [PubMed]
8. Young, K.P.; Kolcz, D.L.; O'Sullivan, D.M.; Ferrand, J.; Fried, J.; Robinson, K. Health care Workers' mental health and quality of life during COVID-19: Results from a mid-pandemic, national survey. *Psychiatr. Serv.* **2021**, *72*, 122–128. [CrossRef] [PubMed]
9. Kniffin, K.M.; Narayanan, J.; Anseel, F.; Antonakis, J.; Ashford, S.P.; Bakker, A.B.; Bamberger, P.; Bapuji, H.; Bhave, D.P.; Choi, V.K.; et al. COVID-19 and the workplace: Implications, issues, and insights for future research and action. *Am. Psychol.* **2021**, *76*, 63–77. [CrossRef]
10. Chang, C.-H.; Shao, R.; Wang, M.; Baker, N.M. Workplace Interventions in Response to COVID-19: An Occupational Health Psychology Perspective. *Occup. Health Sci.* **2021**, *5*, 1–23. [CrossRef]
11. Dirani, K.M.; Abadi, M.; Alizadeh, A.; Barhate, B.; Garza, R.C.; Gunasekara, N.; Ibrahim, G.; Majzun, Z. Leadership competencies and the essential role of human resource development in times of crisis: A response to Covid-19 pandemic. *Hum. Resour. Dev. Int.* **2020**, *23*, 380–394. [CrossRef]
12. Fairlie, R. The impact of COVID-19 on small business owners: Evidence from the first 3 months after widespread social-distancing restrictions. *J. Econ. Manag Strategy* **2020**. [CrossRef]

13. Spicer, A. Organizational Culture and COVID-19. *J. Manag. Stud.* **2020**, *57*, 1737–1740. [CrossRef]
14. Bartik, A.W.; Bertrand, M.; Cullen, Z.; Glaeser, E.L.; Luca, M.; Stanton, C. The impact of COVID-19 on small business outcomes and expectations. *Proc. Natl Acad Sci USA* **2020**, *117*, 17656–17666. [CrossRef]
15. Van Bavel, J.J.; Baicker, K.; Boggio, P.S.; Capraro, V.; Cichocka, A.; Cikara, M.; Crockett, M.J.; Crum, A.J.; Douglas, K.M.; Druckman, J.N.; et al. Using social and behavioural science to support COVID-19 pandemic response. *Nat. Hum. Behav.* **2020**, *4*, 460–471. [CrossRef] [PubMed]
16. Giorgi, G.; Lecca, L.I.; Alessio, F.; Finstad, G.L.; Bondanini, G.; Lulli, L.G.; Arcangeli, G.; Mucci, N. COVID-19-related mental health effects in the workplace: A narrative review. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7857. [CrossRef] [PubMed]
17. Sinclair, R.C.; Cunningham, T.R.; Schulte, P.A. A model for occupational safety and health intervention diffusion to small businesses. *Am. J. Ind. Med.* **2013**, *56*, 1442–1451. [CrossRef] [PubMed]
18. McCoy, K.; Stinson, K.; Scott, K.; Tenney, L.; Newman, L.S. Health promotion in small business: A systematic review of factors influencing adoption and effectiveness of worksite wellness programs. *J. Occup. Environ. Med.* **2014**, *56*, 579–587. [CrossRef]
19. Centers for Disease Control and Prevention—National Institute for Occupational Safety and Health NIOSH Total Worker Health®Program [CDC/NIOSH web site]. 2018. Available online: https://www.cdc.gov/niosh/TWH/ (accessed on 30 August 2021).
20. Sorensen, G.; Dennerlein, J.T.; Peters, S.E.; Sabbath, E.L.; Kelly, E.L.; Wagner, G.R. The future of research on work, safety, health and wellbeing: A guiding conceptual framework. *Soc. Sci. Med.* **2021**, *269*, 113593. [CrossRef] [PubMed]
21. Schwatka, N.; Tenney, L.; Newman, L.S. Health protection and health promotion in small business. In *Increasing Occupational Health and Safety in Workplaces: Research and Practice*; Richardsen, A., Burke, R., Eds.; Edward Elgar Publishing: Cheltenham, UK, 2019.
22. Schwatka, N.V.; Dally, M.; Shore, E.; Dexter, L.; Tenney, L.; Brown, C.E.; Newman, L.S. Profiles of Total Worker Health® in United States small businesses. *BMC Public Health* **2021**, *21*, 1010. [CrossRef]
23. Schwatka, N.V.; Dally, M.; Tenney, L.; Shore, E.; Brown, C.E.; Newman, L.S. Total Worker Health leadership and business strategies are related to safety and health climates in small business. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2142. [CrossRef]
24. Shore, E.; Schwatka, N.; Dally, M.; Brown, C.E.; Tenney, L.; Newman, L.S. Small business employees' perceptions of leadership are associated with safety and health climates and their own behaviors. *J. Occup. Environ. Med.* **2020**, *62*, 156–162. [CrossRef] [PubMed]
25. Schneider, B.; González-Romá, V.; Ostroff, C.; West, M.A. Organizational climate and culture: Reflections on the history of the constructs in the Journal of Applied Psychology. *J. Appl. Psychol.* **2017**, *102*, 468–482. [CrossRef]
26. Zohar, D. Safety climate in industrial organizations: Theoretical and applied implications. *J. Appl. Psychol.* **1980**, *65*, 96–102. [CrossRef]
27. Christian, M.S.; Bradley, J.C.; Wallace, J.C.; Burke, M.J. Workplace safety: A meta-analysis of the roles of person and situation factors. *J. Appl. Psychol.* **2009**, *94*, 1103–1127. [CrossRef]
28. Clarke, S. The relationship between safety climate and safety performance: A meta-analytic review. *J. Occup. Health Psychol.* **2006**, *11*, 315–327. [CrossRef]
29. Beus, J.M.; Payne, S.C.; Bergman, M.E.; Arthur, W. Safety climate and injuries: An examination of theoretical and empirical relationships. *J. Appl. Psychol.* **2010**, *95*, 713–727. [CrossRef] [PubMed]
30. Zweber, Z.M.; Henning, R.A.; Magley, V.J. A practical scale for Multi-Faceted Organizational Health Climate Assessment. *J. Occup. Health Psychol.* **2016**, *21*, 250–259. [CrossRef] [PubMed]
31. Basen-Engquist, K.; Hudmon, K.S.; Tripp, M.; Chamberlain, R. Worksite health and safety climate: Scale development and effects of a health promotion intervention. *Prev. Med.* **1998**, *27*, 111–119. [CrossRef]
32. Ribisl, K.M.; Reischl, T.M. Measuring the climate for health at organizations. Development of the worksite health climate scales. *J. Occup. Med.* **1993**, *35*, 812–824. [CrossRef]
33. Zohar, D. Thirty years of safety climate research: Reflections and future directions. *Accid. Anal. Prev.* **2010**, *42*, 1517–1522. [CrossRef]
34. Kaluza, A.J.; Schuh, S.C.; Kern, M.; Xin, K.; Dick, R.V. The importance of organizational health climate for employee health: A multilevel cascading model. *Acad. Manag. Proc.* **2018**, *2018*, 11709. [CrossRef]
35. Kelloway, E.K.; Barling, J. Leadership development as an intervention in occupational health psychology. *Work Stress* **2010**, *24*, 260–279. [CrossRef]
36. Schwatka, N.V.; Tenney, L.; Dally, M.J.; Scott, J.; Brown, C.E.; Weitzenkamp, D.; Shore, E.; Newman, L.S. Small business Total Worker Health: A conceptual and methodological approach to facilitating organizational change. *Occup. Health Sci.* **2018**, *2*, 25–41. [CrossRef]
37. Health Links Certified 2018. Available online: https://www.healthlinkscertified.org (accessed on 15 March 2021).
38. Schwatka, N.V.; Brown, C.E.; Tenney, L.; Scott, J.G.; Shore, E.; Dally, M.; Newman, L.S. Evaluation of a Total Worker Health® leadership development program for small business. *Occup. Health Sci.* **2021**, *5*, 163–188. [CrossRef]
39. Lee, J.; Huang, Y.H.; Robertson, M.M.; Murphy, L.A.; Garabet, A.; Chang, W.R. External validity of a generic safety climate scale for lone workers across different industries and companies. *Accid. Anal. Prev.* **2014**, *63*, 138–145. [CrossRef]
40. Topp, C.W.; Østergaard, S.D.; Søndergaard, S.; Bech, P. The WHO-5 Well-Being Index: A systematic review of the literature. *Psychother. Psychosom.* **2015**, *84*, 167–176. [CrossRef] [PubMed]

41. Harris, P.A.; Taylor, R.; Minor, B.L.; Elliott, V.; Fernandez, M.; O'Neal, L.; McLeod, L.; Delacqua, G.; Delacqua, F.; Kirby, J.; et al. The REDCap consortium: Building an international community of software platform partners. *J. Biomed. Inform.* **2019**, *95*, 103208. [CrossRef] [PubMed]
42. Harris, P.A.; Taylor, R.; Thielke, R.; Payne, J.; Gonzalez, N.; Conde, J.G. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. *J. Biomed. Inform.* **2009**, *42*, 377–381. [CrossRef] [PubMed]
43. Schneider, B. Organizational climates: An essay. *Pers. Psychol.* **1975**, *28*, 447–479. [CrossRef]
44. Kuenzi, M.; Schminke, M. Assembling fragments into a lens: A review, critique, and proposed research agenda for the organizational work climate literature. *J. Manag.* **2009**, *35*, 634–717. [CrossRef]
45. Lee, J.; Huang, Y.H.; Cheung, J.H.; Chen, Z.; Shaw, W.S. A systematic review of the safety climate intervention literature: Past trends and future directions. *J. Occup. Health Psychol.* **2019**, *24*, 66–91. [CrossRef]
46. Denison, D.R. What IS the difference between organizational culture and organizational climate? A native's point of view on a decade of paradigm wars. *Acad. Manag. Rev.* **1996**, *21*, 619–654. [CrossRef]
47. Brown, C.E.; Schwatka, N.; Dexter, L.; Dally, M.; Shore, E.; Tenney, L.; Newman, L.S. The importance of small ubsiness safety and health climates during COVID-19. *J. Occup. Environ. Med.* **2021**, *63*, 81–88. [CrossRef] [PubMed]
48. Lacerenza, C.N.; Reyes, D.L.; Marlow, S.L.; Joseph, D.L.; Salas, E. Leadership training design, delivery, and implementation: A meta-analysis. *J. Appl. Psychol.* **2017**, *102*, 1686–1718. [CrossRef] [PubMed]
49. Davidson, B.; Schmidt, E.; Mallar, C.; Mahmoud, F.; Rothenberg, W.; Hernandez, J.; Berkovits, M.; Jent, J.; Delamater, R.N. Risk and resilience of well-being in caregivers of young children in response to the COVID-19 pandemic. *Transl. Behav. Med.* **2021**, *11*, 305–313. [CrossRef]
50. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Ceraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
51. Peckham, T.K.; Baker, M.G.; Camp, J.E.; Kaufman, J.D.; Seixas, N.S. Creating a future for occupational health. *Ann. Work Exp. Health* **2017**, *61*, 3–15.
52. Rogers, T.N.; Rogers, C.R.; VanSant-Webb, E.; Gu, L.Y.; Yan, B.; Qeadan, F. Racial disparities in COVID-19 mortality among essential workers in the United States. *World Med. Health Policy* **2020**, *12*, 311–327. [CrossRef] [PubMed]
53. Godderis, L.; Luyten, J. Challenges and opportunities for occupational health and safety after the COVID-19 lockdowns. *Occup. Environ. Med.* **2020**, *77*, 511–512. [CrossRef] [PubMed]
54. National Institute for Occupational Safety and Health Priority Areas and Emerging Issues. Available online: https://www.cdc.gov/niosh/twh/priority.html (accessed on 11 June 2021).

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Article

Public Health Impacts of Underemployment and Unemployment in the United States: Exploring Perceptions, Gaps and Opportunities

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Abstract: Background: Unemployment, underemployment, and the quality of work are national occupational health risk factors that drive critical national problems; however, to date, there have been no systematic efforts to document the public health impact of this situation. Methods: An environmental scan was conducted to explore the root causes and health impacts of underemployment and unemployment and highlight multilevel perspectives and factors in the landscape of underemployment and unemployment. Methods: included a review of gray literature and research literature, followed by key informant interviews with nine organizational representatives in employment research and policy, workforce development, and industry to assess perceived needs and gaps in practice. Results: Evidence highlights the complex nature of underemployment and unemployment, with multiple macro-level underlying drivers, including the changing nature of work, a dynamic labor market, inadequate enforcement of labor protection standards, declining unions, wage depression, and weak political will interacting with multiple social determinants of health. Empirical literature on unemployment and physical, mental, and psychological well-being, substance abuse, depression in young adults, and suicides is quite extensive; however, there are limited data on the impacts of underemployment on worker health and well-being. Additionally, organizations do not routinely consider health outcomes as they relate to their work in workforce or policy development. Discussion and Conclusions: Several gaps in data and research will need to be addressed in order to assess the full magnitude of the public health burden of underemployment and unemployment. Public health needs to champion a research and practice agenda in partnership with multisector stakeholders to illuminate the role of employment quality and status in closing the gap on health inequities, and to integrate workforce health and well-being into labor and economic development agendas across government agencies and industry.

Keywords: underemployment; unemployment; health impacts; public health; decent work; United States

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1. Introduction

In the last thirty years the economic realities facing a majority of workers globally have become more severe due to broad shifts in macroeconomic policies and "disruptions involving new technologies and growing trade links" [1]. Often referred to as the "changing nature of work", workers across the income spectrum increasingly face labor market insecurities and austerity in public programs designed to alleviate worker hardships [2–6]. These trends will likely continue as work becomes more precarious across numerous industrial sectors and worker protections, such as labor unions, are weakened [2]. Much

has been written about the changing nature of work and growing labor market insecurities since the 1980s [2–4]. The changing nature of employment relationships and the contemporary "fissured workplace" [6] has resulted in a decline in the number of secure, full-time jobs [3–5]. There is a growing awareness that these economic forces may result in adverse effects on mental health, health behaviors, and chronic disease; however, there is a limited understanding of the full impact of the changing nature of work on the health and well-being of the workforce [7–9].

A renewed call for contemporary research to understand the relationship between health implications and unemployment, underemployment, and the changing nature of work has arisen in the past decade [10,11]. Rosenthal et al. [7] argue that because of "changes and cuts to social welfare services, decreases in the number of secure, full-time jobs, and general changes in the workforce over the past several years, it is important to re-examine the associations of employment status with mental and physical health, as they may differ from past decades". Rosenthal [7] also suggests that it is "vital for the health and well-being of all people to increase not simply employment, but specifically full-time employment".

The United States has experienced an alarming increase in suicide rates, opioid/other drug and alcohol abuse, and poorer physical and mental health, which can be traced in part to unemployment, underemployment, and the quality of working lives [12–15]. Research indicates that the absence of employment in good jobs contribute to these "deaths of despair" [12]. The lack of skills and opportunities and an increase in hopelessness and despair have led to a drastic increase in mortality arising in middle-age, white Americans [12], increased depression in young adults [13,14], the increased likelihood of unemployment and health problems in African Americans [13], and increased opioid overdose mortality associated with automotive assembly plant closures, "highlighting the role of declining economic opportunity in the US opioid overdose crisis" [15].

Underemployment and unemployment (and employment status in general) are often framed as economic problems, but they are also complex and multifaceted public health issues interacting with multiple social determinants of health that play a crucial role in perpetuating health inequities. Even before the COVID-19 pandemic, unemployment, underemployment, and the quality of work were national occupational health risk factors that drove critical national problems. The pandemic has made it very evident that the economy and jobs are social constructs that impact the distribution of health outcomes across a population [16,17]. Distribution of benefits and risks associated with work, just like the distribution of health outcomes, are inequitable and impacted by social factors, such as race and gender [18]. According to data from the Bureau of Labor Statistics [19], as of April 2021 the unemployment rate was 6.1 percent, and the number of unemployed persons, at 9.8 million, was still 4.0 million higher than in February 2020. The number of permanent job loses, at 3.5 million, is 2.2 million higher than February 2020. The number of long-term unemployed (those jobless for 27 weeks or more), at 4.2 million, is up by 3.1 million since February 2020 accounting for 43.0 percent of the total unemployed. It is anticipated that both the economy and jobs will continue undergoing significant changes and some jobs lost during the pandemic may be lost for good because businesses have adopted new ways to operate [1,20]. COVID-19 has only accelerated existing trends in remote work, e-commerce, and automation [1] and it may take several years to fully-realize the societal impacts of the new post-pandemic economy.

One key concept in public health is preventability, and there are conceivable ways to reduce and/or prevent the impacts of underemployment and unemployment. Work can be understood as a primary vehicle for responding to the *Surgeon General's Call to Action on Community Health and Prosperity* [21]. The simple distinction of comparing employment to unemployment obscures the complexity of the relationship between work and health. Ezzy [22] and Warr [23] show that unemployment is not always harmful, and reemployment does not necessarily remediate underlying issues. Friedland and Price [24] succinctly summarized the research on these experiences: "when people lose jobs that

are especially stressful, they often do not experience declines in well-being" [25] and "the quality of work plays a critical role in determining whether work is a source of well-being or cause of ill-being" [26]. Failure to account for the quality of employment may lead to an underestimation of both the harmful effects of unemployment and the beneficial effects of high-quality employment [27]; "Being unsatisfactorily employed is as bad as being unemployed" [28–30].

According to the International Labour Organization's (ILO) definition, decent work "involves opportunities for work that is productive and delivers a fair income, security in the workplace and social protection for families, better prospects for personal development and social integration, freedom for people to express their concerns, organise and participate in the decisions that affect their lives and equality of opportunity and treatment for all women and men" [31]. During the United Nations General Assembly in September 2015, decent work and the four pillars of the Decent Work Agenda—employment creation, social protection, rights at work, and social dialogue—became integral elements of the new 2030 Agenda for Sustainable Development [32]. Goal 8 of the 2030 agenda calls for the promotion of sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work, and will be a key area of engagement for the ILO and its constituents [32]. Furthermore, key aspects of decent work are widely embedded in the targets of many of the other 16 goals of the UN's new development vision. While the United States is a large donor [33] and supporter of the ILO's Decent Work Agenda, there is limited evidence of efforts to fully adopt or implement this agenda within the US. Decent work provides economic security, self-esteem, and social connectedness, and, as COVID-19 has highlighted, work can also undermine these same factors and contribute to the inequitable distribution of health outcomes [16–18].

Although there is an awareness of the impact of underemployment and unemployment on the health and well-being of US workers, to date there have been no systematic efforts to document the public health impact of this situation. The goal of this study was to gather evidence to reframe underemployment and unemployment (including, but not limited to, as it relates to a lack of employability skills) as public health problems and to contribute to the development of a strategic public health action agenda to address the identified areas of strengths, gaps, and opportunities. Systems thinking is a discipline for seeing wholes and interrelationships rather than linear cause–effect relationships. It involves a process of continuous change rather than perspectives at one point in time [34,35]. Applying a systems lens can reveal the causal pathways for underemployment and unemployment that exist at multiple levels within and outside organizations and institutions, and the resources and opportunities needed to address them. The authors conducted an environmental scan [36] with qualitative methods to "unpack" underemployment and unemployment through a public health lens to assess the challenges, needs, strongest areas of alignment, and possible leverage points for future research and action.

This study was completed just before the onset of the pandemic and the findings describe the pre-pandemic state of underemployment and unemployment in the US workforce by exploring the perspectives and interrelationships of stakeholders. However, these findings also forecast the fractured experience and challenges faced by workers and stakeholders during the on-going pandemic, and highlight the urgency in accounting for the growing impacts of underemployment and unemployment on the health and well-being of the workforce as we navigate the post-pandemic economy and future of work.

Objectives

The primary objectives of this study were to: (1) describe the root causes/drivers of underemployment and unemployment; (2) document perceptions of underemployment and unemployment among multilevel stakeholders alongside the perceived barriers and facilitators to employment; (3) describe health and economic impacts of underemployment and unemployment; and (4) identify connections and points of leverage for action.

2. Materials and Methods

2.1. Literature Review

Multiple comprehensive and structured searches of the scholarly literature were conducted between October 2018 and December 2019 in the following databases, without date restrictions: PubMed, Business Source Premier, CINAHL, EconLit, PsycINFO, Sociological Abstracts, and Web of Science Core Collection. Several iterative searches were performed using search terms centering on the two conceptual domains of underemployment/unemployment and health outcomes (health care services, mental health, depression, anxiety, suicide, addiction, food insecurities, homelessness, interventions, program evaluation, program implementation, skills gap, public health, community health, economy, labor policies). No specific exclusion criteria were used for this phase of the search. Separate searches on a number of subtopics were carried out in order to address the multiple facets of this broad topic. Subtopic searches included, but were not necessarily limited to: how underemployment and unemployment are defined in the literature, drivers of underemployment and unemployment, health and economic implications at both the individual and community levels, facilitators and barriers to employment, and key stakeholders in addressing these issues. General web searches were performed to identify gray literature, as well as targeted searches of the websites of organizations known to be working on addressing issues of underemployment and unemployment. These searches included, but were not limited to, policy groups such as the Economic Policy Institute and the National Bureau of Economic Research, the Harvard Business Review, the International Labour Organization, the World Health Organization, J.P. Morgan Chase, the National Employment Law Project, the Bureau of Labor Statistics, the Organisation for Economic Co-operation and Development, the National Institute for Occupational Safety and Health, the National Skills Coalition, the US Department of Labor, and federal, state, and local workforce training groups. Literature retrieved included think tank and research reports, white papers, and US national, state, and local government reports. A total of 327 articles were amassed according to the methods outlined above (these included 286 peer-reviewed publications and 41 gray literature publications). The abstracts were scanned by three team members (including a university librarian) and sorted by the following themes: health impact, mental health, community and social aspects, skills gaps, economics, policies and programs related to skills training, public–private workforce partnerships, underemployment, and unemployment. Two coders initially scanned articles and reports that they were familiar with from the literature and identified additional articles which were cited. A memoing process [37] was used to identify recurring themes related to the a priori research questions, which led to a comprehensive review of 52 articles and a basic examination of an additional 45 articles (including 13 gray literature publications). The authors prioritized US-specific publications and reports for this phase of the review; however, a few key studies from other developed countries, such as the United Kingdom, were included to support literature findings or draw comparisons. Initial results of the literature review were used to identify domain areas for the interviews.

2.2. Interviews

Representatives from nine different organizations were individually interviewed between March and September 2019, with each interview lasting approximately 45–60 min. Key informants included representatives from two nonprofit policy think tanks, two workforce development organizations, a national skills coalition, a grassroots worker center focusing on temporary staffing workers, one community colleges system (amongst the largest in the United States) and two industry representatives, one from a regional hotel and lodging trade association and one from a national manufacturing association. Key informants were identified from a pool of local, regional, and state, and national nonfederal organizations who are addressing worker health and safety, specifically through initiatives addressing underemployment and unemployment in the United States. An initial purposive sample of potential participants and their contact information was generated by the

project team. The participants were then recruited to ensure that we captured a wide range of responses that illustrate the diverse interests and possible commonalities in addressing underemployment and unemployment and its connection to health. The participants selected were chosen to maximize understanding by increasing the likelihood of gaining access to perspectives that challenge, alter, and further inform our initial understanding of these issues from the literature.

A predetermined, semi-structured interview tool was used to elicit respondent beliefs and concerns about underemployment and unemployment and the impact on health. The interview tool was structured to cover specific topics, including: (1) how the concepts of underemployment and unemployment are perceived and characterized (including drivers) by stakeholders at the local, regional, and national levels; (2) health and its relationship to underemployment and unemployment; (3) initiatives currently underway that identify and address possible pathways to employment and the barriers to implementation of these initiatives; and (4) strengths and opportunities for engaging multisector stakeholders to align and increase resources to address underemployment and unemployment. Respondents were asked to express their opinions and concerns on these topics.

Analysis of the transcripts was conducted using qualitative content analysis (thematic), a method used to categorize large amounts of text from transcripts by assigning initial codes to text segments based on attributes to the phenomenon that accurately reflected the a priori research questions and relevant research findings [38]. Two coders reviewed and coded each interview transcript based on the focused coding categories: the perspectives on the definitions of underemployment and unemployment; drivers of each; health factors connected to the ability to access, or not access, work and livable wages (an approximate income to meet a family's basic needs [39]); how they view work as a meaningful and significant determinant of health outcomes; perceptions about skills gap in the labor market; barriers to doing the work they are doing; and emergent themes (i.e., those unanticipated issues relevant to the topic that participants raised). An intra-case/cross-case analysis was performed to analyze and code both the anticipated (a priori) and unanticipated themes. Relevant quotations thus organized were selected for further analysis (based on the initial coding and alignment with research objectives).

All phases of coding and analysis were performed manually. Data were analyzed through an iterative process of reflective reading of transcripts, interpretive memoing, and coding and exploring inconsistencies and divergent perspectives, or cases that did not fit with the initial interpretations [37]. Respondents' accounts of their experiences working in policy, advocacy, workforce development, and other relevant labor market issues were then clustered together in themes to provide an account of respondent meanings and interpretations of the phenomenon [37]. The open-ended questions used to guide the interviews elicited a variety of participant responses, and qualitative analysis uncovered an assortment of main themes. Key themes from the literature review and key informant interviews were examined to identify a crosswalk of common and divergent themes, areas of alignment, and gaps in evidence [38]. The uniformity of themes across interviews seems to suggest that the results are reasonably reliable.

3. Results

The findings presented in this section highlight the four overarching themes and several subthemes emerging from the crosswalk of themes from the review of 74 peer-reviewed and gray literature publications and the nine key informant interviews. These themes describe the landscape of unemployment, underemployment, and the impact on health outcomes.

3.1. Large Macro-Level Issues Are Driving the Underemployment and Unemployment Narrative

A number of convergent themes emerged from the literature review and discussion around the significant drivers of underemployment and unemployment. While the cyclical nature of the labor market and recession were commonly reported drivers of underem-

ployment and unemployment, a number of other factors, (Figure 1) including the changing nature of work [40], a lack of quality jobs [41], the devaluing of workers, depressed wages, disinvestments by both the public and private sectors on worker education and training [6], a dynamic labor market, and inequalities in the distribution of public funding/resources emerged in both the literature and key informant interviews.



Figure 1. Description of the key themes emerging from the literature review and key informant interviews.

Fenwick and Tausig [42] argued that we need to address the role that macroeconomic changes have had on the structure of work. As economic changes transformed the organization of work, they modified the work environment, subjecting employees to stressful work conditions. They also linked the economic stress and work stress approaches by arguing that "macroeconomic and economic changes affect exposure to life events such as unemployment as well as the level of stress from changing work roles and the structure of the workplace" [42,43]. Ferman and Gordus [44] proposed a model in which economic change resulted in displacement and loss of work for some groups. In their study, they observed that "displaced individuals may accept employment with fewer economic and other benefits including protection from unfair work practices, or lower status positions . . . " and that "career patterns of these individuals may change, as they find immediate reemployment, move from job to job, or remain unemployed, and this was argued to cause stress and instability" [44].

Research also explores the wage penalty suffered by involuntary part-time workers. Golden [45] found that amongst workers paid by the hour in the US, voluntary part-time workers earned USD 15.61 per hour on average compared with only USD 14.53 for those who could "find only part time work". Using data from the United Kingdom, Blanchflower and Bell obtained similar results in their working paper [46], finding that individuals who wanted more hours (part-timers wanting full-time employment), had lower hourly wages than voluntary part-timers and full-timers. This leads to the implication that "part-timers who want extra hours are paid less than part-timers who are content with their hours". In the US, there was a norm of average wages rising 4 percent per year in the years before the Great Recession (2007–2009) and 2 percent subsequently. The US federal minimum wage has remained unchanged at USD 7.25 since 2009 [47]. Twenty-nine states have set the minimum wage above the federal minimum wage [47]. Research suggests associations of increased wages with improved birth outcomes, lower rates of sexually transmitted infections among women, as well as decreases in both suicide mortality and hypertension [48–51].

One often cited explanation for persisting underemployment and unemployment is the debate over the supposed "skills gap" asserted by US employers. The literature revealed diverse views of the skills gap argument in the academic literature [52–56] versus the consulting world [57–59]. Data from reports (mostly industry specific) in the gray literature and some of the key informant interviews support the fact that there are some skills gaps, but there was no strong evidence to support the argument that there is an overall skills gap; rather, what emerged was a skills mismatch issue, a lack of clear information on what the education and skills acquisition pathway is for the future of work, and employers' lack of investment in skills training for their workers.

Five out of nine interview respondents described the current labor economy as set up to basically discount the value of workers and lamented the role of declining unions and enforcement standards and their impact on job quality and pay:

> *"All of the things that gives power to workers . . . . . like unions, strong labor standards, strong enforcement of those standards. Those have all been diluted so dramatically . . . "*
>
> —interview respondent from a policy group.

> *"you lost the job at the unionized place where you were making USD 30 an hour and the only jobs that are available now are USD 9 an hour. It's just like totally and utterly demoralizing and catastrophic at every level. [. . .] . . . . . where are those other good jobs you can find when you lost a job . . . [. . .] . . . one of the things that made it so bad for so many people is they can't find another one that can sustain their living standards"*
>
> —interview respondent from a workforce development organization.

> *"what used to be the experience of marginalized workers (for whatever reason they were marginalized) has actually become some of the experience of mainstream workers"*
>
> —interview respondent from a workforce development organization.

> *"Employers have no investment in their workers. They're not the employer of record anymore [. . .] . . . they have every incentive in the world to outsource their work. So, it doesn't matter if you're blue collar, white collar or even university professors. [. . .] . . . . . work is constantly being non-standardized"*
>
> —interview respondent from a worker advocacy group.

> *"the jobs aren't particularly good. I just don't know people who are like, "Oh, I'm dying to be in retail." . . . the growth in terms of number of jobs . . . it is in the services, it is in hospitality, retail, education services, and the occupations that grow the most are the lowest paid. I think the wages thing is totally key. We have the employer, who in this country has a lot of power to keep wages down. And they do exercise that power"*
>
> —interview respondent from a policy group.

Among the interview respondents, there was a strong convergence perception that the idea of a skills gap preventing access to the labor market, a claim made by many employers as the most significant barrier to work, is only one explanation for barriers to the labor market. Six of the nine respondents pointed to the role of particularly burdensome barriers (unrelated to skills) for certain individuals and communities in accessing the labor market, including older age, history of incarceration, child/family care needs, transportation needs, and driver's license status, all of which can significantly impede access to employment.

> *"I think that the story is a lot less about workers not having the right skills. I'm not saying that skills are not important but a huge share of jobs in this country require no training or maybe some high school . . . . . [. . .] . . . look at BLS data . . . and the astounding number of jobs that just don't actually require that many specific skills. And the difference between what is a good job and not a good job are unions and labor standards. . . . [. . .] . . . is a bigger player than the skills story . . . "*
>
> —interview respondent from a policy group.

Interview respondents also expressed concerns over the disproportionate amounts of both public and private investment going to people higher along the education spectrum.

> *"we are not targeting that federal or private investment in workers who need it in order to progress along their career pathway. . . . [. . .] . . . we are spending USD 140 billion on federal student aid every year but only 14% of that is going to skills training programs, there's a mismatch between what people are experiencing, and what people want to be doing and what we're actually spending money on"*
>
> —interview respondent from a skills coalition group.

Overall, interview respondents reported that underemployment and unemployment are influenced by a variety of factors that are often ignored by many policy makers and employers, yet have a direct impact on the ability of many people to access the labor market and gain the stability and health outcomes connected to attaching to the labor market in a sustainable way.

3.2. Gaps Exist in the Definitions and Measures of Underemployment and Unemployment

A common theme emerging from both the literature review and key informant interviews was that while the official unemployment rate was at historically low levels in the US prior to the pandemic, the large number of underemployed workers indicates that the country's labor markets were not anywhere close to full employment, even before the pandemic. The Bureau of Labor Statistics (BLS) [60] defines full employment as an economy in which the unemployment rate equals the nonaccelerating inflation rate of unemployment (NAIRU), no cyclical unemployment exists, and GDP is at its potential. The full-employment assumption links BLS projections to an economy running at full capacity and utilizing all of its resources [60]. In order to best understand the negative health impacts linked to a lack of work, researchers are best served looking at the different measures of underemployment and unemployment and its impacts on varying geographies, sectors, and worker demographics.

The BLS has a specific definition of unemployment: those who do not have a job but are available for work and have looked for work in the past four weeks. According to BLS data, in December 2019 (before the pandemic), the US unemployment rate was 3.5 percent, the lowest since 1969, and the number of unemployed persons was at 5.8 million [61]. Although the number of long-term unemployed (those jobless for 27 weeks or more) edged down to 1.2 million (20.9 percent of the unemployed), this number still remained higher than it was before the Great Recession (2007–2009) [61]. Similarly, the proportion of people unemployed for longer periods (52 weeks or more) also remained higher than before the Great Recession and about 1.2 million persons were marginally attached to the labor force in December 2019 [61]. These individuals were not in the labor force, wanted and were available for work, and had looked for a job sometime in the prior 12 months. They were not counted as unemployed because they had not searched for work in the 4 weeks preceding the survey. Among the marginally attached, there were 277,000 discouraged workers in December 2019, which was 98,000 less than the number of such workers in the previous year [61]. Discouraged workers are persons not currently looking for work because they believe no jobs are available for them. The remaining 969,000 persons marginally attached to the labor force had not searched for work for reasons such as school attendance or family responsibilities [61].

As defined by Feldman [62], underemployment is the inability to obtain adequate employment relative to some standard. Based upon previous research conducted by Feldman [62] and McKee-Ryan and Harvey [63], Thompson et al. [64] aggregated the types of underemployment that affect how individuals perceive their job situation. Accordingly, education or experience underemployment occurs when individuals possess more education or experience than is required for their jobs, while "individuals who earn less at their current job than they did previously or those earning 20% less than their peers suffer from wage underemployment" [64]. Job status underemployment characterizes individuals who would like to work full time but who can only find part-time employment, and job field

underemployment affects people who are forced to work in a field of employment that is outside their area of formal education and/or job experience [64].

The most widely available measure of underemployment estimated by statistical agencies around the world, such as the BLS in the US, the Office for National Statistics in the UK, and the EU statistical agency Eurostat, is the share of involuntary part-time workers in total employment, also known as the involuntary part-time rate (IPTR). In Europe, involuntary part-timers are described as part-timers who want full-time jobs (PTWFT). In the United States they are described as part-time for economic reasons (PTFER). The number of PTFER, sometimes referred to as involuntary part-time workers (or underemployed workers) was at 4.3 million in the US in December 2019 [61], representing 2.7 percent of the working population. These individuals, who would have preferred full-time employment, were working part time because their hours had been reduced or they were unable to find full-time jobs. The fact that millions of workers wanted to work more hours indicated that the labor market still had plenty of slack. Gallup polls from 2010 found that 18 percent to 25 percent of American workers perceived themselves as underemployed—a stark contrast to the BLS underutilization rate of 6.4 percent [65,66]. Previous research by Jensen and Slack [67] concurs that "underemployment was proposed as a more exhaustive and hence more valid measure of employment hardship than mere unemployment." Therefore, in December 2019, while the US unemployment rate had returned to levels seen pre-recession, underemployment remained elevated [61] and undercounted because, although people talk about the term "underemployment", there is not much in the literature or policy about standard ways to measure it in the labor market. The US Labor Department, in its current measure of "part time for economic reasons", does not ask how many hours the underemployed want to work and therefore does not do a good job of measuring underemployment.

The literature on the characteristics of underemployed individuals has grown exponentially in the past three decades. Blanchflower and Levin [68] showed that in the US the rise of underemployment "represents another dimension of labor underutilization." Discrimination in the labor market based on age and race emerged as prominent themes in the literature. Early studies examining underemployment and the experiences of different racial and ethnic groups found that minority groups in the US (e.g., Blacks, Latinos, immigrants) have higher prevalence (compared to non-Hispanic Whites and Asians) of underemployment, even after controlling for human capital, industry, occupation, family structure, and other predictors [69–72]. Valletta et al. [73] found that young workers under the age of twenty-four, the single, the least educated, Blacks and Latinos, and the unincorporated self-employed are most likely to work part time involuntarily. Another early study focused on gender disparities, with women showing higher prevalence of working poverty and involuntary part-time work [74]. The overrepresentation of women, ethnic/racial minorities, and foreign-born individuals among the unemployed and underemployed suggests that structural disadvantages overlap and interact with one another in the lives of many workers, leading to cumulative precariousness that likely aggravates existing health inequities [75,76].

Key informants were first asked to provide their own personal definitions of the terms (underemployment and unemployment). Respondents shared the meaning, significance, and outcomes of varied perceptions about the definitions of underemployment and unemployment. Comments from respondents reveal miscommunication of unemployment rates provided to the public, influencing decisions and considerations from the public and policy makers. Most described a common public perception that while unemployment numbers may look good overall, substantial differences are experienced in the labor market not related to the economy or recessions, but based on factors related to age, race, immigrant/refugee status, trauma history, parenting status, caregiving/family/child responsibilities, history of incarceration, food insecurity, poverty, transportation access, driver's license status, literacy skills, status of protections afforded from participation in unions, enforcement of labor standards, disability status, presence of addictions (with the individual or within the family), and homelessness.

" . . . there are many ways to measure unemployment and there's the standard rate that gets reported in the mainstream media every month. A lot of people think the more accurate analysis of the strength of the economy is the employment to population ratio . . . . . . And we are actually lower by historical standard in the employment to population ratio. Another standard is for people who are still unemployed (long-term unemployment) . . . [. . .] . . . usually post-recession in a recovery the length of long-term unemployment starts to shorten and that hasn't been happening"

—interview respondent from a policy group.

"unemployment is at 3.5 percent. . . . ..the overall numbers have enormous variation . . . . . .and enormously different outcomes for different individuals and different groups. Like the demographics and certain classes of workers. And the racial/minority unemployment rate is almost vastly different . . . essentially the black unemployment rates is twice the white unemployment ratings this time or that time"

—interview respondent from a workforce development organization.

"unemployment rate . . . is a kind of a marker that people are familiar with. For those of us in the field, we know that [. . .] marker that people talk about globally is actually not a full picture. So that number doesn't necessarily encompass all the folks out there who aren't working. . . . we just need to make sure that people understand that"

—interview respondent from a policy group.

"Underemployment for me is really just about folks that are working in subpar economic scenarios . . . . . . underemployment could also then be defined as working multiple jobs to barely make it, or working multiple jobs to make it . . . but being underemployed in each of those areas makes it more difficult to participate say fully in family or whatever the circle of peoples experience is . . . "

—interview respondent from a community colleges system.

3.3. Need for Quality Data on Health Outcomes for Individuals and Communities by Demographics and Geographic Levels; and for Connecting Health Data to Policy Makers, Workforce Development Agencies, Employers and Funders

3.3.1. Extensive Empirical Literature on Impacts of Unemployment (Mostly Long Term) on Physical, Mental Health and Psychological Well-Being

The connection between unemployment and negative health outcomes has been well-established in the academic literature [77]. For the most part, unemployment, particularly episodes that last longer than six months, is associated with significant detrimental effects in psychological and physical well-being [78,79]. Perhaps most profound is how unemployment has been linked with increased mortality [80–89]. A number of studies have demonstrated the link between unemployment and mental health problems, including depression, somatization, anxiety, and substance abuse [90–92]. In their three-wave panel study on the relationships between auto plant closings and unemployment of blue-collar workers, Broman et al. explored how the mental health impacts of long-term unemployment vary across race and gender [93]. Specifically, they found that the "effect of long-term unemployment on distress and drinking was more severe among less educated workers, and responses of blacks were especially sensitive to level of education" [93]. A number of studies have also found a correlation between unemployment and increased smoking and alcohol usage [94–96].

A 2003 study conducted by Brown et al., from the CDC National Center for Chronic Disease Prevention and Health Promotion, examined the relationships between unemployment and frequent mental distress (FMD), defined as 14 or more mentally unhealthy days during the previous 30 days, in a study of over 98,000 men and women aged 25–64 years in the United States [97]. This team of researchers discerned similar patterns across gender, race/ethnicity, education, income, and high unemployment areas of the US, and concluded that "unemployed persons are a population in need of public health intervention

to reduce the burden of mental distress", and that "public health officials should work with government officials to incorporate the health consequences of unemployment into economic policymaking" [97]. In 1986, Dooley and Catalano found that communities with high rates of unemployment have higher rates of suicide and mental hospitalization [98]. Research published in 2011 by Luo et al. examined the relationships between overall and age-specific suicide rates and US business cycles from 1928 to 2007 [99]. Results from their analyses showed that the "overall suicide rate generally rose during recessions and fell during expansions", while "age-specific suicide rates responded differently to recessions and expansions" [99]. In conclusion, researchers found that business cycles (and thus unemployment levels) have the propensity to affect suicide rates, although different age groups responded differently, and that "public health responses are a necessary component of suicide prevention during economic downturns" [99].

McGee and Thompson [13] used data from the 2010 Behavioral Risk Factor Surveillance System (BRFSS) to specifically analyze the relationship between unemployment and symptoms of depression among emerging adults (aged 18 to 25 years). Findings from their research show that almost 12 percent of emerging adults were depressed and about 23 percent were unemployed, and that significantly more unemployed than employed young adults were diagnosed with depression. In summary, their models concluded that the "odds of depression were about 3 times higher for unemployed than employed emerging adults" [13]. While many factors can contribute to depression, unemployment is typically associated with high rates of depression among adults [78,100] due in part to losses in social contact and status or stress related to income loss [101]. Earlier research by Galambos et al. [102] established that for emerging adults, "long experiences of unemployment increase the likelihood of experiencing depression throughout the transition" [102].

Moller [103] also noted that not all unemployed persons will seek medical assistance and that all policy initiatives must always take note that society's most disadvantaged populations are likely to suffer most from unemployment, and that these groups might have more difficulty in accessing services and support programs [103,104]. A 2013 study [105] also drew the link between changes in the unemployment rate and health care choices among the affected. Specifically, Tefft et al. found that a 1 percent increase in state unemployment corresponded to a 1.58 percent reduction in the use of preventive health care services for women such as mammograms, pap tests, and annual check-ups [105]. Study researchers discerned that women and people who are already economically disadvantaged were especially sensitive to economic fluctuations. This is in part due to the fact that, as the authors noted, preventive medical care is underutilized in the United States, with only about half of the population following recommended guidelines. They suggested that "preventive care can carry a relatively high one-time cost and may be more likely to be seen as a relative luxury; therefore, changes in income, or fears of an impending loss of income during a downturn, may have a greater effect on their use" [105].

3.3.2. Limited Research on Impacts of Underemployment on Physical, Mental and Psychological Well-Being

While the health effects of unemployment have been studied for a long time, the impacts of underemployment are less studied. The limited research in this area suggests that underemployment also negatively impacts health. Friedland and Price characterize "underemployment as a potential social stressor that places demands on workers and may compromise their health and well-being" [24]. Accordingly, "social stress is arousal due to an imbalance between perceived environmental demands and perceived capacity to respond to those demands" [24,106]. Using longitudinal data for the US from the Americans' Challenging Lives study from 1986–1994, Friedland and Price [24] observed some support for the hypothesis that underemployment is related to lower levels of physical health. People who are status-underemployed report more chronic disease and less functional health than do adequately employed workers. People who are income-underemployed report less functional health than do adequately employed workers. Friedland and Price caution that the "relationship between underemployment and health and psychological well-being

varies by both types of underemployment and indicator of health and wellbeing" [24]. They advise researchers to specify types of underemployment and specific health indicators when describing their relationships, rather than relying on generalizations.

In their July 2018 working paper, Blanchflower and Bell examined the intersection between underemployment and well-being using data from the UK [107]. The five main measures they used to measure well-being include: happiness; life satisfaction; whether life is worthwhile; anxiety and depression. Their research found that "those who wished to increase their hours (the underemployed) rose sharply in the years after 2008, while the number who wished to reduce their hours (the overemployed) fell slightly" and that post-recession, "over-employment fell back to pre-recession levels, but underemployment did not". Blanchflower and Bell found that while the underemployed have higher levels of well-being than the unemployed and disabled, they have lower levels of well-being than any other group of workers, full- or part-time. Both unemployed and underemployed individuals were unhappy and depressed, due in large part to their loss of earnings and the coinciding lower standards of living. Blanchflower and Bell found that the fear of unemployment was on the rise, and also found evidence of a large rise in anxiety and depression among the underemployed (between 2008–2018), especially underemployed women [107]. Research by Jones-Johnson [108] suggests a link between underemployment and both psychological and interpersonal stress that may be particularly severe when minority group status is added to the mix.

Wooden, Warren, and Drago [109] and Wilkins [110] used longitudinal data from the 2001 Household, Income and Labour Dynamics in Australia (HILDA) survey, and found that underemployment lowers job and life satisfaction. Income and hours underemployment have also been shown to affect the health and well-being of workers. Prause and Dooley [111] found that underemployment lowered individuals' self-esteem, while the following year, Dooley and Prause [112] found that workers who experience chronic hours or income underemployment report increases in symptoms of alcohol abuse. Workers who become hours- or income-underemployed after leaving high school report lower self-esteem than those who become adequately employed [111]. Finally, workers who moved from adequate employment into income underemployment experienced increases in depression, while underemployment by hours did not increase depression [27].

3.3.3. Organizations do not Routinely Consider Health Outcomes as They Relate to Their Work in Workforce Development, Policy Development or in Programs Addressing Underemployment and Unemployment

All nine interview respondents described how their work does not primarily focus on health outcomes as it relates to underemployment and unemployment. When specifically asked how health relates to underemployment and unemployment, six out of nine respondents mentioned that they believe mental as well as physical health suffers in the face of unemployment or underemployment because of feelings of worthlessness, the stress of the instability, and/or the trauma associated with the exploitation experienced when employees work for abusive employers for the purpose of being able to take care of their families, but have no recourse and no support for their situation.

Respondents described being aware of unemployment related to mental health issues and post-traumatic stress disorder, and that mental health issues and addiction issues are often part of the reasons why adult workers have not been able to successfully attach to the labor market; however, organizations are limited in the knowledge and ability to measure or address these health and trauma-related impacts.

> *"We don't have any kind of connections to the health impact of a worker of not having a job. That's not a lens that we look at"*
>
> —interview respondent from industry.

"Unfortunately, the link between unemployment and health and how unemployment might cause ill health is really not something that we've done any work on ourselves. It's a little bit peripheral to what we have typically looked at but I agree that we should better understand what the health impacts are"

—interview respondent from a policy group.

"So much of your identity is tied up in what you do for a living and how you take care of your family that I think that mental health is a natural impact of unemployment and we as a field don't have a good way of dealing with that"

—interview respondent from a workforce development organization.

Exposure to trauma was mentioned as being a significant mental health issue associated with those who experience underemployment and unemployment. Trauma was described as a consequence that they believe is associated with living in long-term poverty. Organizations in workforce development are seeing an increasing need to be "trauma-informed" in their work with issues related to underemployment and unemployment and are now providing trauma-informed training for their direct service providers, especially when dealing with young adult workers. Respondents in workforce development and in industry concurred that the lack of knowledge of trauma history/experiences for marginalized populations impacts strategies to bring them (these populations) into the labor workforce.

"People don't sleep because they work back to back jobs. People use all sorts of stimulants, everything from drinking lots of soda and pop to other substances to keep going when they have to work multiple jobs . . . .I think you have issues of people's security when you have to really think about how you manage your childcare when you're working third shift and there's no third shift childcare in this country. But just the running at 200% all the time, sort of no sleep, the precariousness of that has effects on people's health"

—interview respondent from a worker advocacy group.

"I think one of the things that we do poorly as a system is address the health needs of—again, we meet people where they're at. Often when we meet them, they are having health problems often related to the thing we're trying to help them with. And we don't have a good way of dealing with that"

—interview respondent from a workforce development organization.

3.4. Other Challenges Expressed by Stakeholders

3.4.1. Lack of a Common Agenda and Aligned Goals of Multiple Stakeholders Creates a Burden for All in Accomplishing Goals

Several interview respondents mentioned that it is challenging to align goals with local and political agendas and navigate a cluttered system.

" . . . one of the things I've struggled with . . . is there's so many different nonprofit groups out there . . . . . depending on who you talk to within government, everybody has their own pet project or their own organization that they have an allegiance to or a connection to"

—interview respondent from industry.

"everybody has to have their own program at the federal level, and there are 2000 competing programs out there. And we've made it so hard to navigate the system"

—interview respondent from a skills coalition group.

Participants bemoaned the lack of sustained political will in advocating for workers and described how several US policies and practices favor powerful employers.

"As far as things boosting labor standards and enforcement and unionization . . . those things have really honestly faced no support from (Congress) . . . It's been sort of a both-sides-of-the-aisle are problematic."

—interview respondent from a policy group

3.4.2. Current Workforce Development and Education Systems Lack the Coordination and Scale Needed to Support the 21st Century US Workforce

Respondents also believed that people are getting further and further left behind because community colleges (or higher education more broadly), vocational education, work-based apprenticeships, public schools, and second chance workforce systems have so many fewer resources than before.

> *"The US invests at lower rates than every other industrialized country in workforce programming limitations . . . [. . .] . . . funding for the Workforce Innovation and Opportunity Act (WIOA), our public workforce system, has declined 40% since 2001"*
>
> —interview respondent from a skills coalition group.

> *" . . . [. . .] . . . there are far more people that have a college degree than we have jobs that require a college degree"*
>
> —interview respondent from a policy group.

> *"Not just giving businesses tax breaks but what does that mean about developing the infrastructure that this industry needs to survive . . . . the workforce being one of them? . . . ..[. . .] . . . we don't have industrial policy, we don't have any kind of workforce strategy at all.[. . .] . . . .we have built these best practices into policy like demand driven, sector driven, employer driven. But that's still very individualized and neoliberal"*
>
> —interview respondent from a workforce development organization.

Participants also described the increasing need for support of industry–sector partnerships at the local level and the need for leadership and collaboration to bring stakeholders together.

> *"The role of industry and sector partnerships at a local level, these local communities of stakeholders, of local businesses, of community and technical colleges, and community-based organizations, of TANF agencies of the different folks that are interacting with and serving workers and employers is really how workforce development can be done really well. There's good data on the fact that sectoral approaches have been successful in leading to employment and earnings outcomes. But these are the kind of partnerships that are difficult to support and difficult to sustain without federal or state investment in doing so"*
>
> —interview respondent from a skills coalition group.

3.4.3. Need for Strong Public Policies and Programs to Ensure Stability, upward Mobility, and Health Equity

Active labor market policies (ALMP) such as skills training programs or job creation measures may offer a "functional equivalent" to employment, providing, for example, "social contacts, . . . a clear time structure and . . . the feeling of participating in a useful collective purpose" [113]. Voßemer et al. argues that such policies should also "equip the unemployed with a feeling of control counteracting the restrictions on individuals' agency" [114]. A second benefit of such programs is that they may function to provide "some of the social rewards of employment", and "counteract the loss of human capital and improve unemployed individuals' chances for quick and adequate re-employment" [114]. Strandh [115], Gundert and Hohendanner [116], and Wulfgramm [114] all discuss how the positive effects of training or job creation programs depend on their resemblance to regular employment, their response to workers' needs, and participants' perceptions. Importantly, not all ALMP are alike, and "measures that have an enforcing character and are perceived as paternalistic may not improve unemployed persons' health" [113,114]. Despite these limitations, Voßemer et al. concede two additional hypotheses about the moderating effects of labor market policies: the more support through active labor market policies, the weaker the negative effect of unemployment on well-being and health; and the more support

through active labor market policies, the weaker the negative effect of insecure jobs on well-being and health [114].

Poor health related to underemployment and unemployment has historically been ignored in economic policy discussions at the federal and state levels in the United States [117]. Voßemer et al. argues that the link between unemployment and health is "weaker in countries that provide generous unemployment benefits in terms of coverage or eligibility, duration, and wage replacement" [114]. He finds that "in these countries, most unemployed individuals receive benefits that compensate for the income loss for a comparatively long duration" and "therefore, the unemployed are able to afford a search for adequate reemployment, meaning that they do not have to fear any lasting negative career consequences" [114]. Two hypotheses anchor this research: the more generous the unemployment benefits, the weaker the negative effect of unemployment on well-being and health; and the more generous the unemployment benefits, the weaker the negative effect of insecure jobs on well-being and health [114].

Six out of nine respondents discussed the need to develop clearer messages about the experiences of marginalized individuals and communities and advocate for them, stating that there is increasing invisibility of those who are disconnected from the labor market, and that people are "on their own" in solving the problem of being disconnected from the labor market. Other respondents implicated system and public policy failures, stating that policies do not address problems with solutions that incentivize action to increase access for those disenfranchised from the labor market.

> *"(When it comes to childcare) how people make it work is beyond me. I don't understand as a society how we have not figured out how to not make this a burden on individuals because it crosses race lines, it crosses class lines. So, definitely childcare, in particular for women who are on the low spectrum of the income bracket, it's make it or break it . . . if you are a logical, rational person and you are making minimum wage, you should not work because childcare costs more than what—let's just do the numbers, right?"*
>
> —interview respondent from a workforce development organization.

Overall, respondents described how the lack of a stable financial platform impacts people's ability to access healthcare, education, food, and childcare, and supported the idea of some universal benefits.

> *"There is also a gap in planning and understanding and thinking about what the social needs are and then carrying schooling and training to fulfill those needs. And that has to be a partnership, not just between private sector but also public sector because all that has to be paid for"*
>
> —interview respondent from a skills coalition group.

4. Discussion

The following discussion is framed around how the findings aligned or challenged our initial understanding of the issues and the implications for the public health sector.

4.1. Underemployment and Unemployment Are Symptoms of Larger Problems

While on the surface underemployment and unemployment appear to be the problem, evidence from the literature and the interviews highlight the "wicked" [34,118–120] nature of these problems, with multiple macro-level drivers underlying the surface symptoms, including the changing nature of work, a dynamic labor market, inadequate enforcement of labor protection standards, declining unions, wage depression, and weak political will interacting with multiple social determinants of health. Additionally, the US work ecosystem is characterized by multiple stakeholders in government institutions, labor, economics, policy, workforce development, advocacy, industry, and education, who are involved in complex and unpredictable interactions. Therefore, similar to other public health problems, such as housing, access to healthcare, and obesity, it poses an adaptive challenge where there is no one, known solution to the problem, or where there are too

many solutions but no clear choices. Preliminary evidence of the health, economic, and social impact of underemployment and unemployment, along with the relevance of these issues in global discussions regarding the future of work and health equity, make these "public health concerns". Addressing these "wicked" problems in a sustainable way will require a systems perspective, taking into account the complex interrelationships and divergent perspectives of the key stakeholders to design effective interventions [34].

Therefore, there is a need to increase awareness across government, business, education, and community groups that underemployment and unemployment are not only economic problems, but also public health problems, and that a concerted national, systemic effort is needed to address both. Without intervention, a growing share of workers in the United States will experience unemployment, precarious employment and/or continue to feel underemployed, regardless of occupation, which may result in an increase of adverse social, emotional, mental, and physical health effects among workers and within the workforce. However, it is important that initiatives aimed at addressing the root causes of underemployment and unemployment occur at multiple social ecological levels. Often times, interventions focus on "downstream" behaviors, such as the recent focus on enhancing or expanding skills training programs, without acknowledging and addressing other inequities in education, funding, access, and job quality/pay. These initiatives do not acknowledge or address the "upstream" inequities, and therefore will not serve as a good strategy for the future. Regardless of whatever solution is proposed, it is important to recognize that the US economy is incredibly complex and varied: "with 1100 classified industries spread across more than 300 metro areas, the US economy is too diverse and unwieldy to fully assess skills gaps for the entire country", while "different regions [are] facing different workforce challenges" [121]. This diversity requires the "development of regional strategies grounded in local data and local context about education providers, workers, and the needs of businesses" [121].

Finding solutions to complex issues like underemployment and unemployment will require coordination among multiple stakeholders, including policymakers, government agencies, educators, and employers, all of whom must be committed to implementing a common, shared agenda. Systems thinking is, by most definitions, more than just collective action; the 'thinking' part means integrating diverse perspectives to arrive at a deeper understanding of the complex dynamics and vicious cycles generating and regenerating wicked problems, with people able to propose interventions that generate virtuous cycles operating in a more benign direction [122]. This involves examining how macroeconomic shifts affect local and family economies, with consequences for the material basis of well-being, and also how shared (but not universal), persistent cultural models connecting employment, material success, status, life satisfaction, and self-esteem have implications for mental as well as physical health. Organizations typically do not use a systems thinking approach [35] in developing and designing programs and interventions. Fostering partnerships and networks among these stakeholders, and facilitating the adoption of systems practice-capability in order to think and act systematically [122], may lead to the identification of gaps and potential solutions in practice and help formulate policies related to underemployment and unemployment.

4.2. Gaps in Data and Research Will Need to Be Addressed in Order to Realize the Full Magnitude and Impact of Underemployment and Unemployment

There is a need for high quality research and reliable data to help improve the measures of underemployment and unemployment, not only at the national level, but at the local level, by community, race, gender, and disability status. This means recognizing other indicators and systems for tracking and reporting the "real" unemployment rates, developing standard definitions for underemployment and collecting, analyzing, and reporting underemployment data for key demographic groups, and, most importantly, finding ways to disseminate this information to sensitize the public, employers, policy makers, and workforce development organizations. It also means that public health data collection systems need to do a better job of incorporating work-related variables [123,124]. This

will require a blurring of the construct of work-related/nonwork-related exposures and outcomes that has served as an artificial line of demarcation between occupational health and the rest of public health research for years [125,126]. For example, the influence that a job, or lack thereof, has on health goes beyond physical, emotional, and social conditions at work. Indeed, one's job or career exerts a significant influence over other aspects of life that contribute or detract from an individual's health and that of their family, such as income, social status, housing, access to healthcare, and free time to spend with family and friends [127]. As a result, work is seen as a principal mechanism for securing the needs to address health inequities and provide a concrete social location for influencing other social determinants of health as well [123,128,129].

There is also a need for standardization of other terms and measures used in the current labor economy. Over the past decade there has been an increasing conversation about different employer—employee relationships, such as contingent work, precarious work, and other nonstandard work arrangements, such as temp work and gig work. Maddocks argues there exists greater need to distinguish the concepts of underemployment from other concepts such as nonstandard work, precarious employment, and job dissatisfaction [43]. Whereas nonstandard work has typically been defined "in contrast to a standard employment relationship where employees work full-time year-round, receiving statutory benefits, and have the expectation that they will be employed indefinitely", . . . "the concept of precarious employment has been put forth by sociologists to describe some forms of non-standard work, including part-time work or variable work schedules, reduced job security, lack of union protection, low wages, lack of employer sponsored benefits, or stressful psychosocial relationships and working conditions" [43,130]. Accordingly, these parameters are designed to identify jobs that espouse precarious work relationships where the worker has "little or no legal or regulatory protection against experiences such as the potential loss of their job, a decline in their hours of work, or control over the labour process" [43,131,132]. Clearly, some of the attributes of precarious work are very similar to those used to identify underemployment, such as part-time work or low wages. However, while precarious jobs are expected to have negative consequences for all workers who hold them, the underpinnings of underemployment are more complex. Maddocks claims that underemployment is "a condition for the individual and not necessarily an inherent feature of the job itself" and that "underemployment indicators identify jobs that are unsatisfactory for the individual in comparison to a previous job or expectations". This means, for example, having part-time employment when full-time work is desired, or earning lower wages than in a previous job rather than simply having part-time work at low wages. Some individuals may desire part-time, flexible work contracts, or may be employed in a precarious employment relationship without being underemployed [43]. Alternate measures of the labor market reported by respondents in the interviews were similar to those found in the literature. Respondents in all interviews stated that they do not believe we have good measures or understanding of both underemployment and unemployment, noting that measuring underemployment is particularly complicated. The labor force participation rate, along with the unemployment rate, could provide a more accurate picture of the job market.

The literature examining the links between unemployment and negative health outcomes spans almost forty years and explores contexts across continents. Substantial statistical evidence has been gathered showing the link between the lack of work in its various forms and workers' physical and mental health problems. Overall, the literature indicates gaps in research on unemployment and specific types of underemployment, and on indicators of health and well-being in specific population groups, such as young workers, women, and low-income people of color living in neighborhoods who are disproportionately burdened by job loss. Key informant interview respondents identified two key barriers in considering health outcomes as they relate to their work in addressing underemployment and unemployment: (1) firstly, while most respondents were aware of the mental and physical impacts of underemployment and unemployment, they did

not have any access to, or use for, health and well-being related tools in their program planning/thinking in workforce development, policy development, skills training, and industry; (2) secondly, respondents acknowledged the need for being "trauma-informed" in addressing prior trauma and mental health issues in workforce development programing and delivery, but were challenged by the lack of available strategies and tools. Organizations have started to develop in-house trainings and tools to address this gap; however, these programs are already underfunded, and investing in the development of these additional tools and training programs to address these barriers increases the strain on their systems and employees.

Other data needs that may promote an improved understanding of the problem include data on the impact of other nonstandard employment conditions on health and well-being, data on the role of education and training in skills gap and/or mismatch, research on sustainable wages and employment, and research on the role of the absence or presence of unions and the enforcement of labor standards.

4.3. Need for Strategic Funding to Foster Scaling-Up and Translation of Successful Models of Initiatives and Partnerships between Employers–Educators, Employers–Workforce Development, Labor Management–Advocacy in Workforce Development, Education, Research and Policy

Place-based strategies can play a critical role in improving the health and well-being of workers and communities. Often such efforts do not get reported in the literature. For example, interview respondents described initiatives where a local skills training program partnered with other local health agencies to provide childcare stipends for women in a construction apprenticeship program, where a workforce development program provided temporary housing for people who are homeless and unemployed, and where a community college system representative described how they negotiated a stipend aligned to federal standards for students enrolled in an "earn and learn" program. These stories need to be told, as they provide rich information on models and enterprises at the community level that can contribute to a comprehensive list of best practices for different economic contexts.

While there is a continued emphasis on traditional research and increasing support for translational research [133], there is also a need to support those kind of practice-based research partnerships because they are really important for providing stability, and because workforce and jobs are inherently local. Evidence produced by academic research institutions is rigorous and often shaped by the traditional values of the academy [134]. However, such research may miss opportunities to understand local contexts and produce actionable findings. Research–practice partnerships could provide policy insights and data that can facilitate rigorous and groundbreaking research; likewise, it could also provide practitioners with easy access to and timely use of research evidence [134]. Opening the door for funding practice-based research partnerships may promote collaboration between researchers and multisector stakeholders in the work ecosystem to define a more holistic agenda that aligns future research, practice, and policy. For example, a systematic analysis and evaluation of current national and local policies, funding, partnerships, and implementation strategies to boost the economy and employment may give some insights into what policies are worth scaling up. What data are being used in these decision-making processes? Workforce development organizations have developed innovative partnerships with employers to create pipelines for jobs. Right now, it is unclear how these best practices and innovative models are being evaluated for their success, how job quality (or good work, or good jobs) is being defined, how such information is being gathered and monitored, and how data (if any) are being used to strengthen the existing funding and policy structures. If we want to be strategic in scaling up these efforts, there is an urgent need for systematically researching, documenting, supporting, and disseminating these efforts.

5. Conclusions and Recommendations

The purpose of the environmental scan was not to be an exhaustive exploration of underemployment and unemployment and their outcomes (health and other). Rather, it was intended to be an exploration of evidence relevant to the field of public health and its partners that ought to be included in discussions of future strategic agendas and initiatives across public health, government agencies, industries, community colleges, universities, trade and business associations, labor organizations, and other stakeholder groups. Although the literature review was not a systematic review, it was a comprehensive review of close to 100 articles. This study could have benefitted from additional interviews that captured perspectives of a diverse spectrum of representatives from state, local, federal agencies, trade and business associations on underemployment and unemployment, and workers; however, the information gathered during the interviews provides very rich information, with convergent themes emerging across a diverse array of stakeholders, that need to be explored further. Finally, this study did not include any direct research on the health impacts of COVID-19.

The impacts of unemployment, underemployment, gig work, precarious jobs, and the changing nature of work is gaining traction around the world amidst the climate of economies struggling with the inconsistencies of the labor market in the post-pandemic world, the impending challenges for employers and workers with the rise of artificial intelligence (AI) and robotics, and the uncertainty surrounding the future of work. While the empirical literature has established that job loss or unemployment results in significant deterioration in well-being, researchers argue that satisfaction with employment is a key ingredient differentiating employment and unemployment experiences. In the wake of the global pandemic and economic crisis, there is a unique window of opportunity to raise consciousness and highlight the urgency of delivering quality jobs along with social protection and respect for rights at work to achieve sustainable, inclusive economic growth and eliminate poverty. Recent months have seen revived discussions, by lawmakers and administration officials, of initiatives to raise the minimum wage, strengthen unions and worker protection standards, and provide a universal basic income and full employment [60]. Laudable as these efforts may be, it is highly likely that the United States could still fall short of actually bringing about the adoption and implementation of these policies and practices because, as a society, we still do not have a shared understanding of the significance of workforce health and well-being to our nation's health.

Workforce health is population health, so what is the value of the health and well-being of the US worker and the workforce? Further, what is the value of decent work in public health policy, or public policy? Public health professionals at the intersection of occupational and population health are in a unique position to address worker and workforce health and well-being beyond the workplace by leading strategic collaborations that integrate health and economic development (work) across government agencies, and in partnership with industries, community colleges, financial institutions, universities, trade and business associations, labor organizations, and other stakeholder groups to support and promote a human-centered, equitable, and decent future of work—a future of work where every worker is healthy and able to achieve their full potential by engaging in meaningful work.

Considerations for future investments in research and practice, and a common framework to address the public health impact of underemployment and unemployment, and promote a decent future of work, are described in Figure 2.

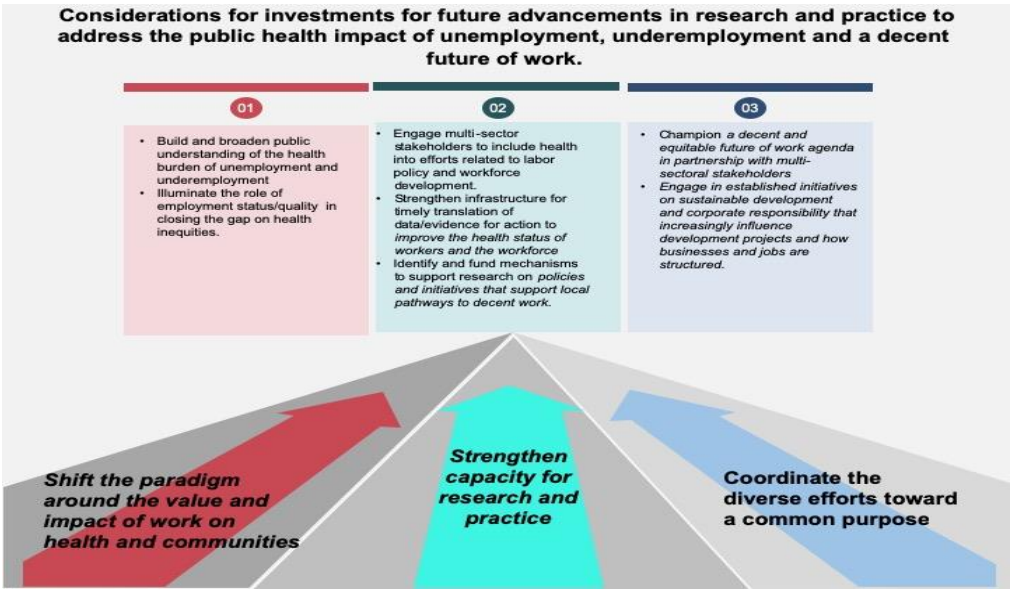


Figure 2. Considerations for a common framework to address the public health impact of underemployment and unemployment, and promote a decent future of work.

- *Shift the paradigm around the value of work and its impact on individual health and communities, by investing in broadening public understanding of the health burden of underemployment and unemployment.* As researchers and practitioners in the field of occupational health, we understand that although social determinants of health (SDoH) "are the conditions in which people are born, grow, live, work and age", what people do for work and at work does not figure in larger discussions related to SDoH [128]. Despite the conceptual acknowledgment that work influences health through numerous pathways, it remains largely absent from examinations of health inequities in the United States [123]. Public health needs to illuminate the role of employment quality and status in closing the gap on health inequities.
- *Strengthen capacity for research and practice by engaging the multisector stakeholders that public health may not routinely engage with, such as workforce development, labor policy, and corporate sustainability.* Inclusion of health into efforts related to labor policy development and other economic development agendas can add value to discussions regarding the burden of the problem on health and the healthcare system, economic investments in skills training and social benefits, and improve the health status of workers and the workforce [124]. Strengthening infrastructure for timely use of data/evidence for action in labor policy and workforce development could ensure the jobs they create are designed to contribute to healthier workers and communities. New funding mechanisms are also needed to support practice-based research partnerships that address institutional and systems-level facilitators and barriers to the innovation and implementation of policies and initiatives in order to support local pathways to decent work.
- *Coordinate the diverse efforts in the work ecosystem towards a common purpose and a shared agenda for a decent future of work.* Currently, diverse agendas and potential misalignment of multiple stakeholders, the overall complexity of the problem, a lack of metrics and actionable data, and a lack of leadership and a common language are limiting the ability of stakeholders in the work ecosystem to collectively address the impact of underemployment and unemployment, and assess the future of work more generally [8]. Under the public health model, increasing the number and quality of jobs can serve as a prevention strategy by increasing economic security, self-esteem, and social connectedness. "*Public Health 3.0 A Call to Action for Public Health to Meet the Challenges of the 21st Century*" [135] refers to a new era of enhanced and broadened

public health practice that goes beyond traditional public health department/agencies functions and programs. Cross sectoral collaboration is inherent in Public Health 3.0. As such, labor policy that is a part of health policy, and a discussion of job quality or decent work, not just job quantity, could help public health professionals engage in more established initiatives on sustainable development and corporate responsibility that increasingly influence development projects and how businesses and jobs are structured [124]. Public health needs to champion an agenda in partnership with multisector stakeholders to integrate workforce health and well-being into labor and economic development agendas across government agencies and industry.

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Institutional Review Board Statement: The University of Illinois Office for the Protection of Research Subjects determined that this study protocol (# 2019-0608) meets the criteria for exemption as defined in the US Department of Health and Human Services Regulations for the Protection of Human Subjects [45 CFR 46.104(d)] Category 2.

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References

1. McKinsey Global Institute. The Future of Work after COVID-19. Available online: https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-work-after-covid-19 (accessed on 4 May 2021).
2. Siqueira, C.E.; Gaydos, M.; Monforton, C.; Slatin, C.; Borkowski, L.; Dooley, P.; Liebman, A.; Rosenberg, E.; Shor, G.; Keifer, M. Effects of social, economic, and labor policies on occupational health disparities. *Am. J. Ind. Med.* **2013**, *57*, 557–572. [CrossRef]
3. Scherer, S. The Social Consequences of Insecure Jobs. *Soc. Indic. Res.* **2009**, *93*, 527–547. [CrossRef]
4. Organisation for Economic Co-operation and Development. Is job insecurity on the increase in OECD countries? In *Employment Outlook*; OECD: Paris, France, 1997. Available online: https://www.oecd.org/employment/emp/2080463.pdf (accessed on 10 December 2019).
5. Organisation for Economic Co-operation and Development. Taking the measure of temporary employment. In *Employment Outlook*; OECD: Paris, France, 2002. Available online: https://www.oecd.org/els/emp/17652675.pdf (accessed on 10 December 2019).
6. Weil, D. *The Fissured Workplace*; Harvard University Press: Cambridge, MA, USA, 2014.
7. Rosenthal, L.; Carroll-Scott, A.; Earnshaw, V.A.; Santilli, A.; Ickovics, J.R. The importance of full-time work for urban adults' mental and physical health. *Soc. Sci. Med.* **2012**, *75*, 1692–1696. [CrossRef]
8. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Ma, M.A.F.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
9. Schulte, P.A.; Streit, J.M.K.; Sheriff, F.; Delclos, G.; Felknor, S.A.; Tamers, S.L.; Fendinger, S.; Grosch, J.; Sala, R. Potential Scenarios and Hazards in the Work of the Future: A Systematic Review of the Peer-Reviewed and Gray Literatures. *Ann. Work. Expo. Health* **2020**, *64*, 786–816. [CrossRef]
10. Bambra, C. Yesterday once more? Unemployment and health in the 21st century. *J. Epidemiol. Commun. Health* **2010**, *64*, 213–215. [CrossRef]
11. Bartley, M.; Ferrie, J. Do we need to worry about the health effects of unemployment? *J. Epidemiol. Commun. Health* **2009**, *64*, 5–6. [CrossRef]
12. Case, A.; Deaton, A. Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 15078–15083. [CrossRef]

13. McGee, R.E.; Thompson, N.J. Unemployment and Depression among Emerging Adults in 12 States, Behavioral Risk Factor Surveillance System, 2010. *Prev. Chronic Dis.* **2015**, *12*, E38. [CrossRef]
14. Athar, H.M.; Chang, M.H.; Hahn, R.A.; Walker, E.; Yoon, P.; Centers for Disease Control and Prevention (CDC). Unemployment-United States, 2006 and 2010. *MMWR Suppl.* **2013**, *62*, 27–32.
15. Venkataramani, A.S.; Bair, E.F.; O'Brien, R.L.; Tsai, A.C. Association between Automotive Assembly Plant Closures and Opioid Overdose Mortality in the United States. *JAMA Intern. Med.* **2020**, *180*, 254–262. [CrossRef] [PubMed]
16. International Labour Organization. ILO Monitor: COVID-19 and the World of Work. *Updated Estimates and Analysis. Third Edition*. 2020. Available online: http://oit.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/briefingnote/wcms_743146.pdf (accessed on 4 May 2021).
17. International Labour Organization. ILO Policy Brief on COVID-19: A Policy Framework for Tackling the Economic and Social Impacts of the COVID-19 Crisis. May 2020. Available online: https://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/documents/briefingnote/wcms_745337.pdf (accessed on 19 June 2021).
18. Faghri, P.D.; Dobson, M.; Landsbergis, P.; Schnall, P.L. COVID-19 Pandemic: What Has Work Got to Do with It? *J. Occup. Environ. Med.* **2021**, *63*, e245–e249. [CrossRef]
19. Bureau of Labor Statistics. The Employment Situation April 2021. 2021. Available online: https://www.bls.gov/news.release/empsit.nr0.htm (accessed on 4 May 2021).
20. Brookings Institution. Race and Jobs at Risk of Being Automated in the Age of COVID-19. 2021. Available online: https://www.brookings.edu/research/race-and-jobs-at-risk-of-being-automated-in-the-age-of-covid-19/ (accessed on 19 June 2021).
21. Centers for Disease Control and Prevention. Surgeon General's Call to Action: Community Health and Prosperity. 2018. Available online: https://www.federalregister.gov/documents/2018/09/06/2018-19313/surgeon-generals-call-to-action-community-health-and-prosperity (accessed on 10 December 2019).
22. Ezzy, D. Unemployment and mental health: A critical review. *Soc. Sci. Med.* **1993**, *37*, 41–52. [CrossRef]
23. Warr, P.B. *Work, Unemployment, and Mental Health*; Oxford University Press: New York, NY, USA, 1987.
24. Friedland, D.S.; Price, R.H. Underemployment: Consequences for the Health and Well-Being of Workers. *Am. J. Commun. Psychol.* **2003**, *32*, 33–45. [CrossRef] [PubMed]
25. Wheaton, B. Life Transitions, Role Histories, and Mental Health. *Am. Sociol. Rev.* **1990**, *55*, 209. [CrossRef]
26. Kahn, R.L. *Work and Health*; Wiley: New York, NY, USA, 1981.
27. Dooley, D.; Prause, J. Underemployment as disguised unemployment and its social costs. In Proceedings of the APA-NIOSH Interdisciplinary Conference on Work, Stress, and Health: Organization of Work in a Global Economy, Baltimore, MA, USA, 11–13 March 1999.
28. Dollard, M.F.; Winefield, A.H. Mental health: Overemployment, underemployment, unemployment and healthy jobs. *Aust. E-J. Adv. Ment. Health* **2002**, *1*, 170–195. [CrossRef]
29. Faragher, E.B.; Cass, M.; Cooper, C. The relationship between job satisfaction and health: A meta-analysis. *Occup. Environ. Med.* **2005**, *62*, 105–112. [CrossRef]
30. Faragher, E.B.; Cass, M.; Cooper, C.L. The Relationship between Job Satisfaction and Health: A Meta-Analysis. In *From Stress to Wellbeing*; Cooper, C.L., Ed.; Palgrave Macmillan: London, UK, 2013; Volume 1. [CrossRef]
31. International Labour Organization. Decent Work, Report of the Director-Genera. In Proceedings of the 87th Session, International Labour Conference, Geneva, Switzerland. Available online: https://www.ilo.org/public/libdoc/ilo/P/09605/09605(1999-87).pdf (accessed on 10 December 2019).
32. International Labour Organization. ILO Implementation Plan 2030 Agenda for Sustainable Development 2016. 2016. Available online: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---webdev/documents/publication/wcms_510122.pdf (accessed on 10 December 2019).
33. Jalles d'Orey, M.A.; How Do Donors Support the Decent Work Agenda? A Review of Five Donors. Overseas Development Institute. 2017. Available online: https://www.ituc-csi.org/IMG/pdf/oda_decent_work_en.pdf (accessed on 4 May 2021).
34. Williams, B.; Van't Hof, S. Wicked Solutions: A Systems Approach to Complex Problems. 2014. Available online: http://www.bobwilliams.co.nz/ewExternalFiles/Wicked.pdf (accessed on 15 November 2018).
35. Senge, P.M. *The Fifth Discipline: The Art and Practice of the Learning Organization*; Doubleday/Currency: New York, USA, 2006.
36. Rowel, R.; Moore, N.D.; Nowrojee, S.; Memiah, P.; Bronner, Y. The utility of the environmental scan for public health practice: Lessons from an urban program to increase cancer screening. *J. Natl. Med. Assoc.* **2005**, *97*, 527–534.
37. Bazeley, P. *Qualitative Data Analysis: Practical Strategies*; SAGE Publications: Thousand Oaks, CA, USA, 2013.
38. Hsieh, H.-F.; Shannon, S.E. Three Approaches to Qualitative Content Analysis. *Qual. Health Res.* **2005**, *15*, 1277–1288. [CrossRef]
39. Glasmeier, A.K. Living Wage Calculator. Massachusetts Institute of Technology. 2020. Available online: Livingwage.mit.edu (accessed on 12 September 2021).
40. Howard, J. Nonstandard work arrangements and worker health and safety. *Am. J. Ind. Med.* **2016**, *60*, 1–10. [CrossRef]
41. Quinlan, M.; Bohle, P. Contingent work and occupational safety. In *The Psychology of Workplace Safety*; Barling, J., Frone, M.R., Eds.; American Psychological Association: Worcester, MA, USA, 2004; pp. 81–105. [CrossRef]
42. Fenwick, R.; Tausig, M. The Macroeconomic Context of Job Stress. *J. Health Soc. Behav.* **1994**, *35*, 266. [CrossRef]
43. Maddocks, H.L. Underemployment, Unemployment, and Mental Health. Electronic Thesis and Dissertation Repository 476. 2012, pp. 17–18. Available online: https://ir.lib.uwo.ca/etd/476 (accessed on 15 November 2018).

44. Ferman, L.; Gordus, J. *Mental Health and the Economy*; Ferman, L., Gordus, J., Eds.; UpJohn Institute: Kalamazoo, MI, USA, 1979; pp. 193–224.
45. Golden, L. Still Falling Short on Hours and Pay: Part-Time Work Becoming New Normal. 2016. Available online: https://www.epi.org/files/pdf/114028.pdf (accessed on 15 November 2018).
46. Bell, D.N.F.; Blanchflower, D.G. Underemployment in the US and Europe. National Bureau of Economic Research Working Paper No. 24927. 2018. Available online: https://www.nber.org/papers/w24927 (accessed on 15 November 2018).
47. National Conference of State Legislatures. Minimum Wage by State. 2021. Available online: http://www.ncsl.org/research/labor-and-employment/state-minimum-wage-chart.aspx (accessed on 4 June 2021).
48. Narain, K.D.C.; Zimmerman, F.J. Examining the association of changes in minimum wage with health across race/ethnicity and gender in the United States. *BMC Public Health* **2019**, *19*, 1069. [CrossRef]
49. Gertner, A.K.; Rotter, J.S.; Shafer, P. Association between State Minimum Wages and Suicide Rates in the USA. *Am. J. Prev. Med.* **2019**, *56*, 648–654. [CrossRef] [PubMed]
50. Wehby, G.L.; Dave, D.M.; Kaestner, R. Effects of the minimum wage on infant health. *J. Policy Anal. Manag.* **2020**, *39*, 411–443. [CrossRef]
51. Ibragimov, U.; Beane, S.; Friedman, S.R.; Komro, K.; Adimora, A.A.; Edwards, J.K.; Williams, L.D.; Tempalski, B.; Livingston, M.D.; Stall, R.D.; et al. States with higher minimum wages have lower STI rates among women: Results of an ecological study of 66 US metropolitan areas, 2003–2015. *PLoS ONE* **2019**, *14*, e0223579. [CrossRef] [PubMed]
52. Abraham, K. Is Skill Mismatch Impeding U.S. Economic Recovery. *ILR Rev.* **2015**, *68*, 291–313. [CrossRef]
53. Capelli, P. Skills Gap, Skills Shortages and Skills Mismatches: Evidence and Arguments for the US. National Bureau of Economic Research Working Paper No. 20382. 2014. Available online: https://www.nber.org/papers/w20382 (accessed on 15 November 2018).
54. Lazear, E.P.; Spletzer, J.R. The United States Labor Market: Status Quo or a New Normal? National Bureau of Economic Research Working Paper No. 18386. 2012. Available online: https://www.nber.org/papers/w18386 (accessed on 15 November 2018).
55. Rothstein, J. The Labor Market Four Years into the Crisis: Assessing Structural Explanations. *ILR Rev.* **2012**, *65*, 467–500. [CrossRef]
56. Dickson, A.D.; Manzo, F.; Bruno, R. A Manufactured Myth: Why Claims of a "Skills Gap" in Illinois Manufacturing are Wrong. University of Illinois at Urbana-Champaign Labor Education Program Briefing Papers. 2013. Available online: https://live-labor-edu.pantheonsite.io/wp-content/uploads/2021/08/LEP-Briefing-Paper-Skills-Gap_-Dickson-Manzo-Bruno.pdf (accessed on 15 November 2018).
57. Accenture, Burning Glass Technologies, & Harvard Business School. Bridge the Gap: Rebuilding America's Middle Skills. 2014. Available online: https://www.hbs.edu/competitiveness/Documents/bridge-the-gap.pdf (accessed on 15 November 2018).
58. Adecco USA. The Skills Gap and the State of the Economy [Blog Post]. 2013. Available online: http://blog.adeccousa.com/the-skills-gap-and-the-state-of-the-economy/ (accessed on 15 November 2018).
59. ManpowerGroup. Skilled Trades Remain Hardest Job to Fill in US for Fourth Consecutive Year. 2013. Available online: https://www.prnewswire.com/news-releases/manpowergroup-annual-talent-shortage-survey-reveals-us-employers-making-strides-to-build-sustainable-workforces-report-less-difficulty-filling-open-positions-209129591.html (accessed on 28 May 2013).
60. Bureau of Labor Statistics. Full Employment: An Assumption within BLS Projections. 2017. Available online: https://www.bls.gov/opub/mlr/2017/article/full-employment-an-assumption-within-bls-projections.htm (accessed on 12 September 2021).
61. Bureau of Labor Statistics. The Employment Situation December 2019. 2019. Available online: https://www.bls.gov/news.release/archives/empsit_01102020.pdf (accessed on 21 February 2020).
62. Feldman, D.C. The nature, antecedents and consequences of underemployment. *J. Manag.* **1996**, *22*, 385–407. [CrossRef]
63. McKee-Ryan, F.; Harvey, J. I Have a Job, But A Review of Underemployment. *J. Manag.* **2011**, *37*, 962–996. [CrossRef]
64. Thompson, K.W.; Shea, T.H.; Sikora, D.M.; Perrewé, P.L.; Ferris, G.R. Rethinking underemployment and overqualification in organizations: The not so ugly truth. *Bus. Horizons* **2012**, *56*, 113–121. [CrossRef]
65. Jacobe, D. US Unemployment Improves in October. Gallup. 2011. Available online: http://www.gallup.com/poll/150527/Unemployment-Improves-October.aspx (accessed on 15 November 2018).
66. Newport, F.; Muller, G. In US, Underemployment Lowest in North Dakota, Wyoming. Gallup. 2011. Available online: http://www.gallup.com/poll/146486/Underemployment-Lowest-North-Dakota-Wyoming.aspx (accessed on 4 March 2011).
67. Jensen, L.; Slack, T. Underemployment in America: Measurement and Evidence. *Am. J. Commun. Psychol.* **2003**, *32*, 21–31. [CrossRef]
68. Blanchflower, D.G.; Levin, A.T. Labor Market Slack and Monetary Policy. National Bureau of Economic Research Working Paper No. 21094. 2015. Available online: http://www.nber.org/papers/w21094 (accessed on 15 November 2018).
69. De Anda, R.M. Unemployment and Underemployment among Mexican-Origin Workers. *Hisp. J. Behav. Sci.* **1994**, *16*, 163–175. [CrossRef]
70. De Jong, G.F.; Madamba, A.B. A Double Disadvantage? Minority Group, Immigrant Status, and Underemployment in the United States. *Soc. Sci. Q.* **2001**, *82*, 117–130. [CrossRef]
71. Soltero, J.M. *Inequality in the Workplace: Underemployment among Mexicans, African-Americans, and Whites*; Garland: New York, NY, USA, 1996.
72. Zhou, M. Underemployment and economic disparities among minority groups. *Popul. Res. Policy Rev.* **1993**, *12*, 139–157. [CrossRef]
73. Valletta, R.G.; Bengali, L.; van der List, C. Cyclical and Market Determinants of Involuntary Part-Time Employment. Working Paper No. 2015-19. 2018. Available online: http://www.frbsf.org/economic-research/publications/working-papers/2015/19/ (accessed on 15 November 2018).
74. Mutchler, J.F. Underemployment and Gender: Demographic and Structural Indicators. Ph.D. Thesis, The University of Texas, Austin, TX, USA, 1985.

75. Flynn, M.A.; Cunningham, T.R.; Guerin, R.J.; Keller, B.; Chapman, L.J.; Hudson, D.; Salgado, C.; Cincinnati, O.H.; National Institute for Occupational Safety and Health, American Society of Safety Engineers (NIOSH/ASSE). Overlapping vulnerabilities: The Occupational Safety and Health of Young Workers in Small Construction Firms. DHHS (NIOSH) Publication No. 2015-178. Available online: https://www.researchgate.net/publication/277213891_Overlapping_vulnerabilities_the_occupational_safety_and_health_of_young_workers_in_small_construction_firms (accessed on 23 August 2021).
76. Gravel, S.; Dubé, J. Occupational health and safety for workers in precarious job situations: Combating inequalities in the workplace. *E-J. Int. Comp. Labour Stud.* **2016**, *5*, 1–32.
77. Kasl, S.V.; Jones, B.A. Unemployment and health. In *Cambridge Handbook of Psychology, Health and Medicine*; Ayers, S., Baum, A., McManus, C., Newman, S., Wallston, K., Weinman, J., West, R., Eds.; Cambridge University Press: Cambridge, UK, 2007; pp. 232–238.
78. Paul, K.; Moser, K. Unemployment impairs mental health: Meta-analyses. *J. Vocat. Behav.* **2009**, *74*, 264–282. [CrossRef]
79. Wanberg, C.R.; Griffiths, R.F.; Gavin, M.B. Time structure and unemployment: A longitudinal investigation. *J. Occup. Organ. Psychol.* **1997**, *70*, 75–95. [CrossRef]
80. Lundin, A.; Lundberg, I.; Hallsten, L.; Ottosson, J.; Hemmingsson, T. Unemployment and mortality—A longitudinal prospective study on selection and causation in 49321 Swedish middle-aged men. *J. Epidemiol. Commun. Health* **2009**, *64*, 22–28. [CrossRef]
81. Zagozdzon, P.; Zaborski, L.; Ejsmont, J. Survival and cause-specific mortality among unemployed individuals in Poland during economic transition. *J. Public Health* **2008**, *31*, 138–146. [CrossRef] [PubMed]
82. Åhs, A.M.; Westerling, R. Mortality in relation to employment status during different levels of unemployment. *Scand. J. Public Health* **2006**, *34*, 159–167. [CrossRef]
83. Gerdtham, U.-G.; Johannesson, M. A note on the effect of unemployment on mortality. *J. Health Econ.* **2003**, *22*, 505–518. [CrossRef]
84. Morris, J.; Cook, D.; Shaper, A.G. Loss of employment and mortality. *BMJ* **1994**, *308*, 1135–1139. [CrossRef]
85. Stefansson, C.-G. Long-term unemployment and mortality in Sweden, 1980–1986. *Soc. Sci. Med.* **1991**, *32*, 419–423. [CrossRef]
86. Martikainen, P. Unemployment and mortality among Finnish men, 1981–1985. *BMJ* **1990**, *301*, 407–411. [CrossRef] [PubMed]
87. Iversen, L.; Sabroe, S.; Damsgaard, M.T. Hospital admissions before and after shipyard closure. *BMJ* **1989**, *299*, 1073–1076. [CrossRef] [PubMed]
88. Iversen, L.; Andersen, O.; Andersen, P.K.; Christoffersen, K.; Keiding, N. Unemployment and mortality in Denmark, 1970–1980. *BMJ* **1987**, *295*, 879–884. [CrossRef]
89. Moser, K.A.; Fox, A.J.; Jones, D.R. Unemployment and mortality in the OPCS Longitudinal Study. *Lancet* **1994**, *2*, 12–24. [CrossRef]
90. Johnson, A.M.; Jackson, P.R. Golden parachutes: Changing the experience of unemployment for managers. *J. Vocat. Behav.* **2012**, *80*, 474–485. [CrossRef]
91. Reininghaus, U.A.; Morgan, C.; Simpson, J.; Dazzan, P.; Morgan, K.; Doody, G.A.; Bhugra, D.; Leff, J.; Jones, P.; Murray, R.; et al. Unemployment, social isolation, achievement–expectation mismatch and psychosis: Findings from the AESOP Study. *Soc. Psychiatry Psychiatr. Epidemiol.* **2008**, *43*, 743–751. [CrossRef]
92. Sadeh, N.; Karniol, R. The sense of self-continuity as a resource in adaptive coping with job loss. *J. Vocat. Behav.* **2012**, *80*, 93–99. [CrossRef]
93. Broman, C.L.; Hamilton, V.L.; Hoffman, W.S.; Mavaddat, R. Race, gender, and the response to stress: Autoworkers' vulnerability to long-term unemployment. *Am. J. Community Psychol.* **1995**, *23*, 813–842. [CrossRef]
94. Hammarström, A. Health consequences of youth unemployment. *Public Health* **1994**, *108*, 403–412. [CrossRef]
95. Hammarstrom, A. Early unemployment can contribute to adult health problems: Results from a longitudinal study of school leavers. *J. Epidemiol. Community Health* **2002**, *56*, 624–630. [CrossRef]
96. Mossakowski, K.N. Is the duration of poverty and unemployment a risk factor for heavy drinking? *Soc. Sci. Med.* **2008**, *67*, 947–955. [CrossRef]
97. Brown, D.W.; Balluz, L.S.; Ford, E.S.; Giles, W.H.; Strine, T.W.; Moriarty, D.G.; Croft, J.B.; Mokdad, A.H. Associations Between Short- and Long-Term Unemployment and Frequent Mental Distress Among a National Sample of Men and Women. *J. Occup. Environ. Med.* **2003**, *45*, 1159–1166. [CrossRef]
98. Dooley, D.; Catalano, R. Do economic variables generate psychological problems? Different methods, different answers. In *Economic psychology: Intersections in Theory and Application*; MacFadyen, A.J., MacFadyen, H.W., Eds.; North Holland: Amsterdam, The Netherlands, 1986; pp. 503–546.
99. Luo, F.; Florence, C.S.; Quispe-Agnoli, M.; Ouyang, L.; Crosby, A.E. Impact of Business Cycles on US Suicide Rates, 1928–2007. *Am. J. Public Health* **2011**, *101*, 1139–1146. [CrossRef]
100. McKee-Ryan, F.; Song, Z.; Wanberg, C.R.; Kinicki, A.J. Psychological and Physical Well-Being During Unemployment: A Meta-Analytic Study. *J. Appl. Psychol.* **2005**, *90*, 53–76. [CrossRef] [PubMed]
101. Wanberg, C.R. The Individual Experience of Unemployment. *Annu. Rev. Psychol.* **2012**, *63*, 369–396. [CrossRef] [PubMed]
102. Galambos, N.L.; Barker, E.T.; Krahn, H.J. Depression, self-esteem, and anger in emerging adulthood: Seven-year trajectories. *Dev. Psychol.* **2006**, *42*, 350–365. [CrossRef] [PubMed]
103. Moller, H. Health Effects of Unemployment. Wirral Performance & Public Health Intelligence Team. 2012. Available online: https://www.wirralintelligenceservice.org/media/1086/unemployment-2-sept-12.pdf (accessed on 15 November 2018).
104. Bartley, M. Accumulated labour market disadvantage and limiting long-term illness: Data from the 1971–1991 Office for National Statistics' Longitudinal Study. *Int. J. Epidemiol.* **2002**, *31*, 336–341. [CrossRef]
105. Tefft, N.; Kageleiry, A. State-Level Unemployment and the Utilization of Preventive Medical Services. *Health Serv. Res.* **2013**, *49*, 186–205. [CrossRef]

106. McGrath, J.E. A conceptual formulation for research on stress. In *Social and Psychological Factors in Stress*; McGrath, J.E., Ed.; Holt, Rinehart and Winston: New York, NY, USA, 1970; pp. 10–21.
107. Bell, D.N.; Blanchflower, D.G. The well-being of the overemployed and the underemployed and the rise in depression in the UK. *J. Econ. Behav. Organ.* **2019**, *161*, 180–196. [CrossRef]
108. Jones-Johnson, G. Underemployment, underpayment, and psychosocial stress among working Black men. *West. J. Black Stud.* **1989**, *13*, 57–65.
109. Wooden, M.; Warren, D.; Drago, R. Working Time Mismatch and Subjective Well-being. *Br. J. Ind. Relations* **2009**, *47*, 147–179. [CrossRef]
110. Wilkins, R. The Consequences of Underemployment for the Underemployed. *J. Ind. Relations* **2007**, *49*, 247–275. [CrossRef]
111. Prause, J.; Dooley, D. Effect of underemployment on school-leavers self-esteem. *J. Adolesc.* **1997**, *20*, 243–260. [CrossRef] [PubMed]
112. Dooley, D.; Prause, J. Underemployment and alcohol abuse in the National Longitudinal Survey of Youth. *J. Stud. Alcohol* **1998**, *59*, 669–680. [CrossRef] [PubMed]
113. Wulfgramm, M. Life satisfaction effects of unemployment in Europe: The moderating influence of labour market policy. *J. Eur. Soc. Policy* **2014**, *24*, 258–272. [CrossRef]
114. Voßemer, J.; Gebel, M.; Täht, K.; Unt, M.; Högberg, B.; Strandh, M. The Effects of Unemployment and Insecure Jobs on Well-Being and Health: The Moderating Role of Labor Market Policies. *Soc. Indic. Res.* **2017**, *138*, 1229–1257. [CrossRef]
115. Strandh, M.; Strandh, M.; Strandh, M.; Strandh, M. State Intervention and Mental Well-being among the Unemployed. *J. Soc. Policy* **2001**, *30*, 57–80. [CrossRef]
116. Gundert, S.; Hohendanner, C. Active Labour Market Policies and Social Integration in Germany: Do 'One-Euro-Jobs' Improve Individuals' Sense of Social Integration? *Eur. Sociol. Rev.* **2015**, *31*, 780–797. [CrossRef]
117. Brenner, M.; Mooney, A. Unemployment and health in the context of economic change. *Soc. Sci. Med.* **1983**, *17*, 1125–1138. [CrossRef]
118. Rittel, H.W.J.; Webber, M.M. Dilemmas in a general theory of planning. *Policy Sci.* **1973**, *4*, 155–169. [CrossRef]
119. Blackman, T.; Greene, A.; Hunter, D.; McKee, L.; Elliott, E.; Harrington, B.; Marks, L.; Williams, G. Performance assessment and wicked problems: The case of health inequalities. *Public Policy Adm.* **2006**, *21*, 66–80. [CrossRef]
120. Conklin, J. Wicked problems and social complexity. In *Dialogue Mapping: Building Shared Understanding of Wicked Problems*; Dans Conklin, J., Ed.; Wiley: Hoboken, NJ, USA, 2006; pp. 1–20.
121. JPMorgan Chase &Co. Skills Gap: A National Issue That Requires Regional Focus. New Skills at Work Report. 2015. Available online: https://www.economicmodeling.com/wp-content/uploads/EMSI-SkillsGap-Brief.pdf (accessed on 15 November 2018).
122. Ison, R. Systems Practice: How to Act. In *Situations of Uncertainty and Complexity in a Climate-Change World*, 2nd ed.; Springer: London, UK, 2017. [CrossRef]
123. Ahonen, E.Q.; Fujishiro, K.; Cunningham, T.; Flynn, M. Work as an Inclusive Part of Population Health Inequities Research and Prevention. *Am. J. Public Health* **2018**, *108*, 306–311. [CrossRef] [PubMed]
124. Flynn, M.A.; Wickramage, K. Leveraging the domain of work to improve migrant health. *Int. J. Environ. Res. Public Health* **2017**, *14*, 1248. [CrossRef]
125. Flynn, M.A. Immigration, Work, and Health: Anthropology and the Occupational Health of Labor Immigrants. *Anthro-Pology Work. Rev.* **2018**, *39*, 116. [CrossRef]
126. Peckham, T.K.; Baker, M.G.; Camp, J.E.; Kaufman, J.D.; Seixas, N.S. Creating a Future for Occupational Health. *Ann. Occup. Hyg.* **2017**, *61*, 3–15. [CrossRef]
127. Flynn, M.A.; Carreón, T.; Eggerth, D.E.; Johnson, A.I. Immigration, Work, and Health: A Literature Review of Immigration Between Mexico and the United States. *Rev. Trab. Soc.* **2014**, *6*, 129–149.
128. World Health Organization. Closing the gap in a generation: Health equity through action on the social determinants of health. In *Final Report of the Commission on Social Determinants of Health*; World Health Organization: Geneva, Switzerland, 2008.
129. World Health Organization. Employment Conditions Knowledge Network of the Commission on Social Determinants of Health. In *Employment Conditions and Health Inequalities*; World Health Organization: Geneva, Switzerland, 2007.
130. Benach, J.; Muntaner, C. Precarious employment and health: Developing a research agenda. *J. Epidemiol. Commun. Health* **2007**, *61*, 276–277. [CrossRef]
131. Cranford, C.J.; Vosko, L.F.; Zukewich, N. Precarious employment in the canadian labour market: A statistical portrait. *Just Labour* **1969**, *3*, 6–22. [CrossRef]
132. Vosko, L.F.; Zukewich, N.; Cranford, C. Beyond Non-standard Work: A New Typology of Employment. *Perspect. Labour Income* **2003**, *4*, 16–24.
133. Schulte, P.A.; Cunningham, T.R.; Nickels, L.; Felknor, S.; Guerin, R.; Blosser, F.; Chang, C.-C.; Check, P.; Eggerth, D.; Flynn, M.; et al. Translation research in occupational safety and health: A proposed framework. *Am. J. Ind. Med.* **2017**, *60*, 1011–1022. [CrossRef] [PubMed]
134. Coburn, C.E.; Penuel, W.R.; Geil, K.E. *Research-Practice Partnerships: A Strategy for Leveraging Research for Educational Improvement in School Districts*; William, T., Ed.; Grant Foundation: New York, NY, USA, 2013.
135. United States Department of Health and Human Services. Public Health 3.0. A Call to Action to Create a 21st Century Public Health Infrastructure. 2016. Available online: https://www.healthypeople.gov/sites/default/files/Public-Health-3.0-White-Paper.pdf (accessed on 10 December 2019).

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Review

Ethics and *Total Worker Health*®: Constructs for Ethical Decision-Making and Competencies for Professional Practice

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Abstract: Work has become increasingly technologically driven and fast paced, with long work hours, new/emerging hazards, and rising health care costs. Threats to worker safety, health, and well-being including non-traditional work arrangements and practices, precarious work, uncertain hazardous exposures, and work organization issues, such as heavy workloads, design of work, uneven work hours, and difficult interpersonal relationships among workers and managers are apparent. Furthermore, the relationship between personal health risk factors and workplace risks and exposures has drawn increased attention and concern. As employer economic pressures continue to build, it is anticipated that ethical dilemmas for practitioners will become increasingly complex. A review of relevant *Total Worker Health*® (TWH) literature, related ethical constructs and competencies, an examination of codes of ethics for occupational safety and health and health promotion/education disciplines was conducted. A case study for TWH utilizing an ethical decision-making model for the analysis of key ethical issues and solutions was completed. TWH approaches to protecting safety, promoting health, and advancing well-being are increasingly being adopted. These approaches can reveal ethical dilemmas, and ethical constructs are needed to guide decision-making. A core set of proposed ethical competencies for TWH professionals are identified as a transdisciplinary framework to support workplace ethical culture.

Keywords: total worker health; professional competencies; ethical decision-making

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1. Introduction

There have been dramatic changes in the nature of work over the recent decades. Work has become increasingly technologically driven and fast-paced, with goods production and service provision more likely to span cycles of twenty-four hours a day, seven days a week. Unsafe work conditions characterized by legacy risks and hazards continue along with the introduction of new work environments that present issues not yet fully understood. As the future of work continues to evolve, it is anticipated these environments will bring new threats to the workplace including those associated with non-traditional work arrangements and practices, precarious work, and organizational design issues, such as long work hours, heavy workloads, and difficult interpersonal relationships among workers and managers, changes to the technologies associated with work, and changing workforce characteristics [1].

Furthermore, the relationship between personal health risk factors and workplace risks and exposures has drawn increasing attention [2,3]. As health care costs continue to rise, issues related to cost containment, such as disability management, have sometimes created unintended conflicts between employers and workers, often putting occupational safety and health professionals in the difficult position of choosing loyalty to their employer or advocating for affected workers. As economic pressures for employers continue to build and work environments continue to change, it is anticipated that ethical dilemmas for practitioners will become increasingly complex, requiring competent ethical decision-making strategies to address and resolve these issues.

The National Institute for Occupational Safety and Health (NIOSH) *Total Worker Health*® (TWH) approach to worker safety, health, and well-being is a comprehensive program that may provide guidance as professionals seek to address these concerns. According to NIOSH, TWH is defined as policies, programs, and practices that integrate protection from work-related safety and health hazards with promotion of injury and illness prevention efforts to advance worker well-being [4,5]. Traditional occupational safety and health protection programs have primarily concentrated on ensuring that work is safe and that workers are protected from the harms that directly arise from work. Building on this foundation, TWH supports a thorough understanding of factors that contribute to worker safety, health, and well-being, including hazards that arise from work and those that develop outside of work [6]. This approach recognizes hazards and exposures, such as those from biologic, chemical, enviromechanical, physical, and psychosocial agents, as well as workplace issues not previously thought to impact worker health, such as hours of work, access to paid leave, healthy leadership, and meaningful work. Scientific evidence now supports what many occupational safety and health professionals, as well as workers themselves, have long suspected—risk factors in the workplace can contribute to health problems previously considered unrelated to work, such as sleep disorders, obesity, musculoskeletal disorders, and cardiovascular disease [6,7]. As the artificial boundaries between work and home life continue to erode, future challenges related to worker safety, health, and well-being will become more intertwined with personal choice and, thus, create a need for ever-more intricate ethical decision-making approaches.

The purposes of this paper are twofold: to focus on ethical constructs for decision-making by occupational safety and health (OSH) professionals in organizations that have adopted TWH approaches to worker safety, health, and well-being, and to propose ethical competencies for practitioners who practice TWH approaches. As the practice of occupational safety and health expands beyond the traditional responsibilities for safety and health protection and worksite health promotion programs move beyond a primary focus on behavior change, professional practice will increasingly engage a TWH approach. This includes, for many, moving into uncharted territory for finding the balance between employer interests and worker well-being. Focused ethical decision-making in total worker health is essential as this practice grows.

2. Ethics

Ethics is a generic term that covers several different ways of examining, understanding, and applying moral principles that guide behavior and actions to address specific problems or dilemmas. Ethics are the standards of right and wrong that guide behavior. An ethical framework or code provides guidance for how people reason, problem-solve, and respond [8]. Ethics connotes a dynamic process of discussion and debate among individuals involved in the decision-making process. An ethical approach requires multidisciplinary cooperation and collaborative participation to arrive at a course of action infused with trust and integrity.

The ethical decision-making process itself may turn out to be more important than its ultimate outcome. That is, how one transparently arrives at decisions shows respect for and fosters trust in the process. Using ethical theories and principles as foundational, ethically derived policies that achieve the greatest benefit (with minimal or no harm) provide concrete guidance for moving forward during challenging circumstances. When confronted with such challenges, occupational safety and health professionals have a responsibility to use independent judgment based on scientific knowledge and technical competence, guided by their professional code of ethics, while avoiding real or perceived conflicts of interest. Ethical competence in applying these principles will support a total worker health ethical culture.

3. Ethical Principles

Basic ethical principles provide guidance for all occupational safety and health professionals to protect the rights of workers and support an ethical culture for safety, health, and well-being in the workplace. There are four basic principles: autonomy, nonmaleficence, beneficence, and justice. However, these principles are not always discrete. They may overlap and sometimes they may conflict with each other. It may be more helpful to consider these principles as a continuum for professional guidance.

The ethical principle of autonomy is a form of personal liberty concerned with the right to self-determination; it respects the individual's right to make informed decisions [8]. Autonomy necessitates that personal values and goals be considered in major decisions affecting individual welfare and negates occupational safety and health professionals or others making decisions for a worker without autonomous input and consent. Autonomy encompasses the idea that everyone has the right to make his or her own choices in life. The principle of autonomy is especially predominant in Western cultures.

When applied to the workplace, complete and full disclosure regarding potentially harmful work is essential for informed decision-making and self-determination. Such disclosure includes information regarding work-related risks, known hazard or exposure interactions with personal health conditions, the right to know about potentially hazardous substances, and the pros and cons of accepting hazard pay for dangerous work. Inherent in this disclosure would be information about measures the employer is taking to protect workers and what decisions workers can make to protect themselves from harm.

In addition, when applied to worker participation in health screenings or health promotion programs, full disclosure is indicated to protect individual autonomy. Individual decision-making is best reflected through informed consent. Coercion and paternalism by management and health professionals regarding employee participation in company-sponsored programs, often tied to cost containment or discrimination against "high risk" workers, violate the principle of autonomy. Each individual worker should have the right to accept or refuse participation in health screening programs and medical treatment for health conditions. Health information and medical records generated by health care practitioners are private and confidential records and are to be protected from unauthorized access, unless otherwise required by law.

Employee autonomy must be safeguarded and of utmost concern is confidentiality and privacy of health information which can be at serious risk. Health information should be shared only with employee informed consent beforehand or when legally required to do so. The employee needs to trust that occupational health care providers will protect health information. Disclosure of personal health information without an employee's prior consent can undermine that trust. Employees may decline to participate in voluntary worksite programs or fail to disclose relevant health information accurately and truthfully to health care providers if they believe the employer will use the information against them in an embarrassing or discriminatory manner.

It is recognized that employers do have legitimate needs for certain types of employee health information, such as health hazard surveillance data. However, the provision of aggregate data to management related to the health effects of work-related exposures should be adequate. Management can also be informed about an individual's fitness to work or illness/injury-related work absences without disclosure of diagnosis or other personal health information unrelated to the employee's ability to perform the job. There is no need for management to "second guess" the health professional's expert judgment about health/medical conditions. The issue of confidentiality and privacy of employee health information is an ethical tenet that should not be violated. No real benefit can be reaped by failure to respect employees' privacy through unwarranted access to personal health information that has no relevance to fitness to work.

Occupational safety and health practitioners are ethically bound to prevent practices related to confidential health information which are ethically unsound, such as misuse or abuse of occupational health data, ignoring informed consent, concealing or withholding

findings, and inadequate protection of worker health records, or data, whether in physical paper or electronic format. Only when individual anonymity is assured can aggregate group health data of workers be disclosed to management and workers' representatives with the goal of protecting and promoting worker health and safety. Unless required by law, personal health information that is not relevant to the protection, maintenance, or promotion of workers' health in relation to work or to the overall health of the workforce must be protected as confidential.

Nonmaleficence is often referred to as the "no harm principle" [8] and it is inherent in professional standards, licensure, and codes of ethics. Within the construct of this ethical principle, occupational safety and health professionals have an obligation to protect workers from the risk of harm. Any potential risk of an intervention to protect safety and health should never outweigh the benefits of the intervention.

For example, a pregnant employee should not be exposed to known or potential teratogens, such as antineoplastic agents or prolonged standing, which may compromise the health of the woman or unborn baby. Another example of the no-harm principle is to avoid the placement of a worker with a known respiratory disease in work that would create or aggravate respiratory distress, including exposure to passive cigarette smoke. A third example relates to employing a young worker in a battery manufacturing company with the potential for lead exposure from welding operations. Although this worker may not be a welder, there will likely be exposure to lead as work takes place in close proximity to welding activities and personal protective equipment, including respiratory protection, is not provided.

Another consideration of nonmaleficence in the workplace is the harm caused by one worker to other co-workers, such as a forklift driver who is actively misusing a substance known to impair driving and judgment, or a worker who engages in bullying behaviors. In the case of the forklift driver, a breach of confidentiality that may violate the principle of autonomy may be necessary to protect the co-workers. Fitness for duty assessments provides an avenue to assist impaired workers, making sure they receive adequate care and treatment, prior to resumption of work responsibilities. Ethical practice would direct health care professionals to advocate for the health of the worker, regardless of conflicting pressure applied by management.

Furthermore, the issue of workplace stress is significant and can be harmful to health and well-being [9]. This is another example of the "no harm" principle where stressful acts and situations must be mitigated or eliminated. Stress is not just emotion; it affects body systems and the ability to do work. Often stress is caused when workers feel little or no control over what they are doing, such as unfair assignments, heavy workloads, long work hours, unfulfilling jobs, dangerous working conditions, bullying, and violence. Unmanaged stress may cause workers to take unsafe shortcuts to produce more, become engaged in conflict, or assume unhealthy behaviors, such as smoking, drug misuse, or poor eating [9].

Beneficence, the third ethical principle, pertains to providing benefits, preventing or removing harm, and balancing benefits against risks and costs [8]. It is the principle that supports occupational safety and health professionals in their efforts to assist workers to achieve their maximum health potential. Interventions aimed at health protection, such as the implementation of the TWH hierarchy of controls [6], health screening for adverse work-related health effects, and surveillance programs exemplify beneficence. The implementation of health-promoting programs, such as smoking cessation, exercise, and good nutrition, also illustrates this principle. Additional examples of beneficence include:

- Conducting team walk-throughs to identify potential hazards and make recommendations for hazard abatement;
- Targeting potential causes of stress be they work (e.g., work overload) or non-work-related (e.g., lactation support) for risk reduction;

- Providing health screenings, such as preplacement and periodic examinations, that may identify early disease or disease interactive agents (e.g., noise exposure and presbycusis);
- Providing protective immunizations (e.g., influenza vaccine; Sars-CoV-2 vaccine);
- Placement of engineering controls or development of a back-injury prevention program for workers with previous back injury;
- Assuring a worker with a disability that they will receive the best possible disability health care, through providing qualified health care providers;
- Providing adequate and continuous training so workers know how to do the job and are aware of potential hazards and their rights and responsibilities.

The TWH approach seeks to both protect workers (nonmaleficence) and promote their well-being (beneficence).

The fourth ethical principle, justice, is directed toward treating workers equally, without discrimination, and distributing benefits, risks, and costs [8]. The principle of justice is embodied in the Americans with Disability Act of 1990 [10] which includes equal opportunity regarding job availability and promotion for individuals with disabilities and those with preexisting conditions. It aims to prevent discrimination against individuals who are capable of performing all job-required job tasks despite the presence of a health condition.

The ethical principle of justice includes the concept of equity. There are numerous definitions of health equity. In general, they incorporate the goal of achieving the highest level of health and well-being for all people, regardless of social and economic status, by eliminating disparities, including disparities related to labor and employment conditions [11]. Health equity is consistent with the TWH approach of protecting all workers from safety and health hazards and advancing the well-being of all workers. Selecting minority or disadvantaged groups of workers based on a common defining characteristic to perform unpleasant or hazardous jobs violates the principle of justice and the goal of health equity. All workers should be treated and respected equally.

4. Ethical Decision-Making

The ethical principles provide guidance for occupational safety and health professionals as they consider the best course of action to take to address issues related to worker safety, health, and well-being. The challenge presented by the TWH approach is the broad assortment of conditions related to work that fall under the TWH umbrella. Thus, practitioners of TWH may be challenged in directions where there is little established guidance. When confronted with ethical issues involving right and wrong, practitioners will naturally rely on their personal and professional values, professional codes of ethics, legal obligations, and the moral code of behavior to which they adhere [12]. However, sometimes a decision-making challenge turns into a conflict or an ethical dilemma.

Ethical dilemmas are difficult problems that have no perfect solutions. They have been defined as "a decision-making problem between two possible moral imperatives, neither of which is unambiguously acceptable or [sic] preferable" [13]. Allen [12] contends that three conditions must be met for a problem to become an ethical dilemma: a choice must be made, there are different possible solutions, and no matter which solution is selected, an ethical principle is violated.

Curtain [14] describes that as various ethical dilemmas are analyzed there will be some situations in which one value conflicts with another, other situations in which duties conflict, or still others where duties conflict with the desired outcome. It may be that what the practitioner wants to do conflicts with what the practitioner thinks ought to be done [15]. The application of general ethical principles may help clarify the problem and guide decision-making.

For example, depending on the work being performed, workers can be exposed to hazardous chemicals or substances and they may not have an adequate understanding of the risks and consequences of their exposure. The legal basis for notifying workers about exposure to toxic substances is clearly embodied in the Occupational Safety and Health

Act [16], the Toxic Substances Control Act of 1976 [17], and the Hazard Communication Standard of 1983 [18]. Underlying these legal requirements are the ethical principles of autonomy and nonmaleficence.

Precepts related to "right to know" are embodied in the principle of autonomy and include access to information, right to self-determination, informed consent, and participation in decision-making. Workers have the right to know about hazardous substance exposure and make informed decisions about their options to limit exposure. They also have the right to develop their own course of action by engaging with the employer to better design and implement safety and health programs, procedures, and equipment to mitigate or eliminate the exposure risk.

Precepts related to "no harm" are embodied in the principle of nonmaleficence. As related to toxic agent exposures, harm can include both short-term and latent health effects on personal health, reproductive toxicity, concern about mental and physical integrity of offspring, fear and anxiety about health effects, and employer costs and benefits [19]. However, regardless of the legal requirements and specific standards designed to protect worker health and prevent harm, workers continue to be exposed to toxic substances and conditions in the workplace that are harmful to them and, potentially, to their families.

Also of importance is the precautionary principle that indicates that when an activity raises a reasonable suspicion of causing harm to human health, though there is no scientific evidence, precautionary measures should be taken just as if proof of its damage actually existed [20]. In the workplace, employers should take every precaution to protect workers from hazards and the precautionary principle should apply in situations where there is no definitive scientific evidence regarding the potential risk posed by a hazard and controls applied related to the hazard [21]. It asserts that when there is suspected harm and the scientific evidence is inconclusive, the prescribed course is precautionary action. The precautionary principle is most powerful when it serves as a guide to making wiser decisions in the face of uncertainty [22]. Protection of workers from uncertain hazards and risks requires the precautionary principle which is considered good practice.

5. Case Study

A framework or model for ethical analysis [23,24] may be beneficial to work through ethical dilemmas and support the formulation of ethical decisions (Figure 1). The case study approach will be used to demonstrate the application of a ten-step, ethical decision-making model. The ten steps are:

1. Know values
2. Gather data
3. Identify ethical problems
4. Identify decision-makers
5. Identify courses of action
6. Develop and apply the ethical ideal
7. Reach a resolution
8. Compare the resolution with values
9. Implement the resolution
10. Feedback

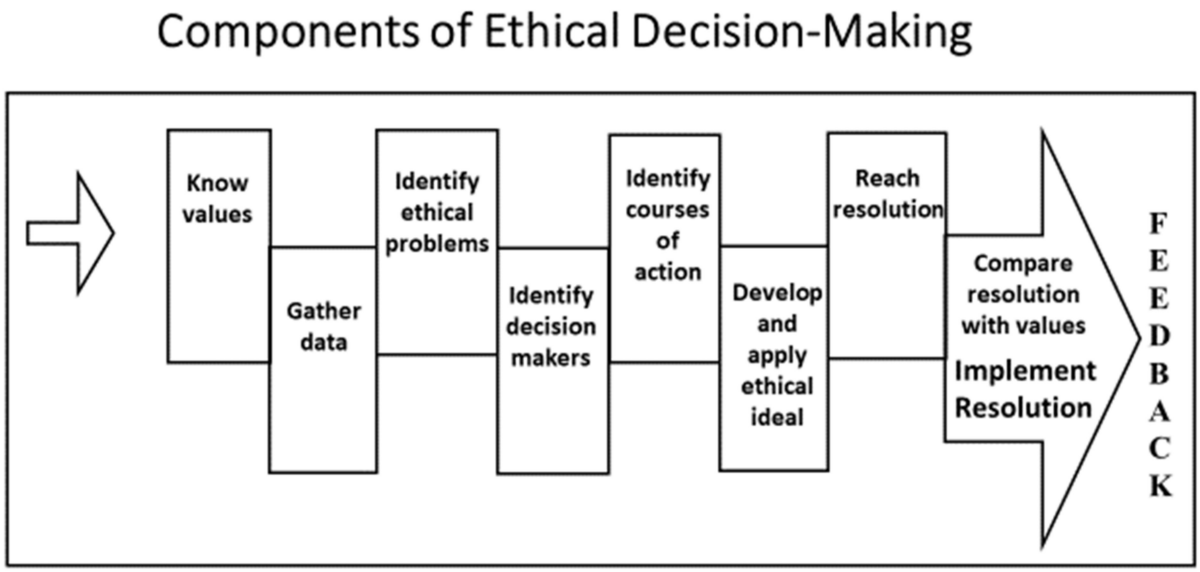


Figure 1. Components of Ethical Decision-Making.

6. Case Presentation

You are an occupational safety and health professional in the corporate offices of a long-term care facility with multiple locations in the Midwest. One year ago, you successfully convinced your boss and other key corporate executives of the benefits of implementing a TWH program for all workers in the local residential facilities. You were authorized to begin the implementation of a TWH program with a mandate to improve worker satisfaction and help with staff retention. Staff members are primarily nurses' aides, but also include nurses, dieticians, rehabilitation therapy staff, recreational therapists, social services staff, housekeeping staff and maintenance staff. You are in the initial stages of TWH program implementation.

This week you received notification that the corporation recently changed health care insurance companies and a new premium structure has been negotiated. Subsequently, you received a phone call from your boss, the corporate vice president of risk management (VP). During the call, the VP advised you of the high health insurance costs related to the number of facility staff who are overweight or obese. In fact, that is why the previous insurance company did not offer a renewal when the term of the prior policy expired.

The VP directed you to implement a mandatory weight loss program for workers who are overweight or obese and has suggested that successful implementation will lead to a substantial bonus for you and perhaps even a promotion. The VP has determined that worker weight loss will lower health insurance costs and reduce workers' compensation claims due to injuries resulting from lifting and assisting residents with limited mobility. You subsequently find out that staff members who do not achieve a "normal" weight within the next six months will be penalized with higher health insurance premiums.

As an occupational safety and health professional and TWH practitioner, you know that a weight loss program alone may be insufficient to help staff members achieve a weight in the normal range [25], especially in the proposed six-month period. You believe a comprehensive approach is needed to assist staff members who are overweight or obese. You are aware that some facilities are understaffed, resulting in nurses' aides and other staff often having to work double shifts. You are also aware that staffing shortages result in highly stressful working environments and you worry that care for the residents is compromised, which creates more stress for the staff. Your previous requests for mechanical lift devices, while supported by the nursing staff, have been rejected due to cost, training needs, and perceptions that residents will ultimately reject them. What do you do?

7. Ethical Analysis

7.1. Know Values

Begin the process of sorting through the issues by identifying the relevant values. Values identification fosters clarification of and reflection on applicable belief systems, including those of the individual doing the analysis. It creates an understanding of self-perspective as a reasoned approach to ethical problem analysis is developed.

In addition to the values held by the individual leading the ethical analysis, it is also critical to consider corporate values, perhaps as put forth in formal vision, mission, and value statements. Other values that are important to identify upfront include those of the involved workers, worker representatives, managers, corporate representatives, and any others who are contributing to the discussions and problem-solving. These values and belief systems should be stated clearly upfront and used to guide the ethical analysis process.

In the case presentation, evident values and beliefs include:

- Corporate executives value a TWH program, specifically to improve worker satisfaction and retention.
- The VP values healthier workers but focuses on the attainment of a healthy weight.
- The corporation values workers by offering health care insurance but believes premiums could be lower if workers were healthier. Lower health insurance premiums would improve the financial health of the corporation and could save money for the workers themselves.
- The TWH practitioner believes a comprehensive approach is needed to address worker health issues, including weight, stress, fatigue, and lifting injuries.
- The TWH practitioner has been offered monetary and prestige incentives to implement the mandatory weight loss program.
- A TWH program is of value to some workers.
- Informed consent for workers and confidentiality of health information is valued by the OSH/TWH professional and workers but their value to corporate executives is uncertain given the directive for a mandatory program.

7.2. Gather Data

In order to proceed with the ethical decision-making process, the fullest possible range of information and data pertinent to the problem should be collected. Sources for this data collection activity should include all of those affected by the problem and potential solutions. Additionally, corporate financial data may also create perspective for eventual problem-solving. Examples of information and data that may aid discussions include:

- Activities undertaken to date for TWH program implementation including the workers' input who have been involved in program development.
- Demographic data of workforce.
- Aggregated statistics related to the prevalence of workers who are overweight and obese, and the associated insurance costs as compared with workers whose weight is in the normal range.
- Aggregated statistics on workers' compensation for worker injuries related to unsafe resident handling procedures.
- Potential burden of health insurance penalties for those who do not achieve the desired weight loss.
- Staffing to resident ratios; current and recent trends.
- Use of mandatory overtime, including double shifts and perceived stress levels among the workers.
- Issues and formal complaints regarding compromised quality of care for residents.
- Costs associated with mechanical lift devices including equipment and training.
- Types of meals offered at the facilities.
- How the confidentiality of health data is managed.

7.3. Identify Ethical Problems

Recall that ethical dilemmas are problems that elude perfect solutions. While there may be different courses of action, choosing one action may support one ethical principle while violating or compromising another ethical principle. However, the ethical principles of autonomy, nonmaleficence, beneficence, and justice, can be used as guides for ethical decision-making and to identify ethical intrusions into the rights of workers. Examples of how these principles might potentially be violated in the case study include:

- Autonomy—Coercion and paternalism by management for mandatory worker participation in a weight loss program; lack of worker informed consent; pressure from management for OSH/TWH professional to conduct a mandatory weight loss program, with a potential conflict of interest for bonus pay/incentives, which could be in conflict with the professional code of ethics and also considered professionally offensive.
- Nonmaleficence—Staff shortages resulting in mandatory overtime, including double shifts for workers creating stress, fatigue, and potential practice errors; exposure to continued unsafe lifting practices of residents create a further risk of harm; failure to achieve weight loss creating worker poor self-image and concern for continued employment.
- Beneficence—Purchase of mechanical device equipment rejected by management because of cost; company meals provided are mostly fatty or fried food.
- Justice—Health insurance penalties for those who do not or who are unable to lose the required amount of weight in the defined period discriminate against this worker group; a monetary penalty may impact worker salary.

7.4. Identify Decision-Makers

Failure to deal with this component of the ethical decision-making process could result in the wrong people, making the wrong decisions, for the wrong reasons. Since the TWH approach to worker safety, health, and well-being is a transdisciplinary effort, many people may be involved in program development. While the number of decision-makers may be large, making the solution-generating process a bit unwieldy, a better outcome is achieved when those affected by the decisions are involved in the process.

In the case study, decision-makers who should be involved in the process include: workers from each department of the local residential facilities, worker representatives (if there are unionized facilities), facility managers, the VP and other corporate executives as appropriate, occupational safety and health/TWH professionals, and dietician. Consideration should also be given to including one or more residents to represent their local facility.

7.5. Identify Courses of Action

By definition, an ethical dilemma will have several potential courses of action, none of them perfect. In this case study, alternative courses of action may include:

- Ask a representative from each department of the local residential facilities to offer one or two suggestions for making the work environment safer and healthier and improving the health of staff members.
- Offer voluntary weight management program with incentives for weight loss, including new uniforms to celebrate weight loss achievements; eliminate health insurance penalties for workers who are unable to achieve the desired biometrics in the defined time.
- Develop a plan for using dietary staff and kitchens in residential facilities to provide healthier meal options for staff during their work shifts.
- Identify funding options (budget, grant, gift) for purchase/rental of mechanical lift devices for residents with limited mobility. Eliminate the need for staff bonuses.
- Focus efforts on becoming a community employer of choice to help eliminate staffing shortages (long-term).

- Refuse to implement weight loss program unless voluntary for workers, without penalty, and with informed consent and confidentiality of health information and seek higher chain of command for discussion. Indicate that this would be a violation of the professional code of ethics.

7.6. Develop and Apply Ethical Ideal

At this stage in the ethical decision-making process, each of the ethical principles—autonomy, nonmaleficence, beneficence, and justice—should be considered in relation to potential courses of action under discussion. For example, in the potential courses of action identified above, involving affected workers in the decision-making process supports the principle of autonomy. The principle of nonmaleficence is evident in efforts to eliminate staffing shortages, provide mechanical lifts, and eliminate the potential financial hardship of buying new uniforms when weight loss is successful. Providing healthier or lower-cost meal options through existing dietary staff and kitchen facilities supports the principle of beneficence. Eliminating the threat of health insurance penalties creates a more just work environment. Once each potential solution is screened for ethical soundness and modified as needed to align with the principles, problem resolution becomes more surefooted.

7.7. Reach Resolution

In all ethical decision-making, each potential course of action should be given serious consideration, especially for alignment with the ethical principles. Successful resolution options will, by necessity, be feasible, practical, affordable, and ethical. As a resolution becomes clearer, it may be helpful to create an ethical statement that addresses what can be done, by whom and under what conditions, rationale for the selected course of action, and feasibility of implementation.

In the case study, an example of an ethical statement might be:

It has been decided that a voluntary weight loss management program will be the most effective approach and will be implemented under the direction of the OSH/TWH professional. The decision for this voluntary program is that it will give workers a greater say in the decision-making about their personal health (autonomy) rather than being coerced into forced participation. Workers will be able to set personal achievement goals including weight loss within the desired timeframe. They will get support, direction, and encouragement from health professionals and may feel significant accomplishment in meeting their goals (beneficence) with potentially less fear of failure to achieve (nonmaleficence) and encouraged to continue with weight management once the program is completed. Health information obtained will be kept strictly confidential by the health professional (autonomy) and only aggregate data will be shared with management. There will be no penalty for non-participation (justice). Incentives will be offered with worker input and with budgetary considerations from the VP of human resources. Other non-participant workers may want to engage once they see the value and success of the program (beneficence).

7.8. Compare Resolution with Values, Implement, and Provide Feedback

Once a resolution has been stated, it should be checked for alignment with values. For example, the above ethical statement aligns with this value statement: This corporation values its workers and, therefore, is committed to improving their safety, health, and well-being (beneficence), including opportunities for workers to participate in decisions that affect them (autonomy). As an application of the resolution proceeds, progress can be assessed by checking in with those responsible for implementation and those who are affected by the resolution. Assessment of the implementation might include answers to questions such as: what outcomes are evident to the affected workers, have corporate objectives been achieved, have the intended benefits been realized by the intended workers, are modifications to the resolution needed, and were the costs associated with resolution acceptable. Seeking this information can be accomplished through confidential interviews, observations, group meetings, and appropriate discussions with management. The ideal

resolution is one that affords the most benefit with the least amount of harm while treating all affected individuals fairly and creating options for participation.

8. Professional Codes of Ethics

Health professionals including those in occupational safety and health, health education, and health promotion will find guidance for ethical decision-making in their respective codes of ethics. Professional associations develop codes of ethics to serve as a framework for guiding professional practice and outlining accountability to the consumer. These codes embody collective philosophies about the values and beliefs for professional practice. In addition to the principles of ethics previously discussed, members of the corresponding profession should use professional codes to guide ethical decision-making.

The American Association of Occupational Health Nurses (AAOHN) and the American College of Occupational and Environmental Medicine (ACOEM) both have codes of ethics that closely track ethical principles [26,27]. At least one of the principles of autonomy, nonmaleficence, beneficence, and justice is embedded in each of the ethical statements that comprise the AAOHN and ACOEM codes. Of the ethical codes for occupational safety and health professionals, the AAOHN and ACOEM codes are unique in that they specifically address issues related to the confidentiality of medical and health information.

Industrial hygienists are served by a code of ethics issued jointly by the American Industrial Hygiene Association (AIHA) and the American Conference of Governmental Industrial Hygienists [28]. For those industrial hygienists who are certified, a certified associate, or a candidate for certification, the American Board of Industrial Hygienists (ABIH) has a code of ethics that closely tracks the AIHA code [29]. While these codes address issues focused on the industrial hygiene profession, the ethical principles are evident in several of the ethical statements. Of note, as related to the case study, one statement addresses refraining from accepting payments that are intended to influence professional judgment. The American Society of Safety Professionals (ASSP) also has a code of professional conduct [30]. Again, the ethical principles are reflected in several of the statements created to guide the practice of safety professionals.

The Society for Public Health Education follows the Health Education Code of Ethics developed by the Coalition of National Health Education Organizations [31]. Similar to the occupational safety and health codes, this is grounded in fundamental ethical principles of honesty, autonomy, beneficence, respect, and justice. These professionals advocate and encourage actions and social policies that promote maximal health benefits and the elimination or minimization of preventable risks and health inequities for all affected parties. They are ethically bound to respect the privacy, confidentiality, and dignity of individuals and organizations.

However, there may be a gap between the code and real-life practice, confusion between the various codes, and the legal standing of these codes is uncertain [13]. In response, the International Commission on Occupational Health (ICOH) [32] has developed the world standard ethical code for occupational health professionals, covering all the disciplines of professionals whose practice relates to work and the workplace. Some countries have adopted the ICOH code of ethics in their legislation related to occupational health professionals [13].

9. Ethical Competencies in Total Worker Health

Competencies for occupational safety and health practitioners were originally defined in 1950 by the International Labour Organization (ILO) and World Health Organization (WHO). They were updated by the ILO/WHO Joint Committee on Occupational Health in 1995 with the following text:

> Occupational health should aim at: the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations; the prevention amongst workers of departures from health caused by their working conditions; the protection of workers in their employment from risks resulting

> from factors adverse to health; the placing and maintenance of the worker in an occupational environment adapted to his physiological and psychological capabilities; and, to summarize, the adaptation of work to man and of each man to his job. The main focus in occupational health is on three different objectives: (i) the maintenance and promotion of workers' health and working capacity; (ii) the improvement of working environment and work to become conducive to safety and health; and (iii) development of work organizations and working cultures in a direction which supports health and safety at work and in doing so also promotes a positive social climate and smooth operation and may enhance productivity of the undertakings. The concept of working culture is intended in this context to mean a reflection of the essential value systems adopted by the undertaking concerned. Such a culture is reflected in practice in the managerial systems, personnel policy, principles for participation, training policies and quality management of the undertaking [33].

A wide range of disciplines work as occupational safety and health professionals including occupational health physicians, occupational health nurses, industrial hygienists, safety specialists, ergonomists, health educators, health promotion specialists, occupational health psychologists, occupational health rehabilitation therapists, employee assistance program therapists, and others. As the TWH approach continues to be adopted in workplaces, it will be important for all disciplines to support a shared set of values and understand each other's responsibilities and professional standards as they relate to ethical decision-making. The competence of these practitioners should be mobilized within the framework of a transdisciplinary team approach to provide leadership for the improvement of the working environment and working conditions, including the design of work with health outcomes in mind, as well as worker safety, health, and well-being [34–36]. Aligning the concept of TWH with an understanding of ethical principles, a proposed set of ethical competencies is presented in Table 1.

Table 1. Ethical Competencies in Total Worker Health.

1. Provide non-discriminatory care or service, based on the principle of equity, to protect health related to work.
2. Practice with professional independence, based on knowledge, scientific evidence, good practice, and the highest professional standards, when making decisions related to the protection and promotion of worker health and safety.
3. Emphasize primary prevention, defined in terms of worksite assessment, policies, design, technology, and practice, to determine if workers can safely complete the required job tasks.
4. Protect confidentiality of individual employee health and medical data and prevent misuse of these data to respect human dignity, protect privacy, and enhance the acceptability and effectiveness of occupational health practice for physicians and nurses.
5. Use validated methods for risk assessment, monitoring, and health promotion, propose effective preventive measures, assess effectiveness of implementation, and be proactive in improving health and safety for workers based on professional codes for competency and ethics.
6. Recognize danger signs for violent or suicidal employees, take appropriate action, make referral, and follow up as appropriate.
7. Provide sound and honest advice to employers about legal, regulatory, and ethical responsibility in the field of occupational safety and health, and to workers for the protection and promotion of their health in relation to work.
8. Balance ethical principles with need to report hazards impacting others.
9. Understand the concepts of risk perception, acceptable risk, and risk communication.
10. Recognize prevention efforts and programs should be provided at both individualized and population-focused levels and be implemented with non-coerced, informed worker consent, including a discussion of potentially positive and negative consequences of participation in screening and health surveillance activities. Screening tests or unproven methods, which are not reliable, or methods that overly invasive should be avoided.

Table 1. *Cont.*

11. Provide guidance to workers and employers about optimal health and productivity programs and the value of health promotion programs, such as those for smoking cessation, physical activity, healthy eating, and fatigue prevention.
12. Provide multidisciplinary team support to the organization in creating and sustaining a culture of health at both system and individual levels while respecting the cultural and health beliefs of workers.
13. Remain knowledgeable about the work, work organization, and the work environment. Be well informed on current scientific and technical knowledge about occupational hazards from biological, chemical, enviromechanical, physical, and psychosocial agent exposures and the most efficient and effective means to eliminate or to minimize toxic agent exposure risk.
14. Conduct and participate in occupational health and safety program evaluations and audits to provide for continual improvement.
15. Contribute to the information for workers on occupational hazards to which they may be exposed in an objective and understandable manner, which does not conceal any fact, recognizes uncertainties of known or suspected hazards, and emphasizes preventive measures while addressing language barriers and cross-cultural differences.
16. Understand that determination of fitness for job duty must be based on a good knowledge of the job demands, essential job functions, the worksite, and assessment of the health of the worker.
17. Seek the participation of both employers and workers in the design and implementation of health education, health promotion, health screening, and public health programs.
18. Design and carry out research activities on a sound scientific basis within the context of ethical principles relevant to health and medical research work.

10. Conclusions

Due to their unique practice settings, occupational safety and health professionals have always faced the potential of navigating situations where the interests of multiple parties conflict, thereby creating decision-making challenges. As more occupational safety and health practitioners adopt TWH approaches to worker safety, health, and well-being, it is anticipated that such conflicts will increase and become even more difficult to resolve. Further complicating the decision-making environment for occupational safety and health professionals will be the evolving nature of work environments, the addition of existing and yet-to-be-discovered technologies to accomplish work and an increasingly diverse workforce. Fortunately, there are accessible tools to aid practitioners, including the basic ethical principles of biomedicine, professional codes of ethics, and the universal ethical code developed by ICOH.

An additional tool to aid occupational safety and health professionals is presented here as a model that delineates the components of ethical decision-making. By working through each component in the model, as demonstrated in the case study, practitioners will have a systematic approach to problem-solving for ethical dilemmas. Using a systematic approach such as this will guide decision-makers as they balance multiple perspectives and an evolving work environment landscape to achieve the greatest benefit with minimal or no harm and fairness to all involved.

A proposed set of ethical competencies for TWH practitioners is presented to stimulate thought about emerging requirements for occupational safety and health professionals who adopt TWH approaches. Educators and continuing education providers will find opportunities in these proposed competencies for expanding offerings to those whose practice includes TWH approaches to worker safety, health, and well-being. These competencies will, by necessity, evolve as the field matures.

The next steps for the intersection of ethics and TWH may be considered from several perspectives. First, research focused on this nexus would provide evidence-based support for TWH practitioners as they navigate through difficult issues. Second, the creation of standards of practice that incorporate the proposed ethical competencies for TWH practitioners would create a foundation of support for the implementation of TWH approaches in diverse practice settings. Professional organizations that support TWH practitioners should consider amending existing practice standards to specifically address potential

ethical challenges posed by TWH approaches. Third, the process of policy development in organizations committed to protecting worker safety, promoting worker health, and advancing worker well-being should incorporate components of ethical decision-making and considerations of health equity to achieve total worker health for each and every worker.

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References

1. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Howard, J. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef] [PubMed]
2. Schulte, P.A.; Pandalai, S.; Wulsin, V.; Chun, H.K. Interaction of occupational and personal risk factors in workforce health and safety. *Am. J. Public Health* **2012**, *102*, 434–448. [PubMed]
3. Pandalai, S.P.; Schulte, P.A.; Miller, D.B. Conceptual heuristic models of the interrelationships between obesity and the occupational environment. *Scand. J. Work Environ. Heath* **2013**, *39*, 221–232. [CrossRef]
4. National Institute for Occupational Safety and Health. What Is Total Worker Health? 2020. Available online: www.cdc.gov/niosh/twh/default.html (accessed on 12 January 2020).
5. Tamers, S.L.; Chosewood, L.C.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.C. Total worker health® 2014–2018: The novel approach to worker safety, health, and well-being evolves. *Int. J. Environ. Res. Public Health* **2019**, *16*, 321. [CrossRef]
6. National Institute for Occupational Safety and Health. *Fundamentals of Total Worker Health Approaches: Essential Elements for Advancing Worker Safety, Health, and Well-Being*; DHHS (NIOSH) Publication No. 2017-112; U. S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health: Cincinnati, OH, USA, 2016.
7. Hudson, H.L.; Nigam, J.A.S.; Sauter, S.L.; Chosewood, L.C.; Schill, A.L.; Howard, J. *Total Worker Health*; American Psychological Association: Washington, DC, USA, 2019.
8. Beauchamp, T.L.; Childress, J.F. *Principles of Biomedical Ethics*; Oxford University Press: New York, NY, USA, 2013.
9. Hammer, L.B.; Perry, M.L. Reducing work-life stress. In *Total Worker Health*; Hudson, H.L., Nigam, J.A., Sauter, S.L., Chosewood, L.C., Schill, A.L., Howard, J., Eds.; American Psychological Association: Washington, DC, USA, 2019; pp. 263–278.
10. Department of Justice. Americans with Disabilities Act of 1990 Amended. 2009. Available online: https://ada.gov/pubs/adastatute08.htm (accessed on 22 January 2020.).
11. Liburd, L.C.; Hall, J.E.; Mpofu, J.J.; Marshall Williams, S.; Bouye, K.; Pennman-Aguilar, A. Addressing health equity in public health practice: Frameworks, promising strategies, and measurement considerations. *Annu. Rev. Public Health* **2020**, *41*, 417–432. [CrossRef] [PubMed]
12. Allen, K. What is an ethical dilemma? *New Soc. Work.* **2012**, *19*, 2. Available online: https://www.socialworker.com/feature-articles/ethics-articles/what_is_an_ethical_dilemma%3F/ (accessed on 9 March 2020).
13. Iavicoli, S.; Valenti, A.; Gagliardi, D.; Rantanen, J. Ethics and occupational health in the contemporary world of work. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1713.
14. Curtain, L.L. How do we get into morally questionable situations? *Am. Nurse Today* **2014**, *9*, 62.
15. Milliken, A. Ethical awareness: What is it and why it matters. *Online J. Issues Nurs.* **2018**, *23*, 1. [CrossRef]
16. Department of Labor. Occupational Safety and Health Act of 1970; Public Law 91-5946. 2004. Available online: www.osha.gov/laws-reg/abstract/completeoshact (accessed on 22 January 2020).
17. Environmental Protection Agency. Toxic Substances Control Act of 1976. 2016. Available online: https://www.ewpa.gov/laws-regulations/summary-toxic-substances-control-act (accessed on 22 January 2020).
18. Department of Labor Occupational Safety and Health Administration. Hazard Communication. 2012. Available online: www.osha/gov/dsg/hazcom (accessed on 22 January 2020).

19. Landsbergis, P.A.; Dobson, M.; LaMontagne, A.D.; Choi, B.; Schnall, P.; Baker, D.B. Occupational stress. In *Occupational and Environmental Health*; Levy, B., Wegman, D.H., Baron, S.L., Sokas, R.K., Eds.; Oxford University Press: New York, NY, USA, 2018; pp. 325–344.
20. Kirch, W. (Ed.) *Precautionary Principle. Encyclopaedia of Public Health 2008*; Springer Science+Business Media: New York, NY, USA, 2008.
21. Pless, I.B. Expanding the precautionary principle. *Inj. Prev.* **2003**, *9*, 1–2. [PubMed]
22. Science and EH Network. Precautionary Principle FAQs. 2013. Available online: https://www.sehn.org/sehn/precautionary-principle-faqs (accessed on 6 September 2021).
23. Rogers, B. *Occupational and Environmental Health Nursing: Concepts and Practice*, 2nd ed.; Saunders: Philadelphia, PA, USA, 2003.
24. Rogers, B. Chapter: Legal and ethical issues. In *Fundamentals of Occupational and Environmental Health Nursin*, 2nd ed.; American Association of Occupational Health Nurses, Inc.: Chicago, IL, USA, 2020.
25. Miranda, H.; Gore, R.J.; Boyer, J.; Nobrega, S.; Punnett, L. Health behaviors and overweight in nursing home employees: Contribution of workplace stressors and implications for worksite health promotion. *Sci. World J.* **2015**, *2015*, 915359.
26. American Association of Occupational Health Nurses. Code of Ethics and Interpretive Statements. 2016. Available online: http://aaohn.org/d/do/165 (accessed on 11 April 2020).
27. American College of Occupational and Environmental Medicine. The Seven Ethical Principles of Occupational and Environmental Medicine. 2010. Available online: https://acoem.org/acoem/media/PDF-Library/About_ACOEM/Code-of-Ethics-Condensed-Version.pdf (accessed on 11 April 2020).
28. American Industrial Hygiene Association. Joint Industrial Hygiene Associations Member Ethical Principles. 2007. Available online: https://aiha-assets.sfo2.digitaloceanspaces.com/AIHA/resources/About-AIHA/Member-Ethical-Principles.pdf (accessed on 11 April 2020).
29. American Board of Industrial Hygiene. American Board of Industrial Hygiene Code of Ethics. 2007. Available online: http://www.abih.org/sites/default/files/downloads/ABIHCodeofEthics.pdf (accessed on 11 April 2020).
30. American Society of Safety Professionals. Code of Professional Conduct. 2012. Available online: https://www.assp.org/about/society-bylaws-and-guidelines/code-of-conduct (accessed on 11 April 2020).
31. Coalition for National Health Education Organizations (CNHEO). Code of Ethics for Health Education Profession®. 2020. Available online: http://cnheo.org/ethics-0f-the-profession.html (accessed on 11 April 2020).
32. International Commission on Occupational Health. International Code of Ethics for Occupational Safety and Health Professionals. 2012. Available online: http://www.icohweb.org/site/multimedia/code_of_ethics/code-of-ethics-en.pdf (accessed on 30 January 2020).
33. Joint International Labour Organization; World Health Organization Commission on Occupational Health. *Definition of Occupational Health*; Twelfth Session; International Labour Organization: Geneva, Switzerland, 1995.
34. Streit, J.M.K.; Swanson, N.G.; Chosewood, L.C.; Pana-Cryan, R.; Reeves, K. *NIOSH Healthy Work Design and Well-Being Program*; DHHS (NIOSH) Publication 2019–171; U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health: Atlanta, GA, USA, 2019. [CrossRef]
35. Rogers, B.; Randolph, S.A.; Mastroianni, K. *Occupational Health Nursing Guidelines for Primary Clinical Conditions*, 5th ed.; OEM Press: Beverly, MA, USA, 2018.
36. Rogers, B. Occupational and environmental health nursing: Ethics and professionalism. *Workplace Health Saf.* **2012**, *60*, 177–181. [PubMed]

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Article

An Exploratory, Qualitative Study of How Organizations Implement the Hierarchy of Controls Applied to *Total Worker Health*®

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Abstract: Understanding of how *Total Worker Health*® (TWH) guidelines are implemented in employment organizations in the USA is not well understood. The purpose of this study is to explore how the principles of the Hierarchy of Controls Applied to NIOSH Total Worker Health (TWH HoC), have been implemented among organizations featured as Promising Practices for TWH between 2012–2019, with special focus on the work-related issues of fatigue, stress, sedentary work, and tobacco control. We also sought to identify benefits, obstacles, and lessons learned in the implementation of the TWH HoC. Eighteen organizations were identified to be included in the study. Using a qualitative cross-sectional design and purposive sampling, seven in-depth interviews were conducted with thirteen key informants. The Consolidated Framework for Implementation Research was used to guide the thematic analysis and interpretation of qualitative data. Four themes identified include recognition of the TWH approach and TWH HoC, implementation of the TWH HoC, barriers and facilitators in addressing specific work-related issues, and implementation climate primes benefits, obstacles, and lessons learned. The inner setting (i.e., culture, implementation climate, readiness for implementation) of organizations was a prominent determinant of the implementation of integrated worker safety, health, and well-being interventions.

Keywords: Total Worker Health; hierarchy of controls; qualitative study; workplace safety; implementation science; future of work; occupational safety and health

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1. Introduction

Since the development of the *Total Worker Health*® (TWH) program led by the National Institute for Occupational Safety and Health (NIOSH) in the United States of America (USA), several guidelines have been created to aid employers in the implementation of integrated interventions that collectively address worker safety, health, and well-being [1–3]. Among these guidelines, the Hierarchy of Controls Applied to NIOSH Total Worker Health (hereinafter referred to as TWH HoC) was published in Fundamentals of Total Worker Health Approaches [2] as a conceptual model designed to aid employers and other professionals interested in implementing workplace safety and health programs aligned with TWH approaches. The TWH HoC expands the traditional industrial hygiene Hierarchy of Controls [4] and addresses strategies to advance worker well-being. The two Hierarchies of Control are complementary and underscore the foundation of worker safety and health. Figure 1 illustrates the TWH HoC and the five control levels arranged in order of effectiveness (most to least effective order) [5].

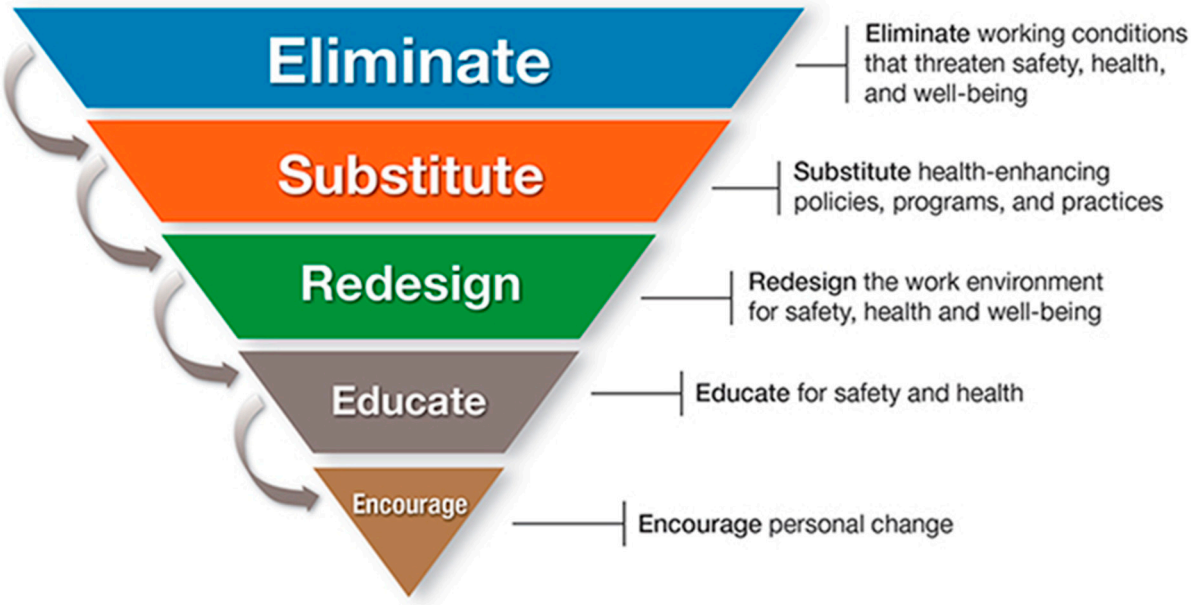


Figure 1. Hierarchy of Controls Applied to NIOSH *Total Worker Health*®.

Application of the TWH HoC begins with eliminating working conditions that threaten safety, health, and well-being. This level is instituted at the highest tier of the organization and its approaches are often impersonal and unyielding; customization or individual considerations will not be included in elimination controls. Examples of the eliminate control include organizational-wide policies for tobacco-free work environments, organizational and management policies that eliminate root causes of stress, such as excess demands or workplace bullying, and policies that provide workers with increased flexibility and control over their work and schedules. The second level focuses on substitution or replacement of unsafe, unhealthy working conditions or practices with safer, health-enhancing policies, programs, and management practices that improve the culture and safety of the workplace. Examples of substitute controls include replacing food options in workplace common areas with healthier versions, encouraging reports of unsafe work practices without fear of reprisal, and self-funded health insurance. The third level, focused on controls to redesign the work environment for safety, health, and well-being, is characterized by the improvement of work-focused interventions. Examples of redesign include the addition of sit-stand workstations to address sedentary work, improved shift work scheduling, and enhancement of employer-sponsored benefits. The fourth control level, educate for safety and health, focuses on interventions and practices aimed to enhance individual knowledge for all workers. Examples include safe patient handling training, motivational interviewing, peer-led meetings, and telephonic counseling sessions. The fifth level is meant to encourage personal change to improve individual and group health, safety, and well-being. This level emphasizes healthier choice making and may include email and text message prompts, posters, and incentive programs.

Despite development of this hierarchy, an understanding of how national worker safety and health guidelines are adopted and implemented in employment organizations is not well understood. In fact, dissemination and implementation (D&I) science has scantly been applied to the fields of occupational safety and health (OSH), [6–8]. D&I science is a multidisciplinary, rapidly emerging field that aims to improve the relevance and uptake of research-based knowledge in real-world settings [9]. Several scholars in the field of OSH recognize there is a need to draw from the field of D&I science to deepen our understanding of factors that influence adoption of evidence into practice as well as further our understanding of how research is applied to policy [8,10–12]. Further, scholars recommend using qualitative and mixed methods as they are expected to provide contextual meaning on the effectiveness of interventions [13].

The TWH HoC has been used to inspire occupational health nurses to implement new approaches for workplace safety, health, and well-being [14]. Some researchers have used it as a framework to evaluate and interpret findings on the effectiveness of integrated occupational safety, health, and well-being interventions and determine priorities and design for future interventions [15,16]. Baron and colleagues [17] adapted the TWH HoC to the social ecological framework to demonstrate how employment and work—a major social determinant of health—are impacted by other domains of social influence. Reolofs [18] used it to develop a conceptual model toward protecting employees and promoting their well-being during and after crises such as weather disasters, pandemics, and acts of terrorism.

Despite its use in the literature, it is unclear how the TWH HoC has been implemented within employment organizations. In the face of rapid changes to the workplace, work, and the workforce, such an understanding will help to elucidate how NIOSH TWH guidelines and recommendations are put into practice in organizations facing these emerging pressures. Work of the future will have significant implications for workers, employers, and society as both anticipated and unforeseen issues impact one another and often interrelate to each other, increasing their complexity [19]. Consequently, there is a need for an increased understanding of why and how existing OSH guidance, such as the TWH HoC, is implemented. This understanding will provide insights to help OSH professionals prepare for future opportunities and challenges.

Punnett et al. [10] and Sorensen et al. [20] cite the need for agreement about the necessary components for an effective TWH approach based in both conceptual and practical constructs. Even similar vocabulary or shared understanding of the terms by which implementation of integrated worker safety, health, and well-being programs are described may aid in the advancement of TWH approaches in the field [6]. Characterization of the TWH HoC as a standardized framework and concurrence about its distinct control levels may offer a clear model for workplaces seeking to protect and promote worker safety, health, and well-being. By understanding the factors which influence adoption and implementation of the TWH HoC in real-world settings OSH researchers can elucidate the needs of employers in identifying and mitigating risks posed by work now and in the future [21].

The overall aim of this study is to explore how the principles of the Hierarchy of Controls Applied to NIOSH Total Worker Health have been implemented among organizations featured as Promising Practices for Total Worker Health (hereinafter referred to as Promising Practices) [22] between 2012 and 2019, with a special focus on the work-related issues of fatigue, stress, sedentary work, and tobacco control. The five areas of special emphasis were chosen because, at the time of the study, organizations sought information on these topics from the NIOSH TWH program. Promising Practices is a periodic feature of the NIOSH TWH in Action! quarterly e-newsletter that spotlights a selected organization's efforts to implement programs, policies, practices that reflect the TWH approach to worker safety, health, and well-being [23].

The primary objectives of this study are:

1. To explore how organizations featured in Promising Practices have implemented the principles of the Hierarchy of Controls Applied to NIOSH Total Worker Health in their programs, policies, and practices that address worker safety, health, and well-being.
2. To explore how organizations featured in Promising Practices have used the TWH approach to address fatigue and sleep, work-related stress, sedentary work, and tobacco control.
3. To identify benefits, obstacles, and lessons learned in the implementation of the TWH HoC among organizations featured in Promising Practices.

2. Materials and Methods

2.1. Study Design

This exploratory study used a qualitative cross-sectional design involving in-depth interviews to gather information about how organizations implemented or are implementing core principles of an integrated approach toward worker safety, health, and well-being. The Consolidated Framework for Implementation Research (CFIR) [24] serves as the guiding theory for understanding the adoption of TWH HoC. The NIOSH Institutional Review Board Human Research Protection Program determined this study to be exempt from requirements for research involving human subjects.

2.2. Study Setting and Sample

The study population was drawn from organizations featured in Promising Practices articles published between 2012 and 2019 [22]. These articles feature early adopter organizations targeting the conditions of work to improve the safety, health, and well-being of workers on and off the job. Early adopter organizations, a commonly used term at NIOSH derived from the Diffusion of Innovations theory [25], will be used in this study to broadly describe organizational change agents that have embraced work-related integrated safety, health, and well-being approaches to advance worker well-being on and off the job. Using a purposive sampling method, a total of 18 articles were selected based on inclusion and exclusion criteria. Inclusion criteria were determined by the research team (HH, AS, RR) through independent article reviews and team deliberations on characterizations and applications of the TWH HoC. To be included in the sample, the article needed to describe a broad application of the TWH HoC and details about the process of implementation in the organization's TWH-related program. Articles were excluded if they did not discuss aspects of the TWH HoC. Of the 18 articles reviewed, a total of 8 organizations were eligible for the study.

Table 1 provides a description of the organizations in the study sample. Organizations are characterized by size, sector, span of operations, manufacturing or non-manufacturing, and program maturity. The number of key informants that were involved in the organizational interviews is also identified. Six out of the seven organizations had more than 500 employees. Two of the seven organizations were in the government sector and the remaining organizations were in the private sector. There was an even distribution between the span of operations with five of the seven considered as non-manufacturing. Five of the seven organization's health, wellness, or TWH program had been in place for less than 15 years.

Table 1. Characteristics of the Selected Promising Practice Organizations.

Organization Code	Organization Size	Sector	Span of Operations	Manufacturing or Non-Manufacturing	Program Maturity	No. Key Informants Interviewed
A	>500	Government	National	Non-manufacturing	<15 years	1
B	>500	Private	State/Regional/Local	Non-manufacturing	<15 years	2
C	<500	Government	State/Regional/Local	Non-manufacturing	<15 years	1
D	>500	Private	National	Manufacturing and Non-manufacturing	>15 years	2
E	>500	Private	State/Regional/Local	Non-manufacturing	<15 years	1
F	>500	Private	Global	Manufacturing	<15 years	4
G	>500	Private	Global	Manufacturing	>15 years	2
H	>500	Private	Global	Manufacturing	Unknown	N/A

2.3. Data Collection Procedures and Measures

The research team consists of current and former core team members of the NIOSH TWH program, including a senior science advisor (AS), a public health analyst (RR), and a health scientist trained in qualitative methods (HH). An interview guide was developed by the research team (AS, HH, RR) and included open-ended questions that were associated

with study objectives. Interview questions asked were relevant to how the organizational program evolved since the publication of the Promising Practices article; application of the TWH approach relevant to organizational safety, health, and well-being concerns; examples of each of the levels of controls in the TWH HoC; use of TWH approach to address tobacco control, sedentary work, fatigue, and work-related stress; and experienced organizational benefits, barriers, and lessons learned in using the TWH HoC or TWH approach. The special focus topics of fatigue and sleep, work-related stress, sedentary work, and tobacco control were selected as these topics were most mentioned by organizations seeking information from NIOSH at the time of data collection.

A research team member (HH) contacted representatives from each of the selected organizations via email to enlist key informants in a one-hour in-depth telephone interview. A key informant is an individual with either direct or indirect responsibility for implementing programs, policies, and practices that safeguard the safety, health, and well-being of their organization's workforce. The key informant may or may not have been involved in development of the Promising Practices article. Once a mutual meeting time was identified, the identified key informant(s) received a letter by e-mail confirming the interview schedule and an overview of the interview focus, including the interview questions, the relevant Promising Practices article, a web link to the Hierarchy of Controls Applied to NIOSH Total Worker Health [5], an article that provided context for the TWH concept and clarity around the TWH HoC [14], and brief biographies of the three interviewers. Providing this information prior to the interview allowed the primary key informant to invite other subject matter experts in their organization to participate in the organizational interview, gather relevant program specifics from other sources and offered the opportunity for the key informants to prepare complete and accurate responses. There was no limit on the number of key informants representing the organization in the interview. All subjects gave their informed consent before participating in the organizational interview. Participants were informed at the time of the interview that they would be given an opportunity to review the manuscript prior to journal submission. After the research team reviewed transcripts and notes, if deemed necessary, a research team member contacted the appropriate key informant to clarify points in the discussion.

Semi-structured interviews were conducted between 16 July 2019 and 09 August 2019, with two team members asking the interview questions (AS and HH) and the other team member serving as notetaker (RR). All interviews were transcribed by a research team member (RR) using MS Word. Of the eight organizations eligible for interviews, seven were scheduled and one was declared lost to follow-up after multiple, failed attempts to reach organizational contacts. After each interview, the notetaker emailed the interview transcription to be reviewed by all members of the research team for accuracy and saved the file in a shared folder. Transcripts were uploaded into Dedoose software (version 8.2.14) for data coding and analysis.

2.4. Qualitative Data Analysis

A mixed inductive-deductive approach was used for data coding and analysis. Initially, each member of the research team (AS, RR, HH) independently reviewed the interview transcripts and then discussed preliminary findings that aligned under the research objectives. After a series of joint discussions drawing from the data, scientific literature in TWH, and expertise in TWH, the research team determined that the Consolidated Framework for Implementation Research (CFIR) [24] would be useful for the data analysis and interpretation of the findings. The CFIR was chosen because of its comprehensiveness for understanding determinant factors or potential barriers and facilitators in the implementation of interventions in an organizational context. This is particularly important given the complex interplay of organizational resources needed to assess, plan, and implement the TWH HoC or other TWH-related interventions.

The CFIR draws from multiple disciplines (e.g., psychology, sociology, and organizational change). CFIR includes five domains (i.e., intervention characteristics, outer setting,

inner setting, individuals involved, and implementation process) which are primary contextual factors that influence implementation effectiveness. Within each domain is a pragmatic constellation of thirty-nine constructs believed to influence implementation, positively or negatively [24]. The intervention characteristics domain refers to the attributes of an intervention that impact the implementation success and includes its perceived internal or external origin or source, relative advantage, adaptability, trialability, complexity, evidence quality and strength, design quality and presentation, and cost. The outer setting domain refers to the external influences of intervention implementation and includes cosmopolitanism or the level at which the implementing organization is networked with other organizations, peer pressure, and external policies and incentives. The inner setting domain refers to characteristics of the implementing organization. The fourth major domain are the individuals involved and include those who are important to the influence of the intervention, integral to the process of implementation, and may come from the inner setting or outer setting. The fifth domain is implementation process which is an interrelated series of subprocesses that don't necessarily occur sequentially and may or may not be planned or spontaneous, and linear or non-linear. Appendix A Table A1 describes the CFIR domains and constructs in the context of the TWH HoC and TWH-related approaches.

An initial codebook was developed that applied a priori codes relevant to the study objectives. Data were analyzed between January and April 2021. Using Dedoose qualitative data analysis software, a single coder (HH) applied a priori codes to the transcripts. Emerging and post hoc codes relevant to CFIR were subsequently added. After first round coding was completed, three transcripts were compared between HH and RR to ensure the data coding and interpretation was prudent. Coded data were reviewed and collated into potential themes and reviewed to refine themes. The most salient CFIR domains and constructs that aligned with the study objectives steered the identification and finalization of primary themes and subthemes. Because the CFIR was used for analysis and not part of the data collection instrument, only certain domains and their constructs were relevant to this study. Exemplary quotes were identified that aligned to each theme and subtheme. The Consolidated Criteria for Reporting Qualitative Research was used to structure reporting of the findings [26].

3. Findings

We interviewed thirteen key informants from seven employment organizations (Table 1). All key informants had direct or indirect roles responsible for implementing programs, policies, and practices that safeguard the safety, health, and well-being of workers in their organization. The findings from this study are reported within four prominent themes: recognition of the TWH approach and TWH HoC, implementation of the TWH HoC, barriers and facilitators in addressing specific work-related issues, and implementation climate primes benefits, obstacles, and lessons learned. The first theme emerged inductively from the data, and the remaining three themes align to the study objectives. The themes, subthemes, and their alignment to relevant CFIR domains are highlighted in Table 2 and subsequently described.

3.1. Theme 1: Recognition of the TWH Approach and the TWH HoC

A prominent theme that emerged in the data was recognition of the TWH HoC and of the overall TWH approach among all organizations interviewed. Relevant to the CFIR domains of intervention characteristics and inner setting, this finding speaks to the implementation attributes of intervention source, relative advantage, adaptability, implementation climate, compatibility, and readiness for implementation. These attributes were among the main constructs that emerged when key informants discussed their organization's overall approach to worker safety, health, and well-being and whether their organization's interventions were directly influenced by NIOSH TWH-related guidelines.

Table 2. Description of Themes and Subthemes Related to Implementation of the Hierarchy of Controls Applied to NIOSH Total Worker Health among Selected Organizations.

Theme 1: Recognition of the TWH Approach and the TWH HoC				
Relevant CFIR Domains: Intervention Characteristics and Inner Setting				
There was varied awareness of the TWH approach and the TWH HoC among selected Promising Practice organizations.		The principles of TWH are part of existing organizational values for building a healthy work culture.		The TWH approach leverages with traditional occupational safety and health approaches to address worker health more broadly.
Theme 2: Implementation of the TWH HoC				
Relevant CFIR Domains: Intervention Characteristics and Inner Setting				
The Eliminate Control was commonly used and trialed.	Adaptability and resources are important in the Substitution of unhealthy working conditions.	The Redesign Control was the most frequently used control and it was likely to provide both quality and advantage.	The Education Control offers advantage by coupling with other organizational efforts.	An organizational culture built around healthier choice making underscores the Encourage Control.
Theme 3: Barriers and Facilitators in Addressing Specific Work-Related Issues				
Relevant CFIR Domains: Inner Setting and Implementation Process				
Leadership engagement, available resources, and access to information are possible facilitators or barriers for organizational efforts that focus on Work-related Fatigue and Sleep.		Culture and available resources were indicated as important supports for organizational Tobacco Control efforts.	Organizational culture and available resources were suggested to provide multi-level efforts for addressing Sedentary Work.	Implementation process was a likely facilitator or barrier for organizational efforts that prevent Work-related Stress.
Theme 4: Implementation Climate Primes Benefits, Obstacles, and Lessons Learned				
Relevant CFIR Domain: Inner Setting				
An existing implementation climate supports the Benefits experienced.		Lack of implementation climate and absence of readiness for implementation were indicated as Obstacles.		Organizational and leadership commitment discussed as Lessons Learned for successful implementation of organizational interventions.

3.1.1. Subtheme: Varied Awareness of the TWH Approach and the TWH HoC

An inductive subtheme that emerged was the varied awareness of the TWH approach and the TWH HoC. Two organizations indicated they were aware of both the TWH approach and the TWH HoC. One organization indicated they were aware of the TWH approach but not the TWH HoC. One organization indicated they were not aware of the TWH HoC or the TWH approach. Three organizations did not indicate they were aware of the TWH approach or the TWH HoC. This finding is possible because the TWH HoC was published in 2016 and some of the articles were published prior to its release. It is also important to note that organizations selected to be featured as Promising Practices may or may not purposely follow the TWH approach and were recognized based on how they targeted the conditions of work to improve the safety, health, and well-being of workers on- and off-the-job.

> "I didn't know about the hierarchy of controls applied to TWH and am embarrassed. It's taken a long time, and [it's] still taking time to see this approach. Not everybody knows about it . . . You can't be thinking about overall employee wellness without thinking that employees feel included, well, healthy, and in a physically safe environment. The TWH model is helping me to broaden my perspective in valuing all parts of the employee." [Organization A]

3.1.2. Subtheme: The Principles of TWH Are Part of Existing Organizational Values for Building a Healthy Work Culture

Despite the varied awareness of the TWH HoC or the TWH approach, the principles of an approach consistent with TWH align with existing organizational efforts for building and maintaining a safe and healthy work culture. Four organizations inferred that TWH principles were only a part of their organization's existing approach towards building and maintaining a workforce culture of health. This relates to the compatibility (a construct of inner setting domain) of the TWH approach or the TWH HoC with organizational values, workflows, or systems and the values and meaning attached to involved individuals implementing the intervention; otherwise, relevant to the construct of implementation climate (a construct of the inner setting domain). Also relevant is the intervention source (a construct of the intervention characteristics domain) referring to the perceptions of key stakeholders about whether the motivation for the TWH approach or the TWH HoC was internally or externally developed. Organizations C, D, F, and G discussed how the tenets of TWH (i.e., elimination of occupational hazards, leadership engagement, and worker involvement) were part of how their organizations operate.

> "I do remember that it was mentioned in some meetings I took part in . . . These ideas are so baked into how we conduct our core business. It's hard to be explicit because it's already interwoven. I think it was [an] integral part of that process, but not in an overt checklist fashion." [Organization G]

3.1.3. Subtheme: The Total Worker Health Approach Leverages with Traditional Occupational Safety and Health Approaches to Address Worker Health More Broadly

When tackling working conditions that threaten the safety, health, and well-being of workers, some organizations discussed how the facets of the traditional HoC were leveraged with the TWH HoC. Respondents often discussed that building off the organization's environmental health and safety plan was a key strategy for beginning to evaluate work-related health risks and devise solutions to address them. Organizations also referred to their use of multi-level or comprehensive approaches that collectively addressed work-related risks examined in this study (e.g., work-related stress, sedentary work, and sleep and fatigue), other potential hazards (e.g., repetitive motion, slips, trips and falls, chemical exposures) and health-enhancing environments (e.g., access to healthy food). This subtheme refers to the construct of adaptability (a construct of the intervention characteristics domain) of the intervention into the organizations.

> "The Total Worker Health approach enabled us to incorporate wellness into the safety, health, and wellness strategy . . . We needed to have a safety strategy and our office was attuned to this. We incorporated wellness into this national strategy which got a lot of attention. For wellness to be included is quite incredible." [Organization A]

3.2. Theme 2: Implementation of TWH HoC

Theme two is relevant to study objective one as it focuses on determining factors in the implementation of the TWH HoC among early adopter organizations featured as Promising Practices published by NIOSH. In the context of implementing TWH HoC, the CFIR domains that were most evident when discussing the application of each of the five controls include intervention characteristics and inner setting. Respondents frequently discussed the significance of available resources (a construct of inner setting domain) in the implementation of the TWH HoC. Subthemes are relevant to determining factors (i.e., CFIR constructs) in the implementation of each of the five levels of controls.

3.2.1. Subtheme: The Eliminate Control Was Commonly Used and Trialed among All Organizations

The eliminate control was reported as commonly used by all organizations interviewed. Respondents shared numerous programs, policies, and practices that applied the eliminate control including:

- implementing company-wide tobacco-free policies,
- use of robots in material handling to eliminate occupational exposures to lifting heavy loads and use of awkward postures,
- elimination of sugar-sweetened beverages sold at the workplace,
- elimination of electric cords from floors to remove hazards for slips, trips, and falls,
- reductions in shiftwork rotations and hours to prevent work-related fatigue, and
- use of machine guarding to prevent traumatic injuries.

Relating to the trialability (a construct of the intervention characteristics domain) of the eliminate control, several organizations referred to a stepwise process, involving multilevels of controls that led to eliminating and reducing working conditions that threaten the safety, health, and well-being of workers. For example, Organizations B, E, and G referred to their efforts for eliminating unhealthy food and beverage options in the workplace through organizational policies and food service contracts.

> "[We] are eliminating sugary beverages from all facilities and [sites]. [They are] not an option anymore. [We] put in healthier beverages like flavored waters. We can teach you about how much sugar is in a soda, but now we're going to make that hazard nonexistent in [the] facility." [Organization G]

Concerning the CFIR inner setting domain, nearly all the organizations discussed a cultural perspective that concentrates on eliminating work conditions that could be threatening to employee safety and health, the first level of control.

> "When redesigning our headquarters building, a concrete example was our IT department collaborated with safety and health looking at trip hazard reduction. All our technology in conference rooms is now in the ceiling . . . That was undertaken from the safety committee to manage trip hazards, so that's an example of the philosophy permeating the organization. There's collaborating, and value placed to spend money on technology to put cords in the ceiling." [Organization B]

3.2.2. Subtheme: Adaptability and Resources Are Important in the Substitution of Unhealthy Working Conditions

In responses for using the substitute control for unhealthy working conditions or practices, most organizations referred to several health enhancing policies, practices, and programs including:

- healthy movement policies,
- access to an onsite psychologist,
- placement of healthier choices in workplace cafeteria, and
- use of a lift-assist device.

Often organizations suggested that substitution controls were adaptable to address threats to worker safety, health, and well-being. They reported the importance of the adaptability of the intervention (a construct of intervention characteristics domain) and dedicated resources (a construct of the inner setting domain) for successful intervention implementation. For instance, Organizations B and D discussed how they reduced worker injury risk by using physical resources (i.e., robots and adjustable furniture) to implement a substitution control.

> "The lift assist device is the people-powered version of the robot. During peak times, there are three stations where the individual has a pistol grip handle with air suction called an air assist device. Stick that handle on a box, pick up the box, turn, and place it on the conveyor. That's a substitute because it still means the

person moves the box, but the weight of the box to the individual is no more than 10 lbs." [Organization D]

3.2.3. Subtheme: The Redesign Control Was the Most Frequently Used Control and It Was Likely to Provide Both Quality and Advantage

The redesign control was the most widely discussed control among all five controls. Respondents provided several examples of the redesign control, including:

- a worker-tailored pacing program for production,
- health insurance based on salary,
- enhanced lighting for an aging workforce,
- upgraded facility for violence protection, and
- an onsite nap room for workers to re-energize during the workday or de-stress before leaving work.

Within the breadth of examples reported, relative advantage and evidence strength and quality (both constructs of the intervention characteristics domain) were the most relevant for the redesign control. For example, Organizations B and E each described how they have redesigned aspects of their facilities, leadership programs, and health benefit plans to improve the safety, health, and well-being of their workforce.

> "[We've completed a] redesign [of the] work [environment] for violence prevention. [We] don't have a higher risk than many other companies but take it seriously. [We] have interview rooms with exterior exits and [the] ability to be locked down, panic alarms, and bulletproof glass . . . We've done physical redesign for violence prevention and response, education with that, and [a] thoughtful approach for eliminating those hazards." [Organization B]

> "I mentioned our benefit plan being redesigned to value-based insurance design. [We offer] free medications and supplies for diabetics. [We redesigned healthcare] premiums based on salary. [The] health savings account contribution from [the] employer [is] now based on salary—[the] less you earn, [the] more you get from [the] employer." [Organization E]

3.2.4. Subtheme: The Education Control Offers Advantage by Coupling with Other Organizational Efforts

The education control was the second most discussed control among organizations interviewed. The education control was often discussed as a method to complement other controls for addressing workplace conditions that threaten the safety, health, and well-being of workers rather than as a method to solely address hazardous working conditions. The combined use of the education control with other organizational efforts that protect worker safety, health, and well-being refers to the control's relative advantage (a construct of the intervention characteristics domain). Reported programs and practices included:

- training for supervisors and leaders that aims to reduce work-related stress among workers,
- health risk appraisals accompanied by health education,
- tobacco cessation training,
- corporate athlete programs, and
- onsite teaching of yoga and mindfulness meditation retreats for workers.

Organizations A, B, and E discussed supervisory-focused trainings that educate leaders on their influence on worker's health and safety and empowering leaders to access available resources (a construct of the inner setting domain) for high-risk workplace situations.

> "[There has been] a big movement to educate supervisors on their role holistically, not just [the] HR aspects of being a supervisor. Often, people are promoted to supervisory positions and haven't had experience supervising . . . That impacts psychological safety and creating [safe] work environments and overall total worker health." [Organization A]

3.2.5. Subtheme: An Organizational Culture Built around Healthier Choice Making Underscores the Encourage Control

Organizations provided a myriad of programs and practices to encourage workers to make personal changes to their health, safety, and well-being both on and off the job. These supports included:

- employee recreational equipment to use during breaktime and meetings,
- special interest groups and outdoor clubs,
- encouraging civility in the workplace,
- health coaching offered through employee assistance programs (EAP), and
- periodic health-related workplace campaigns.

Inner setting domain constructs of culture, implementation climate, and readiness for implementation are likely key determinants for the encourage control. Organizations B, C, G, and F discussed the importance of the encourage control and suggested that there can be degrees of organizational influence within the encourage control and healthy choice making can be built within the organizational culture.

> "This year on the 75th anniversary of [our company] credo, [we] updated the credo. [It's] very much a part of who we are. It's at the front door of every building we operate in and we added our commitment to employee well-being. Safety had been in there, but we added employee health and well-being. It's a huge statement to have something at that level." [Organization G]

3.3. Theme 3: Barriers and Facilitators in Addressing Specific Work-Related

The inner setting domain was a notable determining factor when discussing organizational programs, practices, or policies that address the work-related issues of sleep and fatigue, tobacco use, and sedentary work. Among these three issues of concern, each indicated unique inner setting domain constructs. Culture and available resources were highlighted as important inner setting domain constructs for work-related sleep and fatigue, tobacco control, and sedentary work, whereas planning and engaging (constructs of the implementation process domain) were discussed as important factors in the application of programs, policies, and practices that address work-related stress.

3.3.1. Subtheme: Leadership Engagement, Available Resources, and Access to Information Are Possible Facilitators or Barriers for Organizational Efforts That Focus on Work-Related Fatigue and Sleep

The redesign, education, and encourage controls were used to address work-related sleep and fatigue among the organizations. Organizations described their approaches for addressing work-related sleep and fatigue through a lens of injury prevention and worker health. Organizations provided numerous examples of programs, policies, and practices that addressed work-related sleep and fatigue. These included:

- limited work hours during peak seasons,
- access to onsite nap programs and quiet rooms,
- engaging leadership in encouraging frequent rest and stretch breaks,
- peer support,
- worker training and education,
- providing flexible work schedules, and
- offering sleep care benefits through healthcare plans.

Among the CFIR domains, intervention characteristics and inner setting are likely determining factors for implementing work-related sleep and fatigue interventions. Readiness for implementation (an inner setting construct) was key as respondents referred to the importance of leadership engagement, available resources, and access to knowledge and information in their examples of controls that address work-related sleep and fatigue. For example, Organization F discussed their plans for how they were addressing sleep and fatigue related to shiftwork.

> "At the beginning of next year, [we are] looking at different dimensions of [fatigue]. Times to start and stop shifts, maximum number of working hours, minimum rest time between shifts, fatigue education and training . . . Our initial focus was on shift workers, but everyone can be fatigued." [Organization F]

The relative advantage and complexity (constructs of the intervention characteristics domain) of eliminating or reducing shift work was addressed by a few of the organizations. Organizations C, D, and F described to how they are redesigning their work environment to reduce fatigue and shiftwork among higher-risk jobs by rotating or reducing staff and hours of shiftwork. Their approaches are combined with policies and onsite resources (i.e., nap room and training) that encourage fatigue management.

> "We need a place for someone to come [to sleep], [if for] whatever reason, you don't sleep and are tired. No matter what you do, you need sleep. [Workers] are sleeping [at work] for 30–40 min. We're accepting that behavior and condoning it if we do nothing because we know it exists . . . [we] just implemented [our napping program] this month." [Organization C]

Organizations E and G briefly discussed the complexity within their organization for addressing work-related sleep and fatigue.

> "There has been work [to address work-related sleep and fatigue], but it's complicated. [One of our states] has a 2.4% unemployment rate. We're up against workforce challenges. Some people really prefer the 12 h shift. It gives them additional time 'off'. It's an interesting challenge." [Organization E]

3.3.2. Subtheme: Culture and Available Resources Were Indicated as Important Supports for Organizational Tobacco Control Efforts

Six of the seven organizations interviewed had tobacco-free policies, addressing the elimination control. Some organizational policies emphasized tobacco-free requirements on all property, including vehicles, and prohibited use of electronic cigarettes. Education and encourage controls were used by most organizations and used in concert among organizations that had organization-wide tobacco-free policies. Culture and available resources (constructs of the inner setting domain) were prominently reported for tobacco control among many of the organizations interviewed. Organizations D, E, F, and G discussed how they encourage a tobacco-free culture of health for workers while they are at work and away from work using multi-level controls.

> "Tobacco control [has] a global policy. [We] used to have policies by location, [but] now there's a global policy with smoke free requirements across all sites. [Our] latest position was to include e-cigarettes in this . . . Education is always available . . . [we] subsidize medications for tobacco cessation." [Organization F]

3.3.3. Subtheme: Organizational Culture and Available Resources Were Suggested to Provide Multi-Level Efforts for Addressing Sedentary Work

Among all seven organizations interviewed all five levels of controls were stated for addressing sedentary work. Organizations addressed sedentary work using a multi-faceted approach versus single approach and included numerous programs, practices, and policies at each level of the TWH HoC. These included:

- consultations focused on the principles of ergonomics applied to work environments,
- sit-stand workstations,
- time during work hours for physical activity,
- healthy movement policy,
- enhanced stairwells to encourage use,
- walking meetings,
- access to indoor and outdoor walking trails, and
- on-site and off-site recreation activities.

The redesign control was the most discussed control for addressing sedentary work. Redesigning the work environment to address sedentary work was often perceived as eliminating the working conditions that threaten the safety and health of workers and aligned with a work-related risk assessment. Organizations B and E discussed how they addressed sedentary work by redesigning the work environment with an underlying aim to reduce or eliminate work-related hazards.

> "We took our corporate headquarters with 800 employees and built a new facility [and] significantly remodeled all spaces . . . There were opportunities to incorporate in our design process . . . using TWH principles. Our office furniture is standardized to electric sit-stand desks . . . Eliminating some of the working conditions for sedentary work was a significant risk for us [to address]." [Organization B]

When organizations discussed their approach for addressing sedentary work, aspects of the inner setting domain were prominent. Constructs included implementation climate (i.e., culture) and readiness for implementation (i.e., available resources and leadership engagement). For example, Organizations G and F discussed how the culture of the organization supports their multi-level efforts for encouraging choices for healthy movement throughout the workday.

> "[We have] things like indoor walking trails and efforts to make stairwells improved. Healthy movement policy is a lot of elements so the whole environment coaxes you to make the right choice . . . Culturally, from the CEO level down, being active and taking time to workout isn't seen as evil . . . We're putting our energies and having the cultural support to go in the right direction." [Organization G]

3.3.4. Subtheme: Implementation Process Was a Likely Facilitator or Barrier for Organizational Efforts That Prevent Work-Related Stress

The eliminate control was not used as a control to address work-related stress in any of the organizations. The controls of substitution, redesign, educate, and encourage were among several controls reported to be used by organizations to address work-related stress. Organizations reported other strategies to address work-related stress that aligned with principles of a TWH approach, such as listening to workers to address their needs. Various programs, policies, and practices to address work-related stress included the use of an onsite psychologist, instruction of meditation and/or yoga, use of employer assistance programs, and leadership and worker resiliency training. Mental health promotion, resilience building, emotional intelligence, psychological safety, emotional well-being, and harassment and violence prevention were other terms used when asked to discuss approaches for addressing work-related stress. Often, the referenced controls that addressed work-related stress were concurrently used to address other work-related conditions, such as fatigue and sleep, productivity, and violence prevention.

Though organizations were at different stages of development for addressing work-related stress, respondents commonly referred to planning, engaging, and reflecting and evaluating (constructs of the implementation process) when discussing their approaches for addressing work-related stress. For example, Organizations A, E, F, and G talked about the use of external change agents to influence executive decisions on policy, organization-wide listening tours, individual risk assessments coupled with health education, and job-specific and company-wide surveys for planning organizational programs to address work-related stress.

> "Regarding work-related stress, [we] use a validated tool to identify work groups to identify [stressors] and remove stress hazards from the workplace . . . They work to remove the stressors and eliminate them. When [it is] not possible to remove, they change them. Change the decision-making process, [change the] amount of work, decide how to do it in a different way, [or] redesign." [Organization F]

Relevant to the construct of engaging, Organizations C, D, F, and G discussed the use of training programs at the levels of leadership and workers for addressing work-related stress.

> "Have training for employees and leaders because they need to understand stress differently. Especially leaders need to understand the role they have in causing or creating stress for workers." [Organization F]

3.4. Theme 4: Implementation Climate Primes Benefits and Obstacles

The inner setting domain was notable considering the experienced benefits, obstacles, and lessons learned reported by organizations using an approach consistent with a TWH approach. The implementation climate was a pervasive construct (of the inner setting domain) throughout the respondents' discussions on benefits, obstacles, and lessons learned.

3.4.1. An Existing Implementation Climate Supports the Benefits Experienced

Relevant implementation climate sub-constructs discussed for benefits experienced by organizations included relative priority, compatibility, and organizational rewards and incentives. In terms of relative priority (i.e., perceived importance of implementation), respondents discussed the TWH approach as a useful way to leverage plans that addressed worker well-being through their organizational safety strategy.

> "Focus on how we stop killing people, then worry about wellness. Because of the credibility and foundation of [the TWH] approach, we incorporated wellness, and I would say that wellness programs are being developed in every single [unit] in the [organization]. I couldn't have gotten this started. It helped going through the safety route to get wellness in." [Organization A]

Concerning compatibility, respondents referred to the TWH approach as a tool that provided a common language that could be understood across the entire organization.

> "We're decentralized. Having [a] national tool with common language was helpful. For me calling each [unit and saying], you need to do this wellness stuff wouldn't work for everyone. People use different language for it." [Organization A]

Concerning organizational rewards and incentives, an organization's demonstrated commitment to worker safety and health serves as a means for recruitment and retention.

> "It's helpful in recruitment as an employer of choice. [We] have people who apply for multiple jobs and work to get in the door. The culture with us being a mission-driven organization, we frequently hear the phrase we 'walk the talk'. This is part of us doing that. [A] benefit [of the TWH approach] is contributing to positive culture. [We] have amazing longevity and retention with our employees." [Organization B]

3.4.2. Subtheme: Lack of Implementation Climate and Absence of Readiness for Implementation Were Indicated as Obstacles

Implementation climate and readiness for implementation were notable constructs described by most organizations when discussing obstacles in implementing interventions relevant to TWH. Demonstrating the need for and importance of intervention implementation to leadership and to individual workers was prominently discussed as a barrier by most of the organizations. This is pertinent to leadership engagement (a sub-construct of readiness for implementation) and relative priority (a sub-construct of implementation climate construct). These constructs relate to leadership commitment for the implementation of the intervention and the shared perceptions of the importance of the intervention implementation within the organization. Organization C described challenges of first convincing workers to buy-in to the intervention.

> "Naysayers. You could give a [worker] a gold bar, and they'll complain about how heavy it is . . . Yoga was [seen as being] implemented passive aggressively at

> first with the mentality that you can go to yoga or [go to work]. You'll take all the [work] calls [instead of yoga]. That was at first. Now they love it." [Organization C]

Organizations A and F described cautions to consider for preparing the implementation climate (a construct of inner setting domain) as it relates to engaging leadership and setting goals to ensure the long-term sustainability of the intervention.

> "We set bold, audacious goals, but we're mindful of not letting us go too far into every issue in the company. [You] have to be realistic and caution what's really doable—making sure you think long-term but being realistic in what you can really do. Plan for what comes next." [Organization F]

Securing consistent leadership engagement for the intervention by demonstrating cost value of the investment in the long-term safety, health, and well-being of workforce was discussed as underlying obstacle among Organizations C, D, and G.

> "We have the data, but operating centers don't see [a] cost reduction. Executive team needs to know what we're doing and [the] benefits of it. [The benefit] doesn't always translate across leadership." [Organization D]

> "[You] need to show broad value. It's too simple to say, 'I have an ROI.' When we talk about recruitment, retention, and reputation, defining and measuring that is really hard. It's a challenge and requires a lot of data management which is hard . . . Sometimes a challenge is understanding that it can't be a 1–2-year investment. It can't be a quick hit and get a benefit . . . [We have to] keep leaders reminded of [this time investment]." [Organization G]

While Organization C recognized money and naysayers as obstacles for starting the intervention, they noted the importance of creativity at the early stages of intervention implementation.

> "Don't let money be a deciding factor in initial stages of developing and innovating. Money doesn't exist at those initial conversations. Budgets are budgets. Don't let money be a blocker." [Organization C]

3.4.3. Subtheme: Organizational and Leadership Commitment Were Discussed as Lessons Learned for Successful Implementation of Organizational Interventions

Implementation climate and readiness for implementation were the most relevant inner setting domain constructs among all organizations when discussing lessons learned in developing organizational interventions consistent with a TWH approach. Leadership engagement (a sub-construct of readiness for implementation domain) was the most notably discussed construct among all the organizations. Despite leadership changes, Organizations E and F reported commitment for the implementation of their interventions was maintained through company-wide goals.

> "One thing to consider is, to actually be able to implement TWH, it has to be a company priority. We are lucky because it's a company 2025 goal. We have that frame. If we were just new to this initiative, it might not go as far. It has to be a company priority." [Organization F]

Amidst gaining leadership commitment and workers' buy in, Organizations B and C, which had less mature programs, discussed an important underlying theme of tension for change (a construct of the inner setting domain) for getting their programs started.

> "It was getting that leadership commitment. Don't give up, it might take some time. Make sure employees are engaged and know what it's all about." [Organization B]

Several organizations discussed the importance of aligning the intervention to a systems issue to gain the attention of leaders, or compatibility (a construct of the inner setting domain).

> "By focusing on systems and environmental issues, [we avoid] the tendency to focus on folks at the individual intervention level versus restricting the café contract. I think that having that awareness and being prepared to look at it in that broader system, what are we doing as an organization? Clarifying that role is different from a traditional wellness program. That being effectively communicated is the biggest challenge to leadership support and employee buy-in." [Organization B]

Other inner setting domain constructs discussed as experiences gained from implementing an approach consistent with TWH included networks and communication, culture, goals and feedback, and relative priority.

> "[You] can't do it alone. That's key. Partnering with stakeholders—it's about creating synergies and getting people excited about a culture shift or approach. We've been focused on partnering and ensuring that we include our HR partners, [staff] leaders, and risk and safety [personnel] . . . Let's learn from one another." [Organization E]

4. Discussion

This exploratory, qualitative study sought to investigate how the principles of the Hierarchy of Controls Applied to NIOSH Total Worker Health have been applied and implemented in select employment organizations in the USA, with a special focus on the work-related issues of fatigue and sleep, work-related stress, sedentary work, and tobacco control. Due to the nature of the study, these findings cannot be generalized beyond this small study population. However, this study provided experiential insight into how U.S. organizations are implementing an integrated approach for worker safety, health, and well-being during the study period. Using CFIR to conduct a thematic analysis of in-depth interviews with program implementers from widely varied organizations, four themes were identified that suggested potential facilitators and barriers for implementation of the TWH HoC or other related guidelines in an organizational context.

These themes highlighted the potential significance of the inner setting (i.e., culture, implementation climate, and readiness for implementation) of organizations on the implementation of integrated worker safety, health, and well-being interventions. Additionally, the themes indicated that the characteristics of the interventions (i.e., intervention source, relative advantage, and adaptability) are important considerations for successful implementation of integrated work-related safety, health, and well-being interventions. Table 3 provides a summary of key results according to the levels of controls in the TWH HoC and work-related issues of special interest and highlights relevant themes. Overall, the practical significance of these findings draws from the need for an organizational culture that is supportive of Total Worker Health [27]. Further study using CFIR in its full context is needed to advance a more applied understanding of what factors influence the implementation of the TWH HoC among employment organizations.

These findings are consistent with Schult et al. [16] in that VA employees identified that organizational and structural elements effected employee safety, health, and well-being. The CFIR provided a useful framework for comprehensively examining organizational factors likely to influence the implementation of complex, integrated interventions that address worker safety, health, and well-being. Use of CFIR in the analysis of occupational safety and health innovations has been sparsely applied [6] and our study broadens the application of this framework to TWH policies, programs, and practices. Given the rapidly changing makeup of work, the workplace, and the workforce, these preliminary findings may serve as a building block for informing prospective studies and guidelines for designing programs, policies, and practices that align to the future of work.

Table 3. Summary of Key Results According to Levels of Controls in the Hierarchy of Controls Applied to NIOSH *Total Worker Health*® and Work-related Issues of Special Interest.

Level of TWH HoC	Examples of Implementation in Organizations	Relevant Themes
Eliminate	Implementing company-wide tobacco-free policies, use of robots in material handling to eliminate occupational exposures to lifting heavy loads and use of awkward postures, elimination of sugar-sweetened beverages sold at the workplace, elimination of electric cords from floors to remove hazards for slips, trips, and falls, reductions in shiftwork rotations and hours to prevent work-related fatigue, and, use of machine guarding to prevent traumatic injuries.	Most commonly used and trialed control amongst study popuation Use of stepwise process, involving multi-levels of controls leading to eliminating and reducing working conditions that threaten the safety, health, and well-being of workers Emphasis on cultural perspective that concentrates on eliminating work conditions that could be threatening to employee safety and health, the first level of control
Redesign	A worker-tailored pacing program for production, health insurance based on salary, enhanced lighting for an aging workforce, upgraded facility for violence protection, and an onsite nap room for workers to re-energize during the workday or de-stress before leaving work.	Most frequently used control Use of redesign control focused on relative advantage and evidence strength and quality
Substitute	Healthy movement policies, access to an onsite psychologist, placement of healthier choices in workplace cafeteria, and use of a lift-assist device.	Success of the substitute control is relevant to the adaptability of the intervention and dedicated resources
Educate	Training for supervisors and leaders that aims to reduce work-related stress among workers, health risk appraisals accompanied by health education, tobacco cessation training, corporate athlete programs, and onsite teaching of yoga and mindfulness meditation retreats for workers.	Offers an advantage by coupling with other organizational efforts Second most frequently used control
Encourage	Employee recreational equipment to use during breaktime and meetings, special interest groups and outdoor clubs, encouraging civility in the workplace, health coaching offered through employee assistance programs (EAP), and periodic health-related workplace campaigns.	Underscored by organizational culture built around healthier choice making Culture, implementation climate, and readiness for implementation are likely key determinants
Work-related Issue of Special Interest		
Sleep and Fatigue	Limited work hours during peak seasons, access to onsite nap programs and quiet rooms, engaging leadership in encouraging frequent rest and stretch breaks, peer support, worker training and education, providing flexible work schedules, and offering sleep care benefits through healthcare plans.	Leadership engagement, available resources, and access to information are possible facilitators or barriers Redesign, education, and encourage controls were most commonly used
Sedentary Work	Consultations focused on the principles of ergonomics applied to work environments, sit-stand workstations, time during work hours for physical activity, healthy movement policy, enhanced stairwells to encourage use, walking meetings, access to indoor and outdoor walking trails, and on-site and off-site recreation activities.	Organizations addressed using a multi-faceted approach versus single approach Redesign control was the most discussed

Table 3. *Cont.*

Work-related Issue of Special Interest		
Tobacco Control	Organizational-wide tobacco-free policies, policies that emphasize tobacco free requirements on all property, including vehicles, prohibited use of electronic cigarettes, and education and encourage tobacco cessation at work and away from work	Culture and available resources were indicated as important supports for organizational tobacco control efforts Organizations commonly use of multi-level controls
Work-related Stress	Listening to workers to address their needs, use of an onsite psychologist, instruction of meditation and/or yoga, use of employer assistance programs, and leadership and worker resiliency training.	Implementation process a likely facilitator or barrier for organizational prevention efforts

Prior to this study, it was recognized that organizations are taking steps to apply principles of a TWH approach [12] and are implementing facets of the TWH HoC [15]. However, there was not a clear understanding of how organizations are implementing the TWH HoC or other related guidelines. These findings suggest that despite individual-level awareness of TWH-related guidelines, organizations of varying sizes and program maturity appeared prevention-focused, incorporated the tenets of TWH in their organizational efforts to address working conditions that threaten the safety, health, and well-being of their workforce, and sought to promote a culture of health in their workforce. These findings bear comparison of characteristics of the early adopter organizations including judicious innovation-decision, role models for other organizations, and communicate their subjective evaluation of the idea to their peer networks [25]. Further research is needed to understand the varying contexts of employment organizations and associate those contexts with characteristics of early adopter organizations.

Work-related issues of special interest in this study included fatigue and sleep, work-related stress, sedentary work, and tobacco control, as these topics were most requested from organizations seeking information from NIOSH. All participant organizations were applying multiple levels of controls to address these working conditions as well as several additional working conditions (i.e., workplace violence, access to healthy food, access to affordable healthcare, hazards related to work and workstation design). The participating organizations demonstrated numerous examples of how they individually and collectively applied all five levels of the TWH HoC to address potentially harmful conditions of work and work-related issues of concern.

In many instances, the participating organizations indicated they were applying multiple controls to address work-related issues (i.e., sedentary work, tobacco control, and sleep and fatigue) that threatened worker safety, health, and well-being, which is consistent with the Sorensen et al. [21] finding that implementation of integrated interventions occurs on a continuum. This is an intriguing early finding as it shows progressive use of methods by organizations, the complexities involved in implementing the TWH HoC in organizations, and that participating organizations did not demonstrate regression to the individual worker. Additionally, this finding suggests that the TWH HoC can serve as a model to guide decision-making related to the changing nature of work, changing workforce demographics, and the changing workplace. Tamers et al. [19] suggest a growing need for workers to concurrently manage the responsibilities present in their work and personal lives, and the TWH HoC model encourages a transdisciplinary approach for organizations faced with this consideration.

In their review of effectiveness of 38 TWH interventions, Anger et al. [15] found pairing of the levels of the TWH HoC and that pairing of the education and encourage controls were most common. The results of this study reinforced the idea that the description of the TWH HoC is not discreet and that further characterization of the TWH HoC is needed. Additionally,

research is needed to explore and evaluate organizational determinants of implementing interventions that comprehensively address worker safety, health, and well-being.

One of the major lessons learned from this study is related to the open invitation for unlimited key informants for a time-limited organizational interview of one hour in length. In the interviews with three or less participants, all the interview questions were able to be thoroughly discussed and each participant was able to contribute equally. However, in hour-long interviews with more than three participants, the data collection was limited by time which did not permit the sharing of perspectives from all participants and more in-depth inquiry. As we consider future qualitative studies using semi-structured interviews with more than three key informants from an organization, the allotted time for the interviews would need to expand.

This study is limited by several factors. First, the sample size was small (n = 7), thus limiting the generalizability of the research. However, the small sample size provided an opportunity for a more thorough analysis of implementation of principles consistent with the TWH approach across seven organizations that varied widely according to industry, size, and program maturation. Second, because this is an exploratory study and data were limited to hour-long interviews, the entirety of each organization's safety, health, and wellness or well-being programs was not investigated. Third, all five domains of the CFIR were not examined. Because the CFIR was used for analysis and not part of the data collection, only certain domains were relevant to this study. Fourth, the definitions for the TWH HoC are not discreet. In many instances, the respondents would provide examples of controls that often were characterized differently than the interviewers would characterize and are likely reflected in coding and interpretation of findings. Lastly, we did not collect information about possible gender and/or ethnic differences in the organizations studied. We have no information about how these differences may have impacted the outcome.

5. Conclusions

This exploratory study addresses an important gap in the field of TWH by providing a preliminary and practical understanding into how early adopter organizations of various sizes and sectors have applied principles consistent with the TWH approach. The study provided insights to assess and understand the potential strength of organizational factors that impact the implementation of integrated interventions that address worker safety, health, and well-being. These insights go beyond the knowledge gained from the more common approach of looking solely at whether TWH guidelines, such as the TWH HoC, are implemented. Use of the Consolidated Framework for Implementation Research to identify potential determining factors produced information on the facilitators, obstacles, and lessons learned by organizations during the implementation process.

This knowledge can be used in the future to develop more targeted guidance for employers as they seek to address worker safety and health and enhance worker well-being. Based on the knowledge gained from applying this novel methodology to the TWH approach, more rigorous, qualitative, and mixed methods research is needed to better understand how organizations adopt and implement interventions that promote and sustain worker well-being. Such understanding will become more urgent as work, the workplace, and the workforce rapidly evolve into a new, unknown future.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Descriptions of Consolidated Framework for Implementation Research (CFIR) Domains and Constructs Applied to Total Worker Health.

Domain Primary Contextual Factors That Influence Implementation Effectiveness	Constructs Meta-Theoretical Factors That Help to Explicate Implementation	Application to Study
Intervention Characteristics	Intervention Source	Perception by key implementation leaders that the intervention (TWH HoC or TWH-related approach) was internally or externally developed. Relates to awareness of TWH.
	Evidence Strength & Quality	Perceptions of implementers of the efficacy of TWH-related interventions on improved worker safety and health outcomes and organizational outcomes.
	Relative Advantage	The alternative is not applying an integrated TWH approach or TWH HoC. This may vary according to OSH issue and/or organization.
	Adaptability	TWH HoC or TWH-related approach can be adapted or refined to meet the safety, health and well-being needs of workers and the organizational priorities.
	Trialability	The ability of the TWH HoC or TWH-related approach to be piloted or de-implemented if warranted.
	Complexity	Perceived difficulty of implementing TWH HoC by the key implementation leaders. Interview Question
	Design Quality and Packaging	Perceived excellence by key implementation leaders in how the TWH HoC or TWH-related approach is packaged.
	Costs	Costs associated with implementing the TWH Hoc or TWH-related approaches in the organization including investment, supply, and opportunity costs.
Outer Setting	Worker Community Needs & Resources	The extent to which worker's community and family's needs, as well as barriers and facilitators to meet those needs, are accurately known and prioritized for the organization.
	Cosmopolitanism	The degree to which the organizations are networked with other external organizations
	Peer Pressure	Competitive pressure to implement TWH HoC or TWH-related approaches because most other key peer organizations have already implemented/competitive edge.
	External Policy & Incentives	Other national recommendations, policies, or reporting benchmarks that address the safety, health, and well-being of workers (i.e., OSH VPP program)

Table A1. *Cont.*

Inner Setting	Structural Characteristics	The social architecture, age, maturity, and size of an organization. Part of the demographic characteristics collected in the sampling
	Networks & Communication	The nature and quality of webs of social networks and the nature and quality of formal and informal communications within an organization. This relates to the interactions and integration among different organizational units responsible for the safety, health, and well-being of its workforce.
	Culture	Norms, values, and basic assumptions of a given organization—especially in relation to the worker safety and health culture.
	Implementation Climate	The absorptive capacity for change, shared receptivity of involved individuals to TWH-related interventions or the TWH HoC, and the extent to which use of TWH-related approaches will be rewarded, supported, and expected within their organization.
	Tension for Change	The degree to which the key implementers believe the current situation as intolerable or in need of change.
	Compatibility	The degree of tangible fit between meaning and values attached to the TWH HoC or TWH related approaches by key implementers, how those align with individuals' own norms, values, and perceived risks and needs, and how the TWH HoC or TWH-related approaches fits with existing workflows and systems
	Relative Priority	Key implementers shared perception of the importance of the TWH HoC or TWH-related approach within the organization.
	Organizational Incentives & Rewards	Extrinsic incentives such as goal-sharing awards, performance reviews, promotions, and raises in salary, and less tangible incentives such as increased stature or respect.
	Goals and Feedback	The degree to which goals are clearly communicated, acted upon, and fed back to staff, and alignment of that feedback with goals.
	Learning Climate	A climate in which: (a) leaders express their own fallibility and need for team members' assistance and input; (b) team members feel that they are essential, valued, and knowledgeable partners in the change process; (c) individuals feel psychologically safe to try new methods; and (d) there is sufficient time and space for reflective thinking and evaluation.
	Readiness for Implementation	Tangible and immediate indicators of organizational commitment to its decision to implement the TWH HoC or TWH-related approach.
	Leadership Engagement	Commitment, involvement, and accountability of leaders and managers with the implementation.
	Available Resources	The level of resources dedicated for implementation and on-going operations, including money, training, education, physical space, and time.
	Access to Knowledge Information	Ease of access to digestible information and knowledge about the TWH HoC or TWH-relate intervention and how to incorporate it into work tasks.

Table A1. *Cont.*

Characteristics of Individuals	Knowledge & Beliefs about Intervention	Key implementation leader's attitude toward and valued placed on the TWH HoC, as well as familiarity with facts, truths and principles related to the intervention.
	Self-efficacy	Key implementers belief in their own capability to execute course of action (i.e., TWH HoC) to achieve implementation goals (i.e., improved worker safety, health and well-being and organizational outcomes).
	Individual Stage of Change	Key implementer's characterization of the phase they are in the implementation of the HoC or TWH-related intervention.
	Individual Identification with Organization	Describes how the key implementers perceive the organization and their relationship and degree commitment with that organization.
	Other Personal Attributes	Personal traits of the key implementer (i.e., competence, capacity, motivation, values, tolerance of ambiguity)
Implementation Process	Planning	The degree and quality to which the organization has developed an approach to implement the TWH HoC or related intervention
	Engaging	The degree to which the organization has appointed people to lead the implementation of the TWH HoC or related approach and use a combined strategy to implement in the organization (i.e., social marketing, training, role modeling, education).
	Opinion Leaders	Individuals who have formal or informal influence on the attitudes and beliefs of their colleagues with respect to implementing the TWH HoC or TWH-related intervention
	Formally Appointed Opinion Leaders	Individuals from within the organization who have been formally appointed with responsibility for implementing an intervention as coordinator, project manager, team leader, or another similar role.
	Champions	Individuals who dedicate themselves to supporting, marketing, and driving through an implementation.
	External Change Agents	Individuals who are affiliated with an outside entity who formally influence or facilitate intervention decisions in a desirable direction
	Executing	The degree to which the organization's TWH-related intervention was carried out according to plan.
	Reflecting and Evaluating	Feedback (qualitative and quantitative) about the progress, experience, and quality of implementing the TWH HoC or TWH-related approach. This relates to an interview question.

References

1. McLellan, D.; Moore, W.; Nagler, E.; Sorensen, G. *Implementing an Integrated Approach: Weaving Worker Health, Safety, and Well-Being into the Fabric of Your Organization*; Harvard, T.H., Ed.; Chan School of Public Health, Center for Work, Health and Well-Being: Boston, MA, USA, 2017. Available online: http://centerforworkhealth.sph.harvard.edu/resources/guidelines-implementing-integrated-approach (accessed on 8 March 2021).
2. Lee, M.P.; Hudson, H.; Richards, R.; Chang, C.C.; Chosewood, L.C.; Schill, A.L.; on behalf of the NIOSH Office for Total Worker Health. *Fundamentals of Total Worker Health Approaches: Essential Elements for Advancing Worker Safety, Health, and Well-Being*; NIOSH: Cincinnati, OH, USA, 2017.
3. Robertson, M.; Henning, R.; Warren, N.; Nobrega, S.; Dove-Steinkamp, M.; Tibirica, L.; Bizarro, A.; the CPH-NEW research team. The intervention design and analysis scorecard. *J. Occup. Environ. Med.* **2013**, *55*, S86–S88. [CrossRef] [PubMed]
4. National Institute for Occupational Safety and Health (NIOSH). Hierarchy of Controls. 2015. Available online: https://www.cdc.gov/niosh/topics/hierarchy/default.html (accessed on 7 April 2021).

5. NIOSH. Hierarchy of Controls Applied to NIOSH *Total Worker Health*®. 2020. Available online: https://www.cdc.gov/niosh/twh/guidelines.html (accessed on 7 April 2021).
6. Cunningham, T.R.; Tinc, P.J.; Guerin, R.J.; Schulte, P.A. Translation research in occupational health and safety settings: Common ground and future directions. *J. Saf. Res.* **2020**, *74*, 161–167. [CrossRef] [PubMed]
7. Hudson, H.L.; Nigam, J.A.S. Future directions and opportunities for Total Worker Health. In *Total Worker Health*, 1st ed.; Hudson, H., Nigam, J., Sauter, S., Chosewood, L.C., Schill, A., Howard, J., Eds.; American Psychological Association: Washington, DC, USA, 2019; pp. 295–309. [CrossRef]
8. Dugan, A.G.; Punnett, L. Dissemination and implementation research for occupational safety and health. *Occup. Health Sci.* **2017**, *1*, 29–45. [CrossRef] [PubMed]
9. Estabrooks, P.A.; Brownson, R.C.; Pronk, N.P. Dissemination and implementation science for public health professionals: An overview and call to action. *Prev. Chronic Dis.* **2018**, *15*, E162. [CrossRef] [PubMed]
10. Punnett, L.; Cavallari, J.M.; Henning, R.A.; Nobrega, S.; Dugan, A.G.; Cherniack, M.G.; CPH-NEW Research Team. Defining 'integration' for *Total Worker Health*®: A new proposal. *Ann. Work Expo. Health* **2020**, *64*, 223–235. [CrossRef] [PubMed]
11. Schulte, P.A.; Cunningham, T.R.; Nickels, L.; Felknor, S.; Guerin, R.; Blosser, F.; Chang, C.C.; Check, P.; Eggerth, D.; Flynn, M.; et al. Translation research in occupational safety and health: A proposed framework. *Am. J. Ind. Med.* **2017**, *60*, 1011–1022. [CrossRef] [PubMed]
12. Bradley, C.J.; Grossman, D.C.; Hubbard, R.A.; Ortega, A.N.; Curry, S.J. Integrated interventions for improving total worker health: A panel report from the national Institutes of health Pathways to prevention workshop: Total worker health—what's work got to do with it? *Ann. Intern. Med.* **2016**, *165*, 279–283. [CrossRef] [PubMed]
13. Tamers, S.L.; Goetzel, R.; Kelly, K.M.; Luckhaupt, S.; Nigam, J.; Pronk, N.P.; Rohlman, D.S.; Baron, S.; Brosseau, L.M.; Bushnell, T.; et al. Research methodologies for *Total Worker Health*®: Proceedings from a workshop. *J. Occup. Environ. Med.* **2018**, *60*, 968–978. [CrossRef] [PubMed]
14. Schill, A.L. Advancing well-being through total worker health. *Workplace Health Saf.* **2017**, *65*, 158–163. [CrossRef] [PubMed]
15. Anger, W.K.; Rameshbabu, A.; Olson, R.; Bodner, T.; Hurtado, D.A.; Paker, K.; Wan, W.; Wipfli, B.; Rohlman, D.S. Effectiveness of total worker health interventions. In *Total Worker Health*, 1st ed.; Hudson, H., Nigam, J., Sauter, S., Chosewood, L.C., Schill, A., Howard, J., Eds.; American Psychological Association: Washington, DC, USA, 2019; pp. 61–89.
16. Schult, T.M.; Nagler, E.M.; Sorensen, G.; Sullivan, J.L.; Gendreau, N.; Seibert, R.G.; Mohr, D.C. Perceptions of safety, health, and well-being: Focus group findings from one veterans affairs medical center. *J. Occup Environ. Med.* **2018**, *60*, e582–e588. [CrossRef] [PubMed]
17. Baron, S.; Tsui, E.K.; Cuervo, I.; Islam, N. Community health programs: Promising practices and opportunities for expanding total worker health. In *Total Worker Health*, 1st ed.; Hudson, H., Nigam, J., Sauter, S., Chosewood, L.C., Schill, A., Howard, J., Eds.; American Psychological Association: Washington, DC, USA, 2019; pp. 193–208.
18. Roelofs, C. Employer preparedness: A *Total Worker Health*® conceptual framework and model. *Preprints* **2020**, 2020120535. [CrossRef]
19. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
20. Sorensen, G.; Sparer, E.; Williams, J.A.R.; Gundersen, D.; Boden, L.I.; Dennerlein, J.T.; Hashimoto, D.; Katz, J.N.; McLellan, D.L.; Okechukwu, C.A.; et al. Measuring best practices for workplace safety, health, and wellbeing: The workplace integrated safety and health assessment. *J. Occup. Environ. Med.* **2018**, *60*, 430–439. [CrossRef]
21. Sorensen, G.; McLellan, D.L.; Sabbath, E.L.; Dennerlein, J.T.; Nagler, E.M.; Hurtado, D.A.; Pronk, N.P.; Wagner, G.R. Integrating worksite health protection and health promotion: A conceptual model for intervention and research. *Prev. Med.* **2016**, *91*, 188–196. [CrossRef]
22. NIOSH. Promising Practices for Total Worker Health. 2020. Available online: https://www.cdc.gov/niosh/twh/practices.html (accessed on 7 February 2021).
23. NIOSH. NIOSH Total Worker Health in Action! eNewsletter. 2020. Available online: https://www.cdc.gov/niosh/twh/newsletter/default.html (accessed on 7 February 2020).
24. Damschroder, L.J.; Aron, D.C.; Keith, R.E.; Kirsh, S.R.; Alexander, J.A.; Lowery, J.C. Fostering implementation of health services research findings into practice: A consolidated framework for advancing implementation science. *Implement. Sci.* **2009**, *4*, 50. [CrossRef] [PubMed]
25. Rogers, E. *Diffusion of Innovations*, 5th ed.; Free Press: New York, NY, USA, 2013; p. 283.
26. Tong, A.; Sainsbury, P.; Craig, J. Consolidated criteria for reporting qualitative research (COREQ): A 32-item checklist for interviews and focus groups. *Int. J. Qual. Health Care* **2007**, *19*, 349–357. [CrossRef] [PubMed]
27. NIOSH. NIOSH Total Worker Health Program. 2020. Available online: https://www.cdc.gov/niosh/twh (accessed on 7 February 2021).

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Article

Working Conditions Influencing Drivers' Safety and Well-Being in the Transportation Industry: "On Board" Program

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Abstract: The conditions of work for professional drivers can contribute to adverse health and well-being outcomes. Fatigue can result from irregular shift scheduling, stress may arise due to the intense job demands, back pain may be due to prolonged sitting and exposure to vibration, and a poor diet can be attributed to limited time for breaks and rest. This study aimed to identify working conditions and health outcomes in a bussing company by conducting focus groups and key informant interviews to inform a Total Worker Health® organizational intervention. Our thematic analysis identified three primary themes: lack of trust between drivers and supervisors, the scheduling of shifts and routes, and difficulty performing positive health behaviors. These findings demonstrate the value of using participatory methods with key stakeholders to determine the unique working conditions and pathways that may be most critical to impacting safety, health, and well-being in an organization.

Keywords: healthy work design and well-being; organizational design; healthy leadership; occupational stress; fatigue; bus driver; health promotion; Total Worker Health; focus groups; scheduling

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1. Introduction

Professional drivers, including bus, taxi, and long-haul truck drivers, experience higher rates of health issues compared to other occupations [1]. They suffer from acute and chronic health conditions at higher rates than the general working population, including increased risk of cardiovascular disease [2–4], obesity [5,6], and musculoskeletal disorders [1,7–10], and are more stressed [11,12]. Compared to the general population, professional drivers smoke more, consume higher amounts of alcohol, exercise less and access healthcare less [13,14]. Driver fatigue—caused by long shifts and tight schedules—has been found to result in a higher likelihood of accidents and fatalities on the road [15]. Irregular working schedules of professional drivers often impact their mental health, resulting in depression or anxiety [11,12].

It has been well established that work is a major determinant of health and well-being [16]. The working conditions professional drivers are exposed to day-to-day can have detrimental impacts on their safety, health, and well-being; and are characterized by high physical, psychosocial and organizational hazards, such as high workloads, the need for high levels of mental alertness, erratic and long work schedules, time pressures, exposure to chemicals such as fumes, disrupted sleep patterns, social isolation and loneliness, low job control, customer confrontations, as well as the standard risks of being a driver, such as the sedentary nature of driving, and the exposure to vibration through the seat of

the vehicle and steering wheel [11,17–24]. These risks have been linked with various health conditions and have long-term ramifications on the overall well-being of drivers. The pathways for worker injury and ill-health share common root causes through these conditions of work [25]. Interventions that focus on changing working conditions to improve drivers' safety, health and well-being are largely understudied, yet an important area of inquiry considering the large safety and health impacts that their work can expose them to. There is a shift in both research and practice in support of Total Worker Health® (TWH) interventions that integrate both health protection and health promotion to target the conditions of work through upstream organizational approaches—workplace policies, programs, and practices—to address health and well-being disparities [26]. The goal of TWH interventions are to create safer and healthier work and work environments and advance worker safet, health, and well-being.

Various professional bus driver occupations differ in how their working conditions manifest, based on how their work is structured and by the physical, cognitive, and psychosocial demands required of them. For example, long-haul bus drivers tend to experience longer work hours and monotonous driving conditions when compared with city bus drivers, while city bus drivers often handle a greater intensity of demands due to higher traffic density, more frequent stops, and stressful passenger interactions. Some types of drivers experience a combination of factors experienced by both long-haul and city bus drivers, such as those working as charter or interurban bus drivers. Interventions designed to improve the health of professional drivers must therefore consider the work organization and demands, and how these demands may differ depending on their job and organization.

While industry-specific guidance for professional drivers can elucidate potential risks to workers' occupational safety and health for an organization, the unique root cause for the many and varied safety, health, and well-being issues that drivers face can be difficult to precisely identify [4]. The determination of the root causes of risks to drivers' safety, health, and well-being can be facilitated by working with all stakeholders of the organization to gain a more complete understanding of the factors that might contribute to drivers' safety, health, and well-being using participatory methods. While quantitative surveys alone can be used to determine what is a strength or a challenge for an organization, they sometimes fail to provide the nuances needed to explain how working conditions, through an organization's unique pathways, influence drivers' health and safety behaviors, and their safety, health, and well-being [27]. Because of this, qualitative methods have been recognized as an effective tool to determine the factors that working conditions and other contextual factors have on workers' safety, health, and well-being [28]. These data can then be used for intervention development using participatory methods involving the organization. Previous research with construction workers [29], food service workers [28], and grocery store workers [30] has demonstrated the effectiveness of such an approach.

The significance of this study is twofold. First, the findings of this study will be used to inform and tailor the design of a *TWH* intervention; specifically, the identification of the content mechanisms or working conditions that will be the targets for the intervention, and how these are percieved to influence drivers' safety, health, and well-being. While it is part of a larger study that will develop and evaluate a TWH intervention—"*On Board Program*",this research is necessary as not all working conditions manifest in the same way in companies in the same sector due to their unique characteristics. This will become especially important in the future as workplaces continue to pivot and expand to meet new markets, technologies and demands, and accommodate challenges such as the COVID-19 pandemic, financial crises, or social or political unrest [31]. Using employer-centered participatory methods focusing on upstream integrated approaches has been found to be effective in improving workers' safety, health, and well-being [32,33]. Tailoring an intervention to fit the company is an important step to ensure its success and sustainability. This paper's significance is grounded in a description of how we used replicable qualitative methods to identify working conditions and develop a conceptual model to inform the

intervention design of the *On Board Program*; both researchers and practitioners may find this useful when developing *TWH* interventions. Second, there is little research on how working conditions can influence the safety, health, and well-being of drivers using a framework that considers the psychosocial work environment (e.g., supervisor support, coworker support, customer interactions, and isolation while on the road) and the organization of work (e.g., routes and scheduling and how these factors are intertwined to create considerable safety and health issues).

Thus, the purpose of this study was to (a) identify how working conditions influenced bus drivers' safety, health, and well-being using qualitative methods and (b) develop a unique organization-centered conceptual model of theorized pathways for this organization through which working conditions influence workers' safety, health, and well-being behaviors, and identify outcomes to be used in a future *TWH* intervention.

2. Materials and Methods

This study was the first phase of the *On Board Program* to develop a Total Worker Health® intervention for drivers' safety, health, and well-being. This intervention will later be implemented and evaluated in the second phase of this Project. The first phase of the *On Board Program* used qualitative methods based on grounded theory principles [34,35], and content analysis [36] to create an exploratory model to theorize how the conditions of work and work organizational factors influence drivers' safety, health, and well-being. Using these principles, one examines concepts and interrelationships between concepts to show how and why a phenomenon occurs—such as the relationship between working conditions and drivers' safety, health, and well-being. Capturing variability and trying to understand why variability exists was also important, lending itself to the grounded theory method.

Data were derived from two main sources: interviews with key company personnel and focus groups with drivers. These activities were conducted in late 2018. A model was then developed, based on analysis of these qualitative data.

2.1. Study Context

This study was conducted in collaboration with one medium-sized (450 drivers) privately owned bus transportation organization in Chile. This transportation company was selected because it was a customer of our Chilean collaborators Mutual de Seguridad, CChC, was one of two companies that had participated in research with academic collaborators previously, and its leadership had indicated an interest in implementing a TWH intervention aiming to improve the safety, health, and well-being of their drivers. The bus drivers were all employed by a single transportation organization located in a regional urban center. The organization was contracted by another company ("host company") to transport workers to a remote worksite. The contractual nature of the agreement between the two companies was renewed every 2–3 years for services to transport workers and sub-contractors of the host company to the remote worksite for multiple shifts daily. Thus, workers live in their own urban communities and are picked up before and dropped off after their work shift. Since the worksite is remote, drivers are exposed to roads that are unpaved and at altitude (>1500 m) for up to two hours each way. Drivers' work shifts are designed to accommodate the schedules of the workers such that, for example, drivers can deliver workers to the worksite before they start their shift (e.g., morning shift), and transport workers who are completing their shift (e.g., night shift) in a single round-trip. Drivers operate either large buses which transport up to 45 passengers per bus to the remote worksite or smaller buses up to 15 passengers, which shuttle employees within the remote worksite or provide concierge services for other employees.

2.2. Focus Groups with Drivers

All drivers at the bus organization were eligible to participate in a focus group, regardless of hours worked, tenure, or other factors. Drivers were recruited into the focus groups via

a sign-up process. Six focus groups with 6–9 drivers in each group were held; three of the focus groups were completed with drivers of the large passenger buses and three were completed with drivers of the small passenger buses. Focus groups were held in-person and conducted by an experienced qualitative researcher and focus group moderator following a structured focus group guide. The focus groups were conducted in Spanish. Questions were structured into four main sections focusing on (1) drivers' overall perspectives of their work, and their health, safety, and well-being; (2) specific outcomes of interest to the research team including job satisfaction and happiness, general health, absenteeism from work, job stress, musculoskeletal pain and injuries at work, and fatigue; (3) drivers' perspectives of working conditions that influenced their safety, health, and well-being and drivers' perceived priority areas; and, (4) barriers and facilitators to implementation of an organizational program to improve drivers' safety, health, and well-being.

Questions were designed to answer each research question by probing and asking about information in different ways (Table 1). For example, working conditions influencing drivers' safety, health, and well-being were captured by probing on how their work impacted various health and well-being concerns, as well as by asking questions directly related to their conditions of work. Each focus group took about an hour to complete.

Table 1. Examples of questions for the focus groups and key informant interviews.

Topic Area	Focus Group Questions	Key Informant Questions
Workers' perspectives of their work and key health, safety, and well-being outcomes	What do you enjoy most about your job? What do you enjoy least about your job? What are the main health and safety considerations that impact you on your job? What about your job contributes to your overall quality of life and well-being?	What do think the key priorities for safety of drivers are at <company>? Beyond safety, what other health and well-being priorities are important at <company>? What are the concerns for drivers with respect to their safety, health, and well-being?
Focus on specific safety, health, and well-being outcomes (job satisfaction and happiness, general health, absenteeism from work, job stress, musculoskeletal pain and injuries at work, and fatigue)	What contributes to your overall happiness at work? Do you think your general health is impacted by your job? How?What are some of the main reasons that people miss days at work? Are there things about your work that you find stressful? Do you think that stress affects your health and safety on the job? Are there parts of your body that ache/are painful that you think are caused by or made worse by your work? What aspects of your job contribute to your symptoms? How does your job affect how tired you get during the day?	Can you tell me more about how <outcome> impacts on drivers' safety, health, and well-being?

Table 1. *Cont.*

Topic Area	Focus Group Questions	Key Informant Questions
Working conditions influencing safety, health, and well-being	Thinking about your job, what are the working conditions that most impact your: - General health - Well-being Are there working conditions that make you feel unsafe at work?	While there are various ways to promote safety, health, and well-being, we want you to think broadly about how work is organized and managed here at <company>-how does the work environment influence drivers' safety, health, and well-being? We would like your unique perspective regarding systems already in place and how policies and practices support or promote drivers' safety, health, and well-being. Specific questions on working conditions were asked, e.g., what causes stress on the job? Are there aspects of the physical work environment that impact the drivers' safety, health, and well-being?
Perspectives on priority areas	From your perspective, what should be the top priority with respect to improving: - Worker well-being/ quality of life - Worker health - Worker safety	What types of policies, programs and practices do you see as beneficial in improving drivers' safety, health, and well-being?
Determine barriers and facilitators to intervention	What are the most important things to think about when trying to make positive changes in the workplace? What things could get in the way of making changes in your workplace?	Are there initiatives in place that could be built upon that you think could really make a difference? What do you see as the main challenges we might face in developing a program?

2.3. Key Informant Interviews

Semi-structured key informant interviews were conducted with company personnel who held key roles in the organization with respect to workers' health and safety or who had the power to enact change within the organization required for the implementation of the later intervention. These individuals held either management positions within the company or were union directors who represented the workers. In collaboration with the organization, researchers identified eight key informants to be interviewed. These included the company leadership, operations manager, safety managers, supervisors of the bus drivers, union directors, and a worker representative who participated in the company's safety meetings. Interviews with key informants were conducted in-person by the same moderator who completed the focus groups, and were conducted in Spanish. Questions were structured into similar topic areas as the focus groups (Table 1).

2.4. Data Analysis

The interviews and focus groups were conducted, audiotaped, and transcribed in Spanish. The transcriptions were then translated into English. The English transcripts were coded using NVivo software (Version 11, QSR International) and were then thematically analyzed [37]. We used a multi-stage coding process that included both predefined and emergent codes in a two-step process: we used a pre-defined coding tree based on the Harvard Center for Work, Health, and Well-being's conceptual model [8]. New codes were added inductively to the coding tree as new themes arose in the data. Codes were structured in the coding tree under the following 'parent codes' which included: working conditions (e.g., shifts, scheduling, vacations, routes, compensation, benefits, physical environment, psychosocial work environment, promotions), job demands (e.g., alertness,

workload, sedentary work), utilization of company resources and benefits (e.g., gym), safety (e.g., practices, regulations), worker health and well-being (e.g., mental health, stress, diet, chronic health conditions, health behaviors, fatigue/sleep), workers' life outside of work (e.g., financial stressors, second jobs), enterprise outcomes (e.g., absenteeism, tardiness). Some of these codes also had additional child (sub-)codes. For example, child codes in the 'psychosocial work environment' included: supervisor support, work–life/family balance, violence and harassment, relationships with colleagues, relationships with passengers, and communication. Relationships between codes were then mapped using the 'relationships function' in NVivo. This function in the more recent version 11 of NVivo allows the coding of a special type of 'relationship node' that provides a connection between two codes [38]. These relationships between codes can then be displayed visually using the relationship mapping function, in NVivo. For example, a relationship between specific working conditions and health outcomes can be mapped (e.g., shift schedules impact the distribution of shift; the distribution of shifts can result in some drivers being required to drive the more difficult routes which take longer to complete, more often; this can then result in driver fatigue due to limited time to rest and sleep; fatigued drivers have limited time to exercise and tend to select pre-packaged or fast food options; these poor health behaviors were reported to result in higher incidences of chronic health conditions). We used this relationship map–generated from NVivo–to create a map of themes (as displayed in Figure 1). From these data, we developed a model linking working conditions and other organizational factors with drivers' safety, health, and well-being.

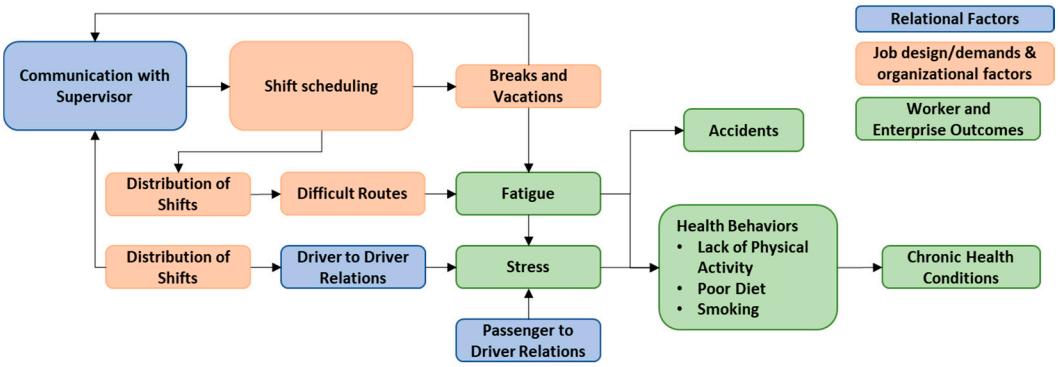


Figure 1. Map of Themes from Interviews and Focus Groups. Conditions of work captured by the relational (Blue), job demands, and organizational factors (Orange). Worker and Enterprise outcomes (Green) include the immediate proximal outcomes and the more distal downstream outcomes of accidents, health behavior, and chronic health issues.

3. Results

The analysis of the key informant interviews and focus groups resulted in overarching themes related to (a) working conditions—work relationships (supervisors, coworkers, and passengers), and organization of work (shifts, scheduling, and routes) and (b) health and well-being outcomes (fatigue, stress, health behaviors, chronic health conditions).

3.1. Work Relationships

3.1.1. Driver Relationships with Supervisors

Drivers and supervisors felt differently with respect to their relationship with each other: drivers generally felt that they had a poor relationship with their supervisors, whereas supervisors considered their relationships with drivers had improved in recent times. This tension was noted by some of the key informants who operated at higher management levels within the company. Drivers stated that it was difficult communicating with their supervisors, notably when reporting using the emergency "stop work" code when drivers identified hazardous conditions. This code could be used to indicate if there were poor road conditions, the driver was feeling tired, or any other emergency that the

driver was experiencing while on the road, and if called, another driver may even be called to take over their shift. Regarding utilizing this emergency code, a driver stated:

> *"The person (supervisors) does not even take his time to ask, for example, what happened to you, whether you are OK, to show concern, you'd better go home . . . you, see? Right away, the first thing, a grim face. . . . You (the driver) have to apologize, to say the least, because you are not in good condition, when it should be the other way around." (Driver)*

The shame of using the emergency code caused drivers to reconsider using the emergency code in the future. This led to an erosion of trust between the drivers and supervisors, something that the supervisors had been acutely aware of. Supervisors knew that drivers had feared retaliation due to reporting their concerns in the past. The supervisors had tried to improve the trust with their drivers, with one key informant stating:

> *"We are supporting the drivers, helping them, we have even communicated to them that if it is necessary for a service to arrive late, we are going to arrive late, the important thing is not to have accidents, not to put the driver or the passengers at risk." (Key Informant)*

Both drivers and supervisors stated that one of their main goals was to prevent drivers from driving tired, in unsafe conditions, or in an emergency. However, the lack of trust that the drivers had with the supervisors when reporting such situations inhibited effective communication between them. Supervisors and key informants both considered building this trust with their drivers as an important organizational goal that was currently not being adequately addressed. One key informant stated:

> *"Something is still lacking; we have to continue to work in building a climate of trust." (Key Informant)*

3.1.2. Relationships between Drivers

Drivers, with few exceptions, thought positively of one another. Despite the drivers working in isolation day-to-day, many considered their fellow drivers to be more than just coworkers; some considered them to be friends and there was a certain level of comradery among them:

> *"What I enjoy the most is comradeship. Here we share with our mates, we get together with different workmates, different people . . . it is very pleasant." (Driver)*

However, despite this comradery, some drivers who had different job titles did feel some resentment due to their differing job demands. Small bus drivers stated that they must make additional stops beyond their schedule to pick up and drop off passengers. When this occurs, the small bus drivers do not receive additional compensation, but large bus drivers had previously fought to receive additional compensation for similar circumstances and now receive it. The small drivers failed to receive additional compensation after requesting it, leading these drivers to believe that they were of unequal standing within the company compared to the large bus drivers. Ultimately, this impacted the small bus drivers' relationships with the large bus drivers and their supervisors. A small bus driver said the following:

> *"We are not considered at all. Not even when we've had meetings with them (supervisors), you can't talk, you can't say anything." (Driver)*

3.1.3. Drivers' Relationships with Passengers

Although drivers reported having generally good relationships with their passengers on a day-to-day basis, certain circumstances (such as passengers making special requests of the drivers), which occurred with regular frequency, caused additional challenges. This resulted in significant stress and additional pressures for the drivers. For example, drivers preferred cold air conditioning as it helped them stay awake during long shifts, but passengers would complain, requesting warm air as this helped them to sleep on their journey home after a long shift. Similarly, passengers often wished to be dropped off at a non-designated stop closer to their home, rather than at the authorized stop. This

could result in drivers making many undesignated stops in a shift and adding considerable time to an already long shift for the driver. Drivers felt uncomfortable dealing with these situations and being conflicted with appeasing the passengers and keeping the client company happy (avoiding complaints being made). Drivers reported that they were often disrespected if they did not comply with passenger requests:

> *"(The passengers) show the driver bad manners . . . lack of respect, say, lack of judgement toward the driver . . . that's stressful. Us drivers have a huge responsibility in the end." (Driver)*

3.2. Organization of Work

3.2.1. Breaks and Vacation Time

Drivers were provided with vacation time by their organization; however, drivers stated that they had few opportunities to use it. The drivers often attempted to use their vacation time by making a request many months in advance; however, it could be canceled on short notice due to the scheduling needs of their supervisors. Drivers stated that this resulted in their often using their sick leave to take a vacation:

> *"My wife works, and we never have vacations together. When she is on vacation I am working. And she says hey 'get'" a sick leave so that we have some days off. That is where sick leaves come from." (Driver)*

Many drivers considered the use of sick leave as their only method to gain sufficient rest or take vacations. As more people used sick leave for vacations, fewer drivers could take their preplanned vacations. The company leadership stated that they were aware of this issue, but it had proven to be difficult to solve. A member of the leadership team reported that at any given time, nearly 10% of all drivers were out on sick leave, though it was unclear how many were using it for vacation purposes.

> *"We have a severe problem that we've had a lot of demand for transport, and we've had to cut into the drivers' vacation time, so we're not giving them all the vacations that we ought to, so the vacation time starts to build up, the rest time that the drivers ought to have, and we're postponing their vacations." (Key Informant)*

3.2.2. Distribution of Shifts

The frequency and distribution of shifts were the main concern discussed among the drivers. They acknowledged that they work irregular hours but that the scheduling can often be inflexible with regard to their personal and self-care needs. Additionally, there may only be a few hours rest for a driver between routes, depending on their route or shift allocation. Drivers may also need to work these shifts back-to-back, multiple days in a row. In some cases, workers reported only getting a few hours of sleep each night between shifts and this could occur over consecutive days. This leads to exhaustion, which can result in additional sick leave, and worry that if they do drive tired then they may be involved in an accident.

> *"You get home by midnight, and you are supposed to get up at 4:30 a.m. . . . Then, you come here [to work] already feeling sleepy since you have slept just four hours . . . Then repeat the process 5 days in a row." (Driver)*

3.2.3. Route Scheduling

Of particular concern were the shift distribution and scheduling of a particularly challenging and difficult route ("Desafiante route", name changed for anonymity). The Desafiante route was noted by nearly all drivers and key informants, and was much longer, had narrow and often congested roads, and intersected with areas with high traffic density.

> *"The drivers say to themselves 'I'm going down that route again,' Now I'm going down in a bad mood, I'm going to be late, I'm going to run into a traffic jam . . . (Key Informant)"*

The way the Desafiante route was scheduled allowed the drivers to have only a few hours of rest if they were assigned it multiple days in a row. The added stress of workers

asking for additional stops could increase the duration of the shift even longer. One driver thought that balancing the Desafiante route with other shorter, or simpler routes might make it easier to manage for the drivers and allow for more rest between shifts.

> *"At least they should be distributed in a more balanced way. If I have a busy day, the next day I should have a more relaxing day, and the one who got a less busy day, the next day should have a busier day. It can be compensated in that way." (Driver)*

However, those involved in scheduling in the company, and other key informants, explained that this was a very complex and dynamic problem, with shift schedules being provided by the client and changing rapidly. Compounded with an older scheduling system that did not accommodate the idiosyncrasies of their scheduling or shift needs and a workforce of approximately 450 drivers, it was an extremely difficult problem to solve.

3.2.4. Bus Design and Maintenance

While the drivers acknowledged that the company had strong bus maintenance policies and practices in place, they highlighted a few aspects that negatively contributed to their safety, health, and well-being. Some drivers discussed issues associated with driving buses which are normally driven by other drivers. Since these buses are adjusted for the previous bus driver, the orientation of the seat is sometimes not in an optimal position, which leads to musculoskeletal pain. The drivers explained that the set-up cannot be easily changed before a shift and therefore one drives with the bus adjusted to another person's requirements.

In addition, bus maintenance is occasionally not fully completed at the end of a late shift. In these instances, a driver may arrive for their shift the next day unaware that the bus was not completely serviced the night before, and this delays the start of the day. This can also result in some resentment between the drivers.

Drivers also noted problems with certain aspects of the buses that they perceived directly caused them pain and discomfort. For example, in many buses, the clutch was difficult to use. One driver described a significant injury he sustained as a result:

> *"Yeah, the gearshift of the vehicles, the ones we drive, they are hell, shifting gears, and look, I'm not exaggerating, once I put the vehicle into reverse and ended up with my hand cut open." (Driver)*

3.3. Driver's Health and Well-Being

3.3.1. Fatigue

Fatigue was the most frequently discussed safety concern for the drivers, supervisors, and other key informants interviewed. This is of concern because fatigue can result in accidents and in the worst cases, fatalities of both drivers and passengers in more serious crashes. While fatigue is a serious issue for professional drivers in general, in this scenario it manifested through trust concerns between drivers and supervisors. The difficulty, or reluctance, drivers had using vacation time or emergency codes meant that they had little ability to rest when needed. Fatigue compromised the health of drivers, as one driver explained:

> *"Fatigue . . . makes your health poor, you lack sleep, it's quite powerful, as time goes by you simply start wearing away." (Driver)*

Drivers and informants also associated drivers' fatigue with poor health behaviors and other chronic health conditions.

3.3.2. Stress

Drivers discussed how stress arose from fatigue, stemming from a lack of rest, poor interactions with passengers, and the difficulty associated with driving certain routes. Individually, these factors might not be as significant; however, drivers emphasized that they were being impacted by these factors every day.

> *"You really feel under pressure as you know that you have to get somewhere and the guy is gonna be worried about this, about that, about the guy over here, about the vehicle over*

here, I think all that makes you . . . I think all that stuff has a negative impact on your health." (Driver)

3.3.3. Health Behaviors

In response to fatigue and stress, drivers stated that they coped by participating in unhealthy behaviors such as smoking, eating unhealthy foods, and drinking coffee in excess. Coffee, sugary and other high caloric foods, and smoking were used to stay awake while the drivers were operating on only a few hours of sleep.

"You eat badly, you get used to eating badly or drinking lots of coffee. Some guys drink more, they start smoking a lot, drinking too much coffee to stay awake." (Driver)

Processed and ready-to-eat packaged foods were eaten because they allowed the drivers to rest for longer periods of time on their breaks.

"Most of the sick leave is, some for stress, panic attacks, what else do we have . . . stomach aches, which are caused by the same (stress-related) eating disorders, excess sometimes of coffee, cigarettes. Basically, poor habits." (Key Informant)

3.3.4. Chronic Health Conditions

Unhealthy behaviors, fatigue, and stress, and challenging working conditionswere perceived by both drivers and key informants to contribute to chronic health conditions such as diabetes, hypertension, and obesity. Drivers were aware that these chronic diseases were common among themselves and their coworkers, and considered their sedentary work environment, schedules, and diet choices as the primary causes.

"[Our] diet messes you up . . . diabetes and hypertension are quite common among colleagues and it must be a result of that (not having time to eat) . . . we eat in a rush and not in an organized way." (Driver)

The bussing organization had been acutely aware of the issue of chronic disease amongst its drivers. It had implemented voluntary access to a gym, complimentary health checkups every six months to assess risks for chronic diseases, and access to a physiotherapist and a nutritionist. However, these benefits were reportedly under-utilized by drivers, possibly due to the fatigue that they were experiencing, and lack of time and energy to use these services.

"We are constantly worrying about [the drivers], obesity is a common result of sedentary work, therefore we are always concerned about hypertension, high blood-pressure, obesity." (Key Informant)

3.4. Informing a Total Worker Health® Intervention

Grounded in the qualitative data, we developed a conceptualization by mapping how these themes were related (Figure 1). Working conditions were associated with drivers' health and well-being outcomes including stress and fatigue and their health behaviors. These in turn were thought to impact more distally on drivers' health conditions, such as obesity, diabetes, and hypertension, as well as contributing to drivers' absences from work. This framework will be used to inform the intervention targets of a participatory *TWH* intervention with the same company.

4. Discussion

This study aimed to determine the factors which contributed to the safety, health, and well-being of professional bus drivers using a qualitative approach. Focus groups with drivers and interviews with key informants highlighted root causes through the conditions of work that were contributing to drivers' safety, health, and well-being.

4.1. Working Conditions Influencing Bus Drivers' Safety, Health, and Well-Being

The relationship that a worker has with their supervisor has been linked to workers' well-being [39]. In this study, we also found that lack of trust and poor communication could have significant safety implications if drivers were reluctant to use "stop-work" emergency codes when needed. While the association between supervisor support and workers' health and well-being has been well established in other sectors [40,41], little research has been conducted in transportation on psychosocial work environment factors. One prior study found that strong connections between drivers and dispatchers resulted in more efficient operations, and mutual respect between drivers and dispatchers often improved attitudes and driver retention [42].

Schedules and shifts have been well-established as being potentially harmful to workers' health and well-being [43–45]. Workers with little control over their schedules and shifts have been found to have lower levels of subjective health than those with more control [46]. Longer working hours and short sleep duration (<6 h per day) have been found to be associated with various health conditions, such as metabolic and cardiovascular diagnoses [47]. In companies, such as the one in our study, where drivers are salaried, long working hours and few hours available to sleep between shifts are common and can be detrimental for both physical and mental health [48,49]. In our study, drivers were advised of their schedules at short notice with little control, resulting in considerable impacts on their ability to manage their work demands while maintaining healthy behaviors. Compounded with a growing workforce, and lack of technological support to assist with complex scheduling and shifts, this working condition can have potentially profound impacts on drivers' fatigue, their health behaviors, and long-term health and well-being. As society continues to move towards a 24/7 approach to providing services, the need for work schedules characterized by shift work, rotating schedules, and longer working hours is also increasing; the future of work is likely to exacerbate these problems unless these working conditions are addressed.

There is a body of literature that supports the importance of the physical environment of buses as the main cause of musculoskeletal injuries and accidents [50,51]. This can also be influenced by external factors, such as the weather or road conditions. However, in our study, this was not identified as a main working condition influencing drivers' safety, health, and well-being. One possible reason for this is the company's strong focus on safety and ergonomics; in collaborating with this company, we observed mature safety systems, policies, and practices. The concerns highlighted by drivers and key informants could be related to issues in scheduling, for example, maintenance not occurring if a driver returns late from a shift, or last-minute changes resulting in another driver needing to use a bus not ergonomically set up for themselves.

4.2. Safety, Health, and Well-Being of Professional Bus Drivers

The common concerns for the health of drivers were fatigue, stress, and chronic health conditions. Poor health behaviors were caused by both stress and fatigue as well as lack of access to healthier food options and inability to exercise because of short breaks and rest time. This is not a new finding; these health conditions experienced by the drivers have been well-documented in the literature in several epidemiological studies of drivers' safety and health [22,52]. What is new is the qualitative documentation of the lived experience of these safety, health, and well-being sequelae as a result of their exposures at work and the identification of the pathways and conceptual model (Figure 1). We found that drivers' poor health behaviors had complex pathways through both the conditions of work and other health outcomes, driven by several factors in their work environment and compounded by fatigue and stress. Providing a solution to improve the health behavior directly—through healthier food options or providing access to physical exercise opportunities as has been found successful in other intervention studies for bus drivers—had been trialed in this company without success. For example, the company had attempted to address the obesity problem, and the issue of drivers not performing enough physical activity during the day,

by providing them with an on-site fully equipped gym with a trainer, but, due to schedules, drivers did not have time or were too tired between shifts to use the gym. This proposed solution does not address the conditions of work.

4.3. Using Qualitative DATA to Inform Intervention Design

The findings from this study will be used to inform the content of a participatory *TWH* organizational intervention for bus drivers. Tailoring the intervention to fit the organization is important for implementation success because working conditions can manifest in different ways even within the same industry. Focusing on areas of priority for both the company leadership and, perhaps more importantly, the front-line workers, also contributes to implementation success. Demonstrating the importance of organizational fit, workers and company leaders are more likely to support and participate in program activities for areas that they believe are important priorities. Although legacy working conditions like the physical work environment and chemical hazards such as fumes are important exposures to consider, psychosocial and work organizational exposures are inherently complex and may require more in-depth exploration. This emphasizes the importance of qualitative, stakeholder-driven methods. Every organization is unique even within the same industry. To tailor an intervention that improves the safety, health, and well-being of drivers, we used qualitative methods, including focus groups and interviews, to provide valuable data to inform the intervention's content. However, other methods such as workshops, ethnography, or mixed methods may also be useful depending on the context, time, and resources available to conduct this type of formative research.

4.4. Strengths and Limitations

A strength of this study is the participatory qualitative approach to identifying intervention content based on methods that we have used previously [28,29], and thus, is largely replicable. Through these methods, we obtained perspectives from key stakeholders within the organization including drivers (workers), union representatives and key decision makers (management). We tailored these methods so that they were feasible and easily implemented by an organization in a population of workers that are distributed away from a central workplace—in this case, being on-the-road driving buses or out in the field supporting operations, and safety and health. For example, focus groups were held on work time with drivers, and managers were interviewed at a time of their choosing.

The specific results and findings of this study may not be generalizable due to the study's specific context and geographical location. Additionally, the organization was very supportive of the study and motivated to implement a *TWH* approach. They were amenable to providing organization time to facilitate the completion of the study. There was also significant support and commitment from leadership to enhance the well-being of the drivers at the organization. Other organizations may not have this support and may not be able to collect data as easily. However, the main implications from this study are grounded in the process, the importance placed on psychosocial and work organizational conditions, and the emphasis placed on using this type of approach to identify how these working conditions manifest as the root causes of workers' safety, health, and well-being.

4.5. Implications for Future Research and Practice

Prior research has demonstrated differences in work organization needs between different types of professional drivers [16]. Identification of these needs requires a careful approach to prevent missing important underlying issues by solely relying on those that may be identified through a literature review or survey research. Future interventions should consider a formative qualitative research process involving key stakeholders to ensure that the intervention is tailored to the needs of the organization, and its employees. The "Integrative and Dynamic Healthy Commercial Driving Paradigm" was developed in 2015 as a response to the ineffectiveness of current health and wellness programs. It highlights identifying upstream causes of driver health outcomes by including all stakeholders in the development

of interventions, and preventing poor health outcomes at primary, secondary, and tertiary levels [17]. Programs such as these, which address both the unique work organization of the transportation industry and act to build trust between drivers and supervisors, should be promoted to improve the health and well-being of professional drivers.

The transportation industry can use these findings by ensuring collaboration occurs between supervisors, management, and drivers when implementing safety, health, and well-being initiatives. While there may be success in organizations implementing programs to improve driver well-being by themselves, it is also possible that a poorly tailored program will fail to improve driver well-being. Determining the root cause of drivers' health outcomes through a combination of focus groups and key informant interviews can enable management to create driver safety, health and well-being programs that are beneficial and effective.

5. Conclusions

This study's participatory approach found that while the health outcomes impacting bus drivers may not be unique to an organization, the working conditions which facilitate the health and well-being outcomes can be. Because of this, the determination of which working conditions are causing poor safety, health, and well-being outcomes can be difficult to ascertain. Collecting data through focus groups with drivers and interviews with other key stakeholders can allow for candid discussions about these working conditions and how they uniquely manifest within an organization, which can then be addressed. Bussing organizations and future research can use this TWH approach to determine which working conditions should be modified to improve the safety, health, and well-being of drivers.

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References

1. Rauser, E.; Foley, M.; Bonauto, D.; Edwards, S.; Spielholz, P.; Silverstein, B. *Preventing Injuries in the Trucking Industry*; Technical Report No. 90-17-2008; Washington State Department of Labor & Industries: Tumwater, WA, USA, 2008.
2. Tse, J.L.; Flin, R.; Mearns, K. Bus driver well-being review: 50 years of research. *Transp. Res. Part F Traffic Psychol. Behav.* **2006**, *9*, 89–114. [CrossRef]
3. Bigert, C.; Gustavsson, P.; Hallqvist, J.; Hogstedt, C.; Lewné, M.; Plato, N.; Reuterwall, C.; Schéele, P. Myocardial Infarction among Professional Drivers. *Epidemiology* **2003**, *14*, 333–339. [CrossRef]
4. Gustavsson, P.; Alfredsson, L.; Brunnberg, H.; Hammar, N.; Jakobsson, R.; Reuterwall, C.; Ostlin, P. Myocardial infarction among male bus, taxi, and lorry drivers in middle Sweden. *Occup. Environ. Med.* **1996**, *53*, 235–240. [CrossRef] [PubMed]

5. Rosso, G.L.; Perotto, M.; Feola, M.; Bruno, G.; Caramella, M. Investigating obesity among professional drivers: The high risk professional driver study. *Am. J. Ind. Med.* **2015**, *58*, 212–219. [CrossRef]
6. Birdsey, J.; Sussell, A.L. Prevalence of Obesity, No Leisure-Time Physical Activity, and Short Sleep Duration Among Occupational Groups in 29 States. *J. Occup. Environ. Med.* **2017**, *59*, 1221–1228. [CrossRef] [PubMed]
7. Pope, M.H.; Magnusson, M.; Wilder, D.G. Low Back Pain and Whole Body Vibration. *Clin. Orthop. Relat. Res.* **1998**, *354*, 241–248. [CrossRef] [PubMed]
8. Pope, M.H.; Andersson, G.; Frymoyer, J.; Chaffin, D.B. *Occupational Low Back Pain: Assessment, Treatment and Prevention*; Mosby: St. Louis, MO, USA, 1990.
9. NRC/IOM. *Musculoskeletal Disorders and the Workplaces: Low Back and Upper Extremities*; National Academy Press: Washington, DC, USA, 2001.
10. Bernard, T. *Musculoskeletal Disorders and Workplace Factors*; DHHS Publication (NIOSH) 97-141; DHHS Publication (NIOSH): Washington, DC, USA, 1997.
11. Useche, S.A.; Cendales, B.; Montoro, L.; Esteban, C. Work stress and health problems of professional drivers: A hazardous formula for their safety outcomes. *PeerJ* **2018**, *6*, e6249. [CrossRef]
12. Garbarino, S.; Guglielmi, O.; Sannita, W.G.; Magnavita, N.; Lanteri, P. Sleep and Mental Health in Truck Drivers: Descriptive Review of the Current Evidence and Proposal of Strategies for Primary Prevention. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1852. [CrossRef]
13. Ba, A.J.S.; Doucette, J.T.; Garland, E.; McGinn, T. Healthcare and the long haul: Long distance truck drivers? A medically underserved population. *Am. J. Ind. Med.* **2004**, *46*, 463–471. [CrossRef]
14. Apostolopoulos, Y.; Lemke, M.; Sönmez, S. Risks Endemic to Long-Haul Trucking in North America: Strategies to Protect and Promote Driver Well-Being. *New Solut. J. Environ. Occup. Health Policy* **2014**, *24*, 57–81. [CrossRef]
15. Sabbagh-Ehrlich, S.; Friedman, L.; Richter, E.D. Working conditions and fatigue in professional truck drivers at Israeli ports. *Inj. Prev.* **2005**, *11*, 110–114. [CrossRef] [PubMed]
16. Bradley, C.J.; Grossman, D.C.; Hubbard, R.A.; Ortega, A.; Curry, S.J. Integrated Interventions for Improving Total Worker Health: A Panel Report from the National Institutes of Health Pathways to Prevention Workshop: Total Worker Health—What's Work Got to Do with It? *Ann. Intern. Med.* **2016**, *165*, 279–283. [CrossRef] [PubMed]
17. Filho, A.G.; Rocha, M.S.; Oliveira, F.M.; Dos Santos, U.C.; Costa, J.V.R.; De Jesus, J.S. Working Conditions of Bus Drivers in a Large Brazilian Metropolis. *Procedia Manuf.* **2015**, *3*, 2505–2509. [CrossRef]
18. Gómez-Ortiz, V.; Cendales, B.; Useche, S.; Bocarejo, J.P. Relationships of working conditions, health problems and vehicle accidents in bus rapid transit (BRT) drivers. *Am. J. Ind. Med.* **2018**, *61*, 336–343. [CrossRef]
19. Kim, J.H.; Zigman, M.; Aulck, L.S.; Ibbotson, J.A.; Dennerlein, J.; Johnson, P. Whole Body Vibration Exposures and Health Status among Professional Truck Drivers: A Cross-sectional Analysis. *Ann. Occup. Hyg.* **2016**, *60*, 936–948. [CrossRef] [PubMed]
20. Chen, J.-C.; Dennerlein, J.T.; Chang, C.-C.; Chang, W.-R.; Christiani, D.C. Seat inclination, use of lumbar support and low-back pain of taxi drivers. *Scand. J. Work. Environ. Health* **2005**, *31*, 258–265. [CrossRef] [PubMed]
21. Silla, I.; Gamero, N. Psychological safety climate and professional drivers' well-being: The mediating role of time pressure. *Transp. Res. Part F Traffic Psychol. Behav.* **2018**, *53*, 84–92. [CrossRef]
22. Hege, A.; Lemke, M.K.; Apostolopoulos, Y.; Sönmez, S. Occupational health disparities among U.S. long-haul truck drivers: The influence of work organization and sleep on cardiovascular and metabolic disease risk. *PLoS ONE* **2018**, *13*, e0207322. [CrossRef] [PubMed]
23. Guerra, E.B.S.; Suazo, S.V.V.; Campo, V.A.R. Working Conditions, Health and Quality of Life among Drivers. *Rev. Cuid.* **2020**, *11*. [CrossRef]
24. de Croon, E.M.; Sluiter, J.K.; Frings-Dresen, M.H. Need for recovery after work predicts sickness absence: A 2-year prospective cohort study in truck drivers. *J. Psychosom. Res.* **2003**, *55*, 331–339. [CrossRef]
25. Sorensen, G.; McLellan, D.L.; Sabbath, E.L.; Dennerlein, J.T.; Nagler, E.M.; Hurtado, D.A.; Pronk, N.P.; Wagner, G.R. Integrating worksite health protection and health promotion: A conceptual model for intervention and research. *Prev. Med.* **2016**, *91*, 188–196. [CrossRef]
26. NIOSH. Total Worker Health. Available online: http://www.cdc.gov/niosh/twh/ (accessed on 19 September 2017).
27. Nielsen, K.; Abildgaard, J.S.; Daniels, K. Putting context into organizational intervention design: Using tailored questionnaires to measure initiatives for worker well-being. *Hum. Relat.* **2014**, *67*, 1537–1560. [CrossRef]
28. Peters, S.; Nielsen, K.M.; Nagler, E.M.; Revette, A.C.; Madden, J.; Sorensen, G. Ensuring Organization-Intervention Fit for a Participatory Organizational Intervention to Improve Food Service Workers' Health and Wellbeing. *J. Occup. Environ. Med.* **2020**, *62*, e33–e45. [CrossRef] [PubMed]
29. Peters, S.E.; Trieu, H.D.; Manjourides, J.; Katz, J.N.; Dennerlein, J.T. Designing a Participatory Total Worker Health® Organizational Intervention for Commercial Construction Subcontractors to Improve Worker Safety, Health, and Well-Being: The "ARM for Subs" Trial. *Int. J. Environ. Res. Public Health* **2020**, *17*, 5093. [CrossRef] [PubMed]
30. Vignoli, M.; Nielsen, K.; Guglielmi, D.; Tabanelli, M.C.; Violante, F.S. The Importance of Context in Screening in Occupational Health Interventions in Organizations: A Mixed Methods Study. *Front. Psychol.* **2017**, *8*, 1347. [CrossRef] [PubMed]
31. Sorensen, G.; Dennerlein, J.T.; Peters, S.E.; Sabbath, E.L.; Kelly, E.L.; Wagner, G.R. The future of research on work, safety, health and wellbeing: A guiding conceptual framework. *Soc. Sci. Med.* **2020**, *269*, 113593. [CrossRef] [PubMed]

32. Anger, W.K.; Elliot, D.L.; Bodner, T.; Olson, R.; Rohlman, D.S.; Truxillo, D.M.; Kuehl, K.S.; Hammer, L.B.; Montgomery, D. Effectiveness of Total Worker Health interventions. *J. Occup. Health Psychol.* **2015**, *20*, 226–247. [CrossRef] [PubMed]
33. Feltner, C.; Peterson, K.; Weber, R.; Cluff, L.; Coker-Schwimmer, E.; Viswanathan, M.; Lohr, K.N. The Effectiveness of Total Worker Health Interventions: A Systematic Review for a National Institutes of Health Pathways to Prevention Workshop. *Ann. Intern. Med.* **2016**, *165*, 262–269. [CrossRef]
34. Corley, K.G.; Gioia, D.A. Building theory about theory building: What constitutes a theoretical contribution? *Acad. Manag. Rev.* **2011**, *36*, 12–32. [CrossRef]
35. Gioia, D.A.; Corley, K.G.; Hamilton, A.L. Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. *Organ. Res. Methods* **2013**, *16*, 15–31. [CrossRef]
36. Krippendorff, K. *Content Analysis: An Introduction to Its Methodology*; Sage Publications: Thousand Oaks, CA, USA, 2018.
37. Braun, V.; Clarke, V. Using thematic analysis in psychology. *Qual. Res. Psychol.* **2006**, *3*, 77–101. [CrossRef]
38. NVivo. Relationship Nodes: About Relationships. Available online: https://help-nv11.qsrinternational.com/desktop/concepts/about_relationships.htm (accessed on 10 September 2021).
39. Hege, A.; Lemke, M.K.; Apostolopoulos, Y.; Whitaker, B.; Sönmez, S. Work-Life Conflict among U.S. Long-Haul Truck Drivers: Influences of Work Organization, Perceived Job Stress, Sleep, and Organizational Support. *Int. J. Environ. Res. Public Health* **2019**, *16*, 984. [CrossRef]
40. Hämmig, O. Health and well-being at work: The key role of supervisor support. *SSM-Popul. Health* **2017**, *3*, 393–402. [CrossRef]
41. Yanar, B.; Lay, M.; Smith, P.M. The Interplay between Supervisor Safety Support and Occupational Health and Safety Vulnerability on Work Injury. *Saf. Health Work.* **2018**, *10*, 172–179. [CrossRef]
42. Fournier, P.-S.; Lamontagne, S.; Gagnon, J. Interactions between Dispatchers and Truck Drivers in a High Turnover Context. *Articles* **2012**, *67*, 263–282. [CrossRef]
43. Zhao, Y.; Richardson, A.; Poyser, C.; Butterworth, P.; Strazdins, L.; Leach, L.S. Shift work and mental health: A systematic review and meta-analysis. *Int. Arch. Occup. Environ. Health* **2019**, *92*, 763–793. [CrossRef]
44. Liu, Q.; Shi, J.; Duan, P.; Liu, B.; Li, T.; Wang, C.; Li, H.; Yang, T.; Gan, Y.; Wang, X.; et al. Is shift work associated with a higher risk of overweight or obesity? A systematic review of observational studies with meta-analysis. *Int. J. Epidemiol.* **2018**, *47*, 1956–1971. [CrossRef]
45. Winkler, M.R.; Mason, S.; Laska, M.N.; Christoph, M.J.; Neumark-Sztainer, D. Does non-standard work mean non-standard health? Exploring links between non-standard work schedules, health behavior, and well-being. *SSM-Popul. Health* **2017**, *4*, 135–143. [CrossRef]
46. Brauner, C.; Wöhrmann, A.M.; Frank, K.; Michel, A. Health and work-life balance across types of work schedules: A latent class analysis. *Appl. Ergon.* **2019**, *81*, 102906. [CrossRef]
47. Wong, K.; Chan, A.H.S.; Ngan, S.C. The Effect of Long Working Hours and Overtime on Occupational Health: A Meta-Analysis of Evidence from 1998 to 2018. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2102. [CrossRef]
48. Ihlström, J.; Kecklund, G.; Anund, A. Split-shift work in relation to stress, health and psychosocial work factors among bus drivers. *Work* **2017**, *56*, 531–538. [CrossRef]
49. Mello, M.; Santana, M.; Souza, L.; Oliveira, P.; Ventura, M.; Stampi, C.; Tufik, S. Sleep patterns and sleep-related complaints of Brazilian interstate bus drivers. *Braz. J. Med. Biol. Res.* **2000**, *33*, 71–77. [CrossRef]
50. Sekkay, F.; Imbeau, D.; Chinniah, Y.; Dubé, P.-A.; DE Marcellis-Warin, N.; Beauregard, N.; Trépanier, M. Risk factors associated with self-reported musculoskeletal pain among short and long distance industrial gas delivery truck drivers. *Appl. Ergon.* **2018**, *72*, 69–87. [CrossRef]
51. Kim, J.H.; Zigman, M.; Dennerlein, J.T.; Johnson, P.W. A Randomized Controlled Trial of a Truck Seat Intervention: Part 2—Associations between Whole-Body Vibration Exposures and Health Outcomes. *Ann. Work. Expo. Health* **2018**, *62*, 1000–1011. [CrossRef]
52. Crizzle, A.M.; Bigelow, P.; Adams, D.; Gooderham, S.; Myers, A.M.; Thiffault, P. Health and wellness of long-haul truck and bus drivers: A systematic literature review and directions for future research. *J. Transp. Health* **2017**, *7*, 90–109. [CrossRef]

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Has the COVID-19 Pandemic Accelerated the Future of Work or Changed Its Course? Implications for Research and Practice

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Abstract: The COVID-19 pandemic is a unique transboundary crisis which has disrupted people's way of life more dramatically than any event in generations. Given the ambiguity surrounding the end of the COVID-19 pandemic and its enduring negative effects, it is important to understand how this has affected important future of work trends. The aim of the current paper is to assess the impact of the COVID-19 pandemic on commonly discussed future of work trends relevant to occupational safety and health priority areas. These topics include work arrangements, compensation and benefits, and the organization of work. For each topic, we assess trends leading up to the COVID-19 pandemic, discuss the impact of the pandemic on these trends, and conclude with implications for research and practice. Overall, the pandemic appears to have both accelerated and disrupted various trends associated with future of work topic areas. These effects are discussed in terms of implications for both policymakers and organizations.

Keywords: COVID-19 pandemic; future of work; work arrangements; compensation and benefits; worker well-being; occupational safety and health; work organization-related chronic health conditions; including substance use disorders; work-family conflict; trends

1. Introduction

Landmark events are those events that are said to change history. The COVID-19 pandemic (pandemic), already in its second year, will certainly stand as one such event. As of the writing of this paper, over 4.5 million people worldwide have died from COVID-19, and a new variant is rapidly surging in the United States. The onset of the pandemic brought rapid shifts to remote work, hundreds of thousands of job losses due to business shutdowns and closures, school closures, and new work hazards; these challenges have persisted throughout the pandemic. The pandemic has been labeled a transboundary crisis—a crisis that impacts all elements of a social system [1]. With its major impacts on work and work-related well-being, it has been described as "the most widespread and profound occupational health crisis in modern times" [2].

There has been much speculation about how the pandemic has changed the future of work. We leverage available data to examine how the pandemic is shifting trends in the United States surrounding work arrangements; policies, compensation, and benefits; and the organization of work. We identified these themes as major disruptions sparked by the pandemic that are associated with future of work topics and have the potential to

impact occupational safety and health priorities related to worker well-being. Moreover, these are topics for which empirical data exists to facilitate the comparison of trends. Thus, these topics provide a useful starting point to consider how the pandemic is shaping the future of work from an occupational safety and health perspective, and to generate ensuing implications for occupational safety and health research and practice. Although many rich discussions could be had about the pandemic's impact across countries, we restrict our scope to the United States given the focus of this special issue.

In each of the sections that follow, we incorporate previous research findings and available data to synthesize trends both before and during the pandemic for each topic, and then generate implications for research and practice. Across the sections, we address cross-cutting issues including workforce demographics and inequities. We conclude this paper by offering several overarching insights about the ways that research and practice priorities related to the future of work may need to change due to the pandemic.

2. Work Arrangements

Most prognostications of the future of work focus on questions about whether work will continue to exist in the manner it has in the past. These discussions generally involve the disruptive nature of technology in shaping where work is done (e.g., in the office versus virtually), the nature of the employment relationship (e.g., through gig work and non-standard employment relationships), and whether work will even continue to exist for large portions of the population [3–6]. Such questions about work arrangements are highlighted in occupational safety and health and future of work frameworks, which emphasize the interconnection between work arrangements and physical, psychological, social, and economic impacts of work [7].

Work arrangements, or "arrangements between those who perform work and those who provide jobs", are commonly discussed as standard and non-standard [8] (p. 1). Standard work arrangements refer to more traditional employment, wherein individuals work long-term, full-time jobs for the same employer, typically with some ability to advance their career over time [9]. Work arrangements that vary in one or more ways from this pattern are considered non-standard, or flexible, work arrangements [9,10]. This can include independent contract work, remote work, telework, temporary help agency work, freelance work, on-demand or gig work, part-time work, and more [8–10]. This section first focuses on two types of work arrangements highly impacted by the pandemic, remote work arrangements and gig work, before pivoting to consider the displacement of work caused by the pandemic.

2.1. Remote Work

2.1.1. Pre-Pandemic Trends

As technology supporting remote work has continued to advance, a shared physical workspace has grown less necessary in many industries, especially for those involved in knowledge work. Remote work appeals to many workers due to its flexibility and the savings associated with not commuting [11]. From the organization's perspective, cutting the costs associated with renting and maintaining a physical space can translate to significant savings [12]. Simultaneously, flexible work arrangements open organizations to a wider talent pool, allowing them to hire the best people for the job, regardless of physical location; this has the added benefit of increasing the diversity within workgroups, promoting creative problem solving and increasing access to jobs [13,14]. Despite these advantages, remote work was far from the norm leading up to the pandemic. In fact, in 2019, the USA Bureau of Labor Statistics (BLS) reported that 29% of wage and salary workers could work at home and 25% had opted to do so at some point [15]. However, only 15% of employees reported working full days exclusively from home [15]. These figures had advanced little over the preceding decade, suggesting rates of remote work had been largely stagnant despite it being hailed as a hallmark of a technology-mediated future of work [16].

Several circumstances may have contributed to remote work's limited popularity. First, working from home is not a realistic option in many industries. In the aforementioned BLS data [15], the percentage of workers who could work from home in the financial (57%) or information (53%) sectors dwarfed the percentages who reported the same opportunity in leisure and hospitality (9%) or agriculture (11%). Even when remote work is an option, opinions about its efficacy are mixed. Communication that occurs between individuals in the same physical environment allows for greater richness, creating potentially costly barriers when digital communication is poorly leveraged [17,18]. Research suggests knowledge sharing amongst coworkers is negatively affected by both spatial and temporal separation [19]. Remote workers may also experience feelings of isolation, which can lead to stress and decreases in affective commitment [20,21]. Further, physical presence in the office is often interpreted as commitment or "willingness to perform" [22] (p. 13); as a result, remote work may have negative effects on career outcomes [23]. Importantly, a lack of physical presence in the office may not affect all employees equally. Indeed, remote working women, and especially mothers, have reported decreased visibility and concerns about the impact on their career progression [24]. Finally, if poorly managed, employees engaging in remote teamwork may experience more intra-team conflict and struggle to maintain trust, which has implications for well-being [14,25].

2.1.2. Pandemic Trends

Perhaps the most visible effect the pandemic has had on the average office has been emptying it. Particularly at the outset of the pandemic, massive sectors of employees transitioned from primarily working onsite to working remotely from home [26,27]. Compared to roughly 15% of employees occasionally working full days at home prior to the pandemic [15], BLS estimated 35% of the workforce worked from home due to the pandemic at least once in May 2020 [26]. Of note, this data captures those forced to work from home due to the pandemic; adding those who already worked full-time from home prior to the pandemic would inflate the figure even further. This disruption led many in the popular press to speculate whether the pandemic has served as a catalyst for a long-term exodus from the traditional working situation [28,29].

As governmental restrictions are lifted and companies relax their policies, fewer individuals are being forced to work from home. By the end of 2020, those forced to work from home as a result of the pandemic had fallen to 24% [26]. By July of 2021, only 13% reported that they had been forced to work from home at some point in the past four weeks due to the pandemic [26]. Even with this steady decline from remote work's peak in spring 2020, there are still more Americans working from home than before the pandemic [26]. This raises the question of how many employees will continue to work from home after it is completely safe to return to the office. The answer will likely depend on a mixture of organizational decision-making and individual workers' preferences.

Attitudinal surveys provide a useful preview of worker preferences. Between October 2020 and April 2021, Gallup polled white-collar workers, who are typically more able to work remotely, on their preferences [30]. Of those white-collar workers currently working from home, 71% wanted to continue working from home [30]. While 15% of those polled preferred remote work due to concerns about COVID-19, the remaining 56% reported they wanted to continue remote work as a matter of personal preference [30]. Conversely, only 29% reported wanting to return to the office [30]. Similarly, a poll by the Harvard Business School found 81% of professionals who had been working remotely from March 2020 to March 2021 either did not wish to return to the office or wanted to telework via a hybrid schedule (e.g., working 2–3 days at home per week) [31]. Notably, many white-collar industries (e.g., information, professional and business services) are predominantly composed of white and male employees [32], introducing concerns about the availability of remote work opportunities for traditionally disadvantaged groups.

As individual employees' opinions have shifted, a number of high-profile companies have announced decisions to permanently move employees to hybrid schedule telework

or full-time remote work [33,34]. In fact, the Society for Human Resource Management reported that 18% of organizations polled do not plan to bring all employees back to the worksite even when it is safe to do so [35]. Considering these factors jointly, there is good reason to expect a long-lasting shift in remote and telework's popularity, particularly in well-suited industries like professional business and services [36].

2.2. Gig Work

2.2.1. Pre-Pandemic Trends

Gig work can be understood as "a single project or task for which a worker is hired, often through a digital marketplace, to work on demand" [37]. Contingent workers, who do not have an expectation of long-term employment, are subsumed under this category [38]. Varying definitions mean that gig workers "are not easily identified in surveys of employment and earnings" and estimates of gig work's popularity vary [37,39,40]. For example, the most recent pre-pandemic BLS data provided three estimates of the percentage of people employed in contingent work ranging from 1–4% of those employed [38]. In addition to contingent workers, BLS reported that approximately 10% of workers were engaged in alternative work arrangements, including independent contractors, on-call workers, temporary help agency workers, and workers provided by contract firms [38].

Despite forecasts of gig work's prevalence skyrocketing [41,42], the available data represents very little change from previous BLS estimates in 2005 and 1995 [43]. Certain aspects of the work may account for this lack of growth. For example, gig work's inconsistency and lack of benefits are concerns for many employed in this sector [37]. Further, research has indicated that those in non-standard work arrangements are generally exposed to more occupational safety and health risks and report greater musculoskeletal and mental symptoms than those in standard work arrangements [44]. Nonetheless, a Gallup poll found 64% of gig workers reported doing their preferred type of work [45]. This suggests that, at least prior to the pandemic, many gig workers willingly accepted the risks of a non-traditional work arrangement.

2.2.2. Pandemic Trends

The pandemic's effects on gig work are less straightforward than its impact on remote work. Certain segments of the gig economy have thrived. For example, Instacart added 300,000 new shoppers between March and July 2020 to address growing demand; meanwhile, Upwork, which connects freelancers with employers, reported a 50% increase in signups from both workers and employers [46]. At the same time, consumer demand for rideshare companies (e.g., Uber and Lyft) fell by 75–80% in April 2020, compared to April 2019 [46]. Similarly, Airbnb suffered a 70% drop in bookings at the outset of the pandemic [47]. However, as the pandemic has progressed, demand has shifted. Airbnb, for example, has recovered, benefitting from its appeal to customers who want to travel but are wary of staying in large hotels [48]. As the example of Airbnb suggests, the story of the pandemic's long-term impact on gig work may be one of disruption, rather than overall growth or decline.

While app-based gig work has ebbed and flowed, an interesting area of consideration is the shift of knowledge work to the gig economy [49]. Hasija, Padmanabhan, and Rampal note that jobs that are codifiable, can be done remotely, and contain a delay between value creation and consumption are most prone for transitioning to gig work [50]. A survey of HR leaders found that about one third of organizations are actively replacing some full-time employees with contingent workers [51]. In combination with this shift, Autor and Reynolds suggest the pandemic will accelerate the use of automation in organizational processes [52]. This is significant as it may have the potential to push displaced workers into various forms of gig work, especially if they have limited skillsets.

With USA unemployment rates reaching Depression-era levels at the outset of the pandemic, many have turned to gig work to supplement lost wages [46]. This influx, combined with low demand for some types of gig work, led to high competition amongst

workers, threatening an already precarious sector of employees [46]. The influx of new, inexperienced gig workers and greater competition for gigs may serve to exacerbate pre-pandemic findings regarding the increased occupational safety and health risks associated with gig work [44]. At the same time, the pandemic has only served to augment those risks. Many employed in gig work (e.g., delivery workers, rideshare drivers, childcare providers) must interact with a variety of people, increasing their risk of infection [53–56]. These issues have led to articles asking whether it's ethical "to hire someone to assume a risk you don't want to" [57]. On top of the risk of infection, many gig workers are also subject to mistreatment and abuse from customers, which popular press articles suggest has increased during the pandemic [58,59]. Few gig workers have access to benefits typically associated with traditional employment (i.e., healthcare, retirement), creating a situation where greater risk is coupled with fewer resources [60].

2.3. Displacement of Work

2.3.1. Pre-Pandemic Trends

Worker displacement refers to "the involuntary, permanent termination of long-term employees" [61] (p. 1). Speculation on the future of work has long anticipated widespread worker displacement, often as the result of advances in technology and automation [62–64]. Unemployment rates provide a useful metric of pre-pandemic displacement trends. In the USA, civilian unemployment had been steadily declining for more than a decade before the start of the pandemic. From a high of 10.0% in October 2009, the unemployment rate had fallen to 3.5% by January 2020 [65]. Notably, men (3.1%) and women (3.2%) experienced similar levels of unemployment in January 2020 [64].

While the unemployment rate captures only "jobless persons who are available to take a job and have actively sought work in the past four weeks" [66], civilian labor force participation includes employed and unemployed people as a percentage of the civilian noninstitutional population [66]. In the decade prior to the pandemic, labor force participation had declined marginally from 64.8% in January of 2010 to 63.4% in January of 2020 [67]. Additionally, the labor force participation rates of men (69.3%) and women (57.8%) in January 2020 had converged slightly, when compared to men's (71.2%) and women's (58.8%) rates in 2010 [67]. Further, underemployment, (i.e., those working fewer hours than they would like as well as those who are unemployed but not included in the official unemployment rate due to lack of job search activity) decreased from 5.1% in 2015 to 3.5% in 2019 [68–71]. All in all, these trends reflect a slow, yet steady, recovery from the 2008 financial crisis, with little evidence of the technology-induced displacement forecasted for the twenty-first century [63].

2.3.2. Pandemic Trends

Worker displacement caused by the pandemic has far-reaching implications for individuals, organizations, and entire industries. March 2020 marked a massive loss of employment in the United States. Leisure and hospitality was one of the hardest-hit industries, losing about 459,000 jobs [72]. An additional 43,000 jobs were lost in healthcare and 46,000 in retail [72]. Overall, industries women tend to work in have been more severely affected [73].

The outset of the pandemic had a substantial impact on employment, with the civilian unemployment rate hitting 14.8% in April 2020 [65]. Of note, unemployment rates varied noticeably amongst groups. Whereas men's unemployment was 13.1% in April 2020, women's was 15.5% [65]. In fact, over the course of 2020, women lost 1,000,000 more jobs than men, prompting widespread concerns about gender equality [74–76]. Similarly, Caucasian (14.1%) and Asian (14.5%) Americans experienced markedly lower rates in April 2020 than those identifying as Black or African American (16.7%) or Latinx or Hispanic (18.9%) [64].

The cause of these disparities is difficult to pinpoint. For example, disproportionate unemployment amongst women is likely impacted by the industries dominated by women,

but also by women's greater employment in part-time and other precarious work [73,77]. Further, the greater caregiving and domestic responsibilities shouldered by women, in conjunction with widespread closings of schools and daycares, are likely contributors [78–80]. There is already emerging evidence of the pandemic's disproportionate impact on parents', and especially mothers' work-life balance; this is discussed later in conjunction with the organization of work.

As the pandemic has progressed, unemployment and underemployment have begun to improve. The unemployment rate fell to 5.4% by July 2021 [65]. Averaging the third quarter of 2020 through the second of 2021, underemployment had fallen to 5.0% [70]. Additionally, women have gained ground. By July 2021, women's unemployment rate (5.0%) had fallen below men's (5.4%) [65]. Black (8.2%) and Hispanic (6.6%) unemployment continued to lag behind that of white (4.8%) and Asian (5.3%) Americans [65]. Labor force participation in July 2021 was 61.7%; the gap between men's (67.6%) and women's (56.2%) participation in July 2021 was essentially equal to what it had been in January 2020 [67].

These figures provide some reason for hope. Nonetheless, research suggests unemployment has long term impacts on earnings and homeownership [81], particularly when unemployment occurs during a recession [82]. In addition, the impacts on food insecurity are severe; Feeding America has projected that 1 in 8 Americans will experience food insecurity at some point in 2021 [83], with important implications for health and well-being [84]. Moreover, individuals' abilities to cope with financial loss is not equal, and workers of color are overrepresented in the low wage workforce. Despite statistics promising economic recovery, the long-term effects of worker displacement, especially displacement of women and minorities, should not be overlooked.

2.4. Implications

2.4.1. Implications for Research

With the COVID-19 virus, and especially the delta variant, continuing to shift the plans of individuals and organizations alike [85], the 'new normal' of work arrangements remains unknown. With increases in remote work, research is needed to investigate the effects of remote work on individuals who generally opted into working remotely versus those who are forced to work remotely, thus providing insight into the role of choice in shaping occupational outcomes [86]. Leadership styles, behaviors, and performance management strategies may all require adjustment, and research is needed to understand how leadership of fully remote or teleworking teams can promote or detract from healthy work design and worker well-being. Of particular concern are issues surrounding technostress and worker isolation [87,88], which require greater research attention. Remote work during the pandemic has been linked to fatigue and depression [87,88] while home confinement has been associated with decreased physical activity and less healthy eating [89], although research is needed to understand the extent to which this was due to the particular circumstances of remote work during the pandemic. Additionally, the proliferation of electronic performance monitoring (EPM), which involves tracking software, raises challenges for employee privacy, trust, and their consequent effects on well-being [90,91].

As workplaces adopt hybrid approaches, there are also important questions about potential inequities in training, work design, and leadership across remote and non-remote workers and their potential implications for occupational safety and health. The potential for remote work to remain a primary medium of work in the future also raises questions about occupational safety and health-related elements of people's remote work environments, such as the ergonomics of at-home workstations. Improper design of computer workstations has been associated with neck and back pain, eye strain, and carpal tunnel syndrome [92], emphasizing the importance of research related to at-home ergonomics. Finally, Bapuji and colleagues remind us that the ability to work remotely is a luxury [53], especially during situations like the pandemic. Early evidence has already pointed to the disparate respiratory health impacts suffered by remote and non-remote workers during

the pandemic [93]. It will be important to examine the extent to which, and ways by which, remote work during and after the pandemic contributes to health inequities tied to work.

Likewise, there are a number of implications for researchers to consider in examining the gig economy. First and foremost, researchers must determine how to systematically operationalize gig work as there are a number of issues surrounding its current measurement [40]. Second, research is needed to understand how gig work has changed or not changed in terms of its precarious elements and associated short- and long-term well-being outcomes. Gig work during the pandemic has increased in the degree of precarity at work due to the risk of virus exposure and potential increases in customer mistreatment [94]. Research is needed to investigate the policies and practices most effective at limiting the risks faced by gig workers both in terms of the availability of work and the quality, conditions, and experiences on the job along with the availability of worker benefits.

The widespread displacement of work also presents meaningful implications for researchers moving forward. In contrast to proclamations that technology may cause widespread job loss related to the future of work, an important question in light of the pandemic is the extent to which technology (e.g., virtual work) can facilitate a return to work. There are also concerns about the consequences of labor shortages in in-person work for those working in understaffed organizations. For example, hospitality organizations have struggled to hire back employees laid off at the start of the pandemic [95]. These labor shortages, common in many low-wage occupations, may have serious health and well-being implications for employees forced to cover additional tasks [96–98]. For example, research has detailed a variety of adverse health impacts associated with overwork (e.g., cerebrovascular/cardiovascular diseases, mental disorders) [99]. Conversely, this trend may usher in improvements in wages and benefits intended to entice back employees [11].

Additionally, while past research has demonstrated the negative long-term effects of recession unemployment on earnings [82], the pandemic presents an opportunity to focus on the long-term health and well-being effects associated with unemployment and temporary work loss (e.g., furloughs). A focus on inequity associated with race and gender could further enhance this stream of research. As jobs in specific industries have been disproportionately displaced, workers still employed in these industries may grow wary of the future of their roles, potentially leading to increased psychological strain [100]. The transboundary nature of the pandemic makes it difficult to predict how various industries may be affected in the future, potentially contributing to uncertainty for wider groups of workers, with implications for workers' sense of security. Additionally, although unemployment seems to be recovering, research will need to examine the quality of jobs to which previously unemployed people have returned and the potential for health inequities due to disparate opportunities for higher quality jobs.

2.4.2. Implications for Practice

Organizations, too, have much to consider moving forward, given the impacts of the pandemic on work arrangements. Assuming more and more individuals want to move to full-time remote work or hybrid schedules, organizations will need to make informed decisions about the advantages and disadvantages of remote work in their industry. Occupational safety and health professionals should play a valuable role in designing and implementing trainings, guidelines, and support materials regarding topics that have been identified as critical for remote workers' well-being (e.g., ergonomics in the home office, work-life balance, effective virtual communication) to ease the transition to remote work [101].

Organizational leadership will need to ensure that remote employees, many of whom may be women and mothers, are not overlooked for deserved career opportunities [24]. Considering the health concerns associated with remote work and home confinement [87–89], leaders will also want to consider how they treat newly remote employees and engage in behaviors that will promote employee well-being. Authors have

made a variety of recommendations for leaders to support their newly remote teams, such as emphasizing psychological safety and facilitating interpersonal connection [27]. Leaders are also encouraged to provide frequent feedback to remote teams [14,25]. Feitosa and Salas highlight some of the idiosyncrasies between the conventional virtual team's literature and the current situation [27]. For example, in discussing trust, the authors place an emphasis on trust maintenance [27], rather than trust formation as these teams have presumably established trust prior to the pandemic.

Additionally, as organizations increasingly rely on contingent or gig workers during the pandemic and beyond, consideration needs to be given to the occupational safety and health implications of transitioning to a contingent worker model. Previous research has suggested that some types of gig work (e.g., ridesharing) present novel safety risks to workers and non-standard work arrangements are generally associated with greater workplace vulnerabilities than standard arrangements [44,102,103]. Simultaneously, many gig workers receive little to no safety training [8,103]. Further, evidence suggests that job insecurity interacts with contingent status to predict particularly negative safety outcomes [104]. Training and work design are critical first steps in addressing the safety disparities between gig workers and those employed in standard work arrangements [8]. Further, organizations considering the integration of contingent employees into their workforce should thoroughly evaluate the occupational safety and health implications both for contingent workers and for the rest of their workforce. This is critical as research has highlighted that companies tend to assume less responsibility for contingent workers compared to more permanent workers [53] and that the greater usage of contingent workers can promote job insecurity among those with more traditional contracts [105]. Overall, companies should design work in a way that encourages safe working behavior, rather than overemphasizing efficiency [103]. Finally, isolation and lack of social support pose well-being risks for gig workers and other remote workers [20,21,106]. Organizations should foster communication amongst these employees and, where possible, decrease perceptions of competition amongst them [106]. There is also a need for action at the policy level to protect workers in non-standard work arrangements; several such policies (e.g., the Portable Benefits Bill) have been proposed.

The displacement of work also has important implications for practice. The pandemic, and associated school and daycare closures have brought issues surrounding childcare and the gendered nature of domestic work to the forefront [107,108]. In order to hire, retain, and support parents, and particularly mothers, the importance of childcare has never been clearer. Additionally, the severe impacts of unemployment and underemployment make a strong case for an extended social safety net [81–84,109,110]. This argument is further strengthened by 'pandemic success stories', like New Zealand [111,112].

Further, increased job displacement during a global pandemic can trigger employee fears that the stability of their industries and their own health are at risk, potentially leading to a host of negative well-being outcomes. Organizations must be mindful of such fears as they ask employees to perform their work in new and different ways. Communication and support are paramount [113]. Additionally, policymakers may want to explore mechanisms to provide support to workers facing unemployment or pathogen exposure.

3. Compensation and Benefits

Closely related to questions about what work will look like in the future are questions about the quality and conditions of work as well as issues of wage stagnation and income inequality [114,115]. There are concerns about a "race to the bottom" where the combination of precarious employment systems and poor social safety net mechanisms in the United States leave many without necessary benefits to ensure health and safety [116]. With this backdrop, the following sections provide an overview of the impact of the pandemic on issues pertaining to employee compensation (i.e., wage growth and the wage inequality gap) as well as worker benefits and policies, particularly access to paid sick leave, paid family leave, and hazard pay. Paid sick leave is defined as the right to take time off due

to an illness while still receiving compensation. Paid family leave refers to the right to get compensated when taking time off to care for a sick family member, while hazard pay entails getting paid extra for performing difficult or dangerous work [117,118].

3.1. Compensation

3.1.1. Pre-Pandemic Trends

Lack of employee wage growth has been highlighted by NIOSH as integral to occupational safety and health issues and has been identified as a significant problem for workers in recent literature [119–121]. Prior to the pandemic, the Federal Reserve Bank of Atlanta noted that we had yet to reach pre-2008 financial crisis wage growth levels [122], which peaked at approximately 4.5% in mid-2007, fell as low as 1.7% in early 2010, and was 3.5% prior to the pandemic (late 2019–early 2020). This is critical to note as it is documented that wage growth around 4% is necessary for employees to actualize the benefits of macro-economic growth, such as increased disposable income [123]. Under this threshold, it becomes difficult for employees to regain the wage resources necessary to help them bounce back from financial challenges experienced during a recession [124]. This lack of financial realization is detrimental when considering the host of negative well-being effects associated with constant worry over financial security and debt [125,126]. This objective data aligns with employee attitudes regarding pay as Gallup noted 40% of Americans reported feeling underpaid, highlighting pre-pandemic concerns regarding pay inequity [127].

The pre-pandemic lack of wage growth has also been coupled with rising executive pay which now dwarfs employee pay by a 320:1 ratio [128]. This ratio needs to be considered in conjunction with previous research, which has highlighted the negative effects associated with rising wage inequality on a number of employee well-being outcomes [129]. Specifically, rising wage inequality has been conceptualized as a chronic stressor, creating a condition in which employees perceive limited access to the resources needed to cope with this stressor, thus leading to maladaptive coping and straining effects [129]. At a macro level, income inequality has been shown to have negative implications for outcomes, such as population health and health inequalities [130]. Taken together, this evidence suggests employees have been feeling the dual brunt of growing wage inequality and stagnation even prior to the current pandemic.

3.1.2. Pandemic Trends

The economic precarity brought on by the pandemic only serves to exacerbate the negative implications associated with wage inequality and stagnation. Two types of evidence provide indications of how the pandemic is shaping trends in wages: overall change in wage growth and new job offer wage growth. New job offer wage growth refers to pay increases received when obtaining a new job. This allows us to look at the broader wage stagnation landscape while also discussing nuanced data regarding how wages are being distributed for new jobs.

In a whitepaper published by PayScale [131], researchers note that yearly percentage wage growth decreased from 1.2% growth between July 2018 and July 2019 down to 0.3% growth between July 2019 and July 2020. This highlights the rapidly declining trend of employee wage growth during the pandemic, and its disparate impact on industries that typically employ more low wage, minority, and female workers. When examining this data at an industry level, the hardest-hit industry was retail and customer service which experienced a 4.7% decline in yearly percentage wage growth between July 2019 and 2020 while the technology industry experienced a wage growth increase of 3% in the same time period. Overall, women have only experienced a 0.2% increase in yearly percentage wage growth compared to men's 1.2% wage growth [131]. Although overall year-over-year wage growth levels have still remained somewhat stagnant between 2020–2021 (approximately 0.5% wage growth), there is some evidence that specific industries that were hardest-

hit at the onset of the pandemic are beginning to rebound (e.g., food service and retail; approximately 4% wage growth between 2020 and 2021) [132].

When examining these trends in relation to new job offer wage growth, we find a greater disparity exists. PayScale researchers note a decline in new job offer wage growth from 3.3% between July 2018 and July 2019 down to 0.8% between July 2019 and July 2020. With regard to industry trends, we find similar results with retail and customer service employees experiencing a 7.8% decline in new job offer wage growth between 2019 and 2020 while the non-profit and technology industries continue to experience positive new job offer wage growth of 4.2% and 2.8% respectively [131]. Said otherwise, employees in customer service industries experienced an 8% drop in wage growth when accepting a new job in 2020 as compared to 2019. When considering rehire pay during the pandemic, which is defined as pay received by employees who are rehired by their organizations, a recent survey of USA small businesses reports that employee headcount levels are fairly close to pre-pandemic levels while hour and pay rate reductions are currently trending upward [133]. Taken together, these reports paint a grim picture regarding the state of employee wage growth during the pandemic, serving to further exacerbate the negative well-being and public health outcomes associated with rising wage inequality.

3.2. Employee Benefits

3.2.1. Pre-Pandemic Trends

On the federal level, most public and private sector employees in companies with at least 50 workers are covered by Title II of the Family and Medical Leave Act (FMLA) of 1993. Under this act, employees are eligible for up to 12 workweeks of unpaid, job-protected sick or family leave during any 12-month period [134]. As of 2012, an estimated 59% of employees in the USA were eligible for protection under FMLA [135]. Government policy on hazard pay was limited to Title 5 of the Code of Federal Regulations [136], which requires federal employees to receive extra compensation for performing dangerous duties or duties involving physical hardship. Some of the hazardous duties covered include working with virulent biologicals and toxic chemical materials [136]. However, whether or not one is eligible for hazard pay is decided by the employer on a case-by-case basis, and an employee is not likely to be eligible if the duties they are performing were part of the original job description [137].

At the industry and organizational level, paid sick and family leave policies varied significantly across industries and individual companies. According to the Bureau of Labor Statistics while around 90% of private sector employees in management, business, and finance occupations (e.g., corporate executives, software engineers, bankers, and lawyers) had access to paid sick leave, only 58% of service workers did, along with 56% of workers in construction, extraction, farming, fishing, and forestry industries [138]. With regard to family leave benefits, pre-pandemic trends indicated approximately 89% of civilian workers had access to unpaid family leave, but only 17% had access to paid family leave [139]. This figure represents an increase from 2017, when only 15% of USA workers had access to paid family leave [139].

There has been substantial evidence that racial inequalities in access to paid sick and family leave benefits existed long before the current pandemic. Data from 2008–2016 suggests that Hispanic and African American workers consistently had lower rates of paid sick and family leave access and use than non-Hispanic whites [140]. Additionally, Hispanic women were the least likely to have access to paid sick leave amongst all employed women [141]. With regard to gender inequality in access to paid sick leave benefits, data from the 2009 and 2014 National Health Interview Surveys suggest men and women have had relatively equal access (approximately 60%) to paid sick leave [142,143]. In terms of access to paid family leave, only 9% of companies offered paid paternity leave to all of their employees [144]. Data previous to the pandemic suggests that there may be some disparities with regard to utilization of paid family leave between men and women to care for a newborn child. The National Partnership for Women and Families note that

men typically have less access to paid family leave [145], less time available to them, and are subject to workplace stigmatization. These disparities are important to note given the positive effect that paid family leave has on families' economic security, especially within the context of a transboundary crisis that has both economic and health implications.

3.2.2. Pandemic Trends

The federal government's response to the pandemic included the Families First Coronavirus Response Act (FFCRA), which was signed into law on 18 March 2020 and expired on 31 December 2020 [146]. It required employers (both public and private) with fewer than 500 workers to provide 80 h of paid sick leave for employees who were quarantined or experiencing COVID-19 symptoms. It also allowed for up to 10 additional weeks of paid family and medical leave at two-thirds of the regular rate of pay to care for a child, but only for workers who had been employed for at least 30 calendar days. Furthermore, in an effort to increase economic protections for individuals who lost their jobs during the pandemic, unemployment benefits were increased and extended providing individuals with up to an additional $600 per week up until the end of 2020, and $300 per week from the beginning of 2021 up until 14 March of 2021 [147]. Unfortunately, these provisions are no longer in place since they were essential for offsetting some of the economic stress induced by the pandemic.

A number of states (e.g., New York, California) have counteracted some of the economic and health issues faced by employees by enacting emergency legislation extending sick leave paid benefits and guaranteeing job protection [148,149]. These are critical benefits, especially for employees who have limited access to resources to provide care for family. Another example of state-provided benefits is the establishment of front-line employee hazard pay, which provides additional hazard pay for jobs that may not have been traditionally considered high-risk but are increasingly risky due to COVID-19 exposure (e.g., Vermont) [150].

At the organizational level, in March 2020, 31% of 301 listed companies reported granting additional paid sick leave to employees in light of the pandemic [151]. The extent to which these companies plan to maintain such policies after the pandemic subsides remains unclear. A promising sign, however, is the fact that some influential investors have been pressuring large corporations to place a greater emphasis on employee health than they had previously, and to better prepare for future health crises [152]. As Morgan Stanley analysts remarked, "Post-COVID-19, we expect a higher bar in terms of benefits offered to USA employees . . . " [152]. In addition to increases in paid sick leave, some companies are providing hazard pay to employees who would not receive such pay under normal circumstances. For instance, Starbucks employees who worked between 21 March and 31 May 2020 received an extra $3 per hour as part of "Starbucks Service Pay"—a form of hazard pay [153]. There have been calls at the federal level for increased hazard pay for frontline employees (e.g., food services and healthcare workers) [154].

There is limited data to draw from in order to conclude whether pre-pandemic trends of racial inequality in benefit access have shifted as a result of the pandemic. However, there may be some reason for concern. In particular, according to a nationwide survey by the National Employment Law Project in May 2020 [155], African American employees were twice as likely as white workers to have experienced or witnessed retaliation from their employer for raising health and safety concerns related to COVID-19 at their workplace. The survey included open-ended responses, in which some participants revealed that anyone taking a leave of absence may be fired. If such experiences are prevalent, this could signal that the pandemic is maintaining or even exacerbating racial disparities in access to paid sick leave benefits. On the other hand, given the expansion in paid leave benefits from the government and some private companies, there may be reason to believe that overall racial inequalities in access to these benefits may decrease post-pandemic. With regard to gender inequalities, recent evidence suggests that the pandemic has disproportionately affected women, many of whom were forced to reduce their work hours or quit work

altogether to manage childcare responsibilities [156]. We conclude this is partly driven by unequal access to and use of childcare family leave, reflecting traditional societal expectations of women.

3.3. Implications

3.3.1. Implications for Research

Occupational safety and health researchers have highlighted pay inequality as a grand challenge for future research and demonstrated its link to negative well-being outcomes [129,157]. Research on strategies to support employee wage growth and mitigate inequality would be beneficial in reducing economic stress of employees and associated negative health outcomes [124]. Similarly, a better understanding of the nuances surrounding income redistribution policies is necessary to help employees financially cope and rebound from the burdens placed on them during the pandemic [158,159].

Future research should carefully track how employee benefits and policies continue to evolve over the course of the pandemic and beyond. Pre-pandemic research has highlighted increases in employee novel perks (e.g., on-site dining, health facilities) in addition to traditional benefits at the organizational level [160]. These additional perks may become increasingly important over time as employees look to their organizations to provide a comprehensive set of perks and benefits to meet their diverse well-being needs. More research is needed to understand whether such perks meaningfully contribute to employee health and well-being and whether employee needs have shifted due to the pandemic [126]. Given the unique transboundary nature of the pandemic affecting both the health and economic well-being of employees, it is important to understand the benefits and policies that will have the greatest impact on employee well-being now and in the future [1].

Moreover, future research should investigate the downstream effects of disproportionate access to benefits across gender and race. As minorities and female employees make up the majority of blue-collar and service jobs, this further exacerbates deficiencies in access to benefits during the pandemic and beyond, with potentially critical effects for occupational safety and health, as well as well-being. Going further, it is critical to understand the types of benefits, policies, and resources that would improve the health and well-being of individuals in more disadvantaged and precarious work situations at the organizational, community, and federal levels [161]. Given voter support (75%) for federal policies aimed at providing increased access to paid leave [162], future research should seek to understand the best methods for increasing participation in the electoral process, as this could be an integral step in electing representatives that are motivated to form policies impacting these issues.

3.3.2. Implications for Practice

Given recent advances of industry leaders (e.g., Disney, Starbucks, Ikea) raising their organization's minimum wage, more organizations should consider proactively making these changes in an effort to foment employee wage growth. Additionally, governments, industry groups, and employers should consider increasing employee social safety benefits to help counteract lack of wage growth and threats of growing income inequality. To help counteract decreases in new offer and rehire wage growth, organizations need to consider developing long-term plans for restoring wages to pre-pandemic levels to help accelerate post-recession wage growth. Industry groups and governments can help provide businesses with guidance on restoring pre-pandemic wages over a specified time period [163]. For instance, specific recommendations are centered around using policy to restore economic power to the bottom 90% of employees as well as protecting employees' rights for collective bargaining for better wages and working conditions, which have implications for a variety of public health outcomes.

The pandemic underlined that many Americans did not have adequate access to paid sick and family leave prior to the pandemic; despite responses to the pandemic, many still lack adequate access to leave. Providing adequate access to paid sick and family leave (as

well as hazard pay, when necessary) is essential for maintaining a healthy and productive workplace and ensuring that the well-being needs of the workforce and their families are met. This includes the expansion of both traditional benefits as well as additional resources that enhance employee well-being (e.g., on-site health services). Given that such policies may prove costly for small businesses, government subsidies would be beneficial in allowing smaller companies to provide these benefits to their employees. Thus, it would be prudent for both government and private organizations to rethink their pre-pandemic benefit policies and consider expanding them beyond the pandemic.

Given the potential long delay in passing legislation, it would be beneficial for organizations to take an active role in providing these resources to employees in the meantime. Ensuring that all employees have adequate access to health- and well-being-related benefits is a crucial step in alleviating inequities and promoting appropriate health-related behavior for employees (e.g., staying home when sick). Organizations and industry groups should look to put forth policies targeted toward the needs of their workers, especially for segments of their workforce that tend to have limited access to employee benefits (e.g., women and minorities employed in blue-collar work and service jobs). Policies should be focused on improving safety, reducing potential for injury, especially in the context of blue-collar jobs (e.g., agriculture, construction), and promoting psychological and emotional well-being. We also encourage practitioners to challenge the use of the label "benefits" to describe health-related practices such as sick leave or parental leave. This terminology implies these employee resources are not necessary when in fact they are foundational to maintaining a healthy workforce. Given that current Department of Labor policy explicitly describes these resources as benefits, this will require sustained partnerships at the federal level to change how we think about essential health related resources, such as paid sick leave and family leave [164].

4. Organization of Work

Occupational safety and health and future of work initiatives highlight the role of work processes and organizational practices as important contributors to worker health and well-being, through shaping the demands faced at work and workers' abilities to manage and flourish in their roles outside of work [7,165]. The pandemic has disrupted workplace norms and practices (e.g., social distance requirements), introduced new hazards (e.g., COVID-19 exposure), increased individual demands with short-staffing (e.g., overwork) and invaded the non-work domain (e.g., work-life conflict). These issues have been identified as contributors to stress, loneliness, and burnout, suggesting that the pandemic has negatively impacted the mental health of employees [166–168]. This section focuses on the impact the pandemic has had on trends related to the work-life balance and mental health of workers.

4.1. Work-Life Balance

4.1.1. Pre-Pandemic Trends

There has been growing research interest in work-life balance as a determinant of psychological well-being. Work-life balance is defined as an "accomplishment of role-related expectations that are negotiated and shared between an individual and his or her role-related partners in the work and family domains" [169] (p. 458). Alternatively, work-life conflict reflects an incompatibility between work and non-work domains [170]. This conflict is typically studied from a 'work interfering with family' perspective (WIF) or from a 'family interfering with work' perspective (FIW) [171].

Pre-pandemic research points to differences among groups of workers in terms of work-life balance [171]. A 2005 meta-analysis found that men reported slightly more WIF whereas women have reported slightly more FIW [172]. Additionally, parents with more children report more conflict, with single parents, particularly working mothers, reporting higher levels of conflict [172]. Those with higher segmentation (i.e., keeping work and life separate) preferences rather than integration (i.e., blurring work and life boundaries)

preferences were less likely to experience work-life conflict [173]. Importantly, those with less income are less likely to experience work-life balance due to the lack of bargaining power with one's work [174,175]. Despite these individual differences, writers caution that work-life balance is a societal issue rather than one simply belonging to one worker group [176].

Organizational policies play a role in workers' experiences of work-life balance and conflict. Relevant policies include flextime (i.e., adjusting when you work on a particular day), compressed work weeks, telework, remote work, and various forms of leave [177]. While these arrangements may not apply to all occupations (e.g., nurses largely cannot work remotely), other allowances (e.g., flexible shift scheduling for nurses) can be afforded to help employees achieve work-life balance [178]. Along with flexible practices, organizational culture can play a role in promoting work-life balance [179]. Research has suggested that, while flexibility practices are generally helpful in decreasing work-life conflict [177], inequalities exist in the accessibility of these practices. For example, although lower-income workers (e.g., retail food, hotel) benefit the most from flextime, they are also least likely to have access to flextime [180]. Overall, BLS data suggests the percentage of full-time wage and salary workers who have adjusted their start and stop times in some way had gone from 27.6% in 1997, to 57% by 2018 [181,182]. In terms of family leave, 12% of civilian workers had access to paid family leave in March 2012 and that percentage had risen to 17% in March 2018 [183,184]. In line with future of work trends [185], available data suggests organizational policies promoting work-life balance have become slightly more common over the past decade. However, even before the pandemic, there were childcare deserts, especially in lower income neighborhoods [186].

4.1.2. Pandemic Trends

For many workers, the rapid spread of remote work has augmented challenges associated with blurring the lines between the work and family domains (i.e., decreased segmentation). In particular, BLS data suggests that employees in the private sector have been consistently working more hours per week on average since May 2020 compared to pre-pandemic levels [187]. This is particularly true for industries that are well-suited for remote work (e.g., finance) as compared to industries like manufacturing and hospitality [36,187]. While longer workdays may be the norm for remote workers, it is difficult to assess whether this increase is offset by the removal of commuting which has been noted as a benefit for many remote workers [188].

Meanwhile, essential workers, or workers identified as necessary to the everyday functioning of society (e.g., healthcare workers, grocery workers), have experienced increased stress as a result of overwork and have not had access to the paid leave that they need as a result of being exposed to COVID-19 or taking care of exposed loved ones at home [189]. On top of the inherent increased risk essential workers face by interacting face-to-face with people, research has found these individuals did not decrease their mobility patterns with the onset of the pandemic suggesting higher transmission risk [190]. This is likely a result of essential workers having less flexibility in meeting their responsibilities, thus forcing them to carry on their day-to-day work in spite of the increased virus-related risk [191]. Black or African American workers are more likely to be employed in essential industries, especially those with lower pay [192,193]. Many of those employed in essential occupations (e.g., home health aides, other health care support roles) also have an increased prevalence of underlying health conditions or risk factors [194], making the greater risk of work-related exposure to the COVID-19 virus particularly dangerous. As noted previously, bargaining power to establish work-life balance is lower among low-income individuals, further exacerbating threats to essential worker's health and well-being [174,195]. To put it bluntly, there have been two realities for workers in the USA during the pandemic. In one, employees have been forced to adapt as work abruptly invaded their home. In the other, workers attempt to balance physical, mental, and financial survival as they are exposed to safety risks, suffer higher stress and burnout, and lack supportive organizational policies.

With widespread closures still impacting schools and other childcare arrangements, it is clear that the pandemic has especially impacted work-life balance for working parents. The implementation of remote learning from home during standard business hours means that working parents have had to manage both work and family roles simultaneously—or make new provisions for childcare. According to two independent studies, mothers were disproportionately impacted by the pandemic in terms of unemployment, labor force participation, and a slower recovery than other non-parent adults [196,197]. Additionally, the number of families with at least one member unemployed increased to 8.1 million in 2020 compared to 4.1 million in 2019 [198]. Specifically, women with children under 18 decreased in labor force participation, which includes both employment as well as looking for employment, from 72.3% in 2019 to 71.2% in 2020 [198]. Taken in conjunction, these findings suggest many mothers have withdrawn from the workforce to some extent, likely as a result of increasing caretaking responsibilities. As Robinson, Engelson, and Hayes [199] argued with reference to childcare issues faced by workers in the healthcare sector, "This poses incalculable risks to families, science, and society."

4.2. Mental Health

4.2.1. Pre-Pandemic Trends

According to data from the Substance Abuse and Mental Health Services Administration (SAMHSA), mental health issues have been increasing for several years among USA adults before the pandemic. As of 2019, approximately 20.6% of adults reported having any mental illness, reflecting a 2.9% increase since 2008 [200]. The percentage of adults with any mental illness receiving services also increased from 40.9% in 2008 to 44.8% in 2019 [200]. At the same time, however, 26% of adults with any mental illness perceived an unmet mental health service need; this is a higher percentage than every year since 2008 [200]. Substance use disorders co-occurring with mental illness among adults had also increased from 3.3% in 2015 to 3.8% in 2019 [200]. Similarly, both researchers and popular press articles have observed that fatigue and burnout are on the rise [201–203], leading to increased threats of workplace accidents and stress [204,205].

In a survey by the American Heart Association CEO Roundtable, 76% of workers reported having struggled with an issue which impacted their mental health in 2018, with 42% of those respondents having been diagnosed [206]. Comparing data from 2003–2012, researchers found some industries, like management and manufacturing, reported decreasing rates of substance use disorders while other industries remained largely the same [207].

Employee assistance programs (EAPs) represent one way organizations have tried to provide resources to employees afflicted with mental health disorders; however, sources indicate utilization rates were below 10% before the pandemic, bringing doubt to their value and reach [208]. Some experts have predicted further expansions into mental health benefits as part of employer health benefits plans, potentially as a result of industry trends [209]. In a survey gauging workplace health promotion in the USA, nearly half (46.1%) of the responding worksites had a workplace health promotion program in place with occupational safety programs representing the majority of workplace health-related programs [210]. Generally, small worksites (10–24 employees) were less likely to have a program in place than larger organizations [210]. This is concerning considering that, at the time, approximately 21 million people (16.4% of private sector employees) worked for businesses with fewer than 20 employees [211].

4.2.2. Pandemic Trends

Emerging research points to the pandemic as a major challenge for mental health due to isolation, threats to life and livelihoods, and extreme working conditions. One study found that, whereas the prevalence of depressive symptoms among USA adults was about 8.5% before the pandemic, by April of 2020, that percentage leapt to 27.8% [212]. Low income, having less than $5000 in savings, and COVID-19 exposure were associated with greater risk of depression [212]. Additionally, the prevalence of substance use and

suicidal ideation among employed individuals has been shown to have increased as a result of trauma or stress-related disorders associated with the pandemic [213]. While all workers have been impacted by the pandemic, essential workers (e.g., healthcare workers, grocers) have carried a particularly large burden [213–215]. Research indicates increased suicidal ideation (21.7%) and at least one adverse mental or behavioral health symptom (54.0%) among many essential workers [213,214]. It is important to note that women are overrepresented in this type of work, including in healthcare [216]. Thus, such mental health effects further contribute to the pandemic's disproportionate impacts on women.

In a similar vein, workers are experiencing unprecedented levels of fatigue and burnout [217,218]. Among those suffering the most, healthcare workers directly dealing with COVID-19 patients are experiencing heightened physical and mental fatigue, as well as burnout [219]. Other groups of essential workers (e.g., service workers, grocery store employees) have similarly reported mental strain as well as fear and frustration over the burden they face at work due to a lack of resources and workplace and community support [58,220]. Additionally, healthcare workers are reporting increases in compassion fatigue, or an inability to care for patients largely due to the overwhelming nature of the task at hand [221]. The current surge is likely to exacerbate this further [222]. These reports suggest the potential for serious long-term mental health ramifications, particularly among essential employees.

While organizations have largely increased communication efforts in promoting EAPs in response to the pandemic, there is little evidence to suggest significant improvements to the mental health resources offered across a majority of organizations [223]. Even among public health employees, data suggests that only 11.7% used EAPs during March and April 2021 despite 66.1% having EAP availability [224]. However, telehealth appointments have risen, which may have the benefit of expanding reach and coverage of mental health and other healthcare services. One report has found telehealth visits increased 154% in the last week of March 2020, when compared to the same time period in March 2019 [225]. Overall, the pandemic has exacerbated mental health issues in the USA, necessitating greater mental health prioritization among organizations, industry associations, and policymakers alike.

4.3. Implications

4.3.1. Implications for Research

It will remain paramount for research to monitor mental health among workers, and those forced to leave the labor force. For the foreseeable future, remote workers are subject to increased isolation while essential employees continue to face a very different reality of having to balance personal risk with their financial needs [213,214,226]. This kind of disruption has likely affected the way these workers have considered their work-life balance. Remote workers struggle to balance multiple roles (e.g., childcare and employee) with no clear boundaries [227]. Essential workers also must juggle these roles while simultaneously pitting their mental and physical health against their financial security [228,229]. Future research will need to examine the role of organizational and government policies and practices in enabling workers to cope with these challenges and attenuating the long-term negative effects on employee well-being and mental health. There is a particular need for research to examine the experiences of essential workers during and after the pandemic. This research will need to acknowledge the over-representation of racial and ethnic minorities as well as women in 'essential' occupations [205,230]. In general, research is needed to understand how the stressors and demands of the pandemic shape people's health risks and health behaviors both proximally and distally. For example, poor diet and alcohol consumption as a result of the pandemic can increase cardiovascular health risk and may have other health implications as well (e.g., poor mental health) [231].

The pandemic has made mothers, in even some of the more egalitarian societies in the world, reckon with the impacts of gender norms [232]. As we hopefully enter a post-pandemic time period, research will need to investigate the long-term effects of this impact and consider if and how mothers and other caretakers who left the workforce

choose to re-enter. Considering how abruptly many caretakers had to withdraw from the workforce as a result of at-home responsibilities, it is critical to examine the role flexible arrangements or other practices play in assisting re-entry into the workforce and subsequent work-life balance. Additionally, it will be worthwhile to examine the extent to which the workforce in general comes to value greater work-life balance as a result of experiences during the pandemic, as has been proclaimed by popular press reporting of the 'Great Resignation.' [233]. Although prognostications about the future of work have speculated for decades that technological advances would leave more time for leisure, this has not come to fruition. It may be a crisis, rather than technological capabilities, that catalyzes greater movement towards work-life balance and workplace well-being.

Research should continue analyzing the effectiveness of EAPs in organizations in an effort to understand the degree and consequences of underutilization. Additionally, research should consider what kind of alternative mental health resources can be provided by organizations to better support their workers as well as how healthy work design practices can reduce ill-being during crises. Finally, with the rise of telehealth, research is needed to understand changes that can be made to enhance its accessibility and effectiveness as a tertiary intervention strategy [234,235].

As the pandemic evolves and different workplaces and governments enact a range of different policies, research is needed to understand how these changing policies (and uncertainty around these policies) impact workplaces and worker physical and mental health. Research is needed to examine how the inconsistent enactment of health and safety policies across workplaces, states, and national governments may further enhance health inequities faced by workers. Researching national and organizational responses around the world could help provide guidance to practitioners and policymakers to make the informed and appropriate decisions for both the current pandemic and future similar events that may arise.

4.3.2. Implications for Practice

Industries and organizations need to consider how their culture shapes the way employees view issues like mental health and work-life balance. Internal communications using language that encourages self-sacrifice and less segmentation, as well as organizational practices that are not equitable and understanding of different employees' life situations will only exacerbate work-life conflict [236]. Researchers have advocated for policies that increase access to paid sick and family leave, mandate emergency backup staffing especially among essential services, and allow employees to request flexible and reasonable work hours [237]. While these requests may seem like a tall order, research originating in the UK suggests labor union participation and collective bargaining can be pivotal in achieving such policy initiatives [238].

As discussed earlier, more individuals have been able to engage in remote work than ever before. Employees and employers are now grappling with establishing where the line between work and non-work starts and ends. Flexible work practices can be one tool for workers to better manage their work-life balance. Workers unable to work remotely can still benefit from other forms of flexibility (e.g., flextime, compressed workweeks) [178], strengthening the call for policymakers and organizations to increase the availability of multiple forms of flexible work arrangements. At the same time, it is important that workers have a voice in determining their schedules and that work provides a means for financial sufficiency. Expansions in organizational and governmental policies would allow more employees, especially those disproportionately impacted by the pandemic, to carve out their own form of work-life balance.

The severity of the current landscape of mental health among workers (and those forced to leave the labor force) suggests that mental health treatment needs to extend beyond EAPs [223]. Organizations should consider playing a more active role in facilitating mental health resources for their employees like utilizing health advocates that help company employees with a variety of requests, such as help with making appointments and

ensuring they are knowledgeable in how to use mental health resources available to them. Organizations have an important role to play in providing safe workplaces, resources, and support to promote employee welfare.

While recommendations might be made to help ease some of the negative impacts of the pandemic on an individual level, it is important to realize the magnitude of this event and in doing so, recognize the need for large-scale remedies, such as those provided by public policy and legislation. Greater unemployment benefits, leave policies, and access to healthcare would not only benefit employees who utilize these resources; it should also provide a safety net that could reduce the impact of job insecurity on well-being [237,239]. The upheavals associated with the pandemic have illustrated the importance for future of work preparations to consider both work-engendered trends (e.g., remote work) and disruptive events that can shape how these trends will unfold over time [240].

5. Conclusions

Speculation on what the future of work will look like is rampant. As summarized in Table 1, the pandemic has accelerated certain trends associated with the future of work, while shifting the course of others. Unfortunately, many of the changes induced by the pandemic appear to exacerbate work-related inequities, which have critical implications for health. Our analysis suggests there are important opportunities for researchers and practitioners to address these trends and lead the way in creating a healthier and safer future of work in America.

Table 1. Summary of the pandemic's impact on the future of work topics.

Future of Work Topic	Pandemic Trend Impact Summary
Remote Work	There is reason to expect a long-term increase in the prevalence of remote work, particularly among specific industries and demographic groups.
Gig Work	The pandemic disrupted the gig economy by shifting demand and increasing competition as more workers looked toward gig work to compensate for unemployment or underemployment.
Displacement of Work	The pandemic's onset brought about widespread unemployment, especially amongst vulnerable populations (e.g., racial minorities and women, particularly mothers). Despite early signs of economic recovery, the long-term implications of unemployment and underemployment must not be overlooked.
Compensation	Wage inequality and wage growth trends both suggest the growing wage inequality pre-pandemic has been exacerbated during the pandemic while employee wage growth levels have been stagnant.
Benefits	The pandemic has spurred a number of federal and state policies targeted at increasing employee access to benefits (e.g., unemployment, paid leave). However, evidence suggests disproportionate racial and gender inequalities in employer-provided benefits remain.
Work-Life Balance	Overall, the pandemic has presented several different challenges for work-life balance. While some have been forced to adapt to work's intrusion of the home space, others risk their physical, mental, and financial well-being in order to continue working in person.
Mental Health	Despite the increase in telehealth utilization, mental health concerns (either diagnosed or undiagnosed) increased, in part due to a confluence of financial, physical, and emotional strains brought on by the pandemic.

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References

1. Ansell, C.; Boin, A.; Keller, A. Managing transboundary crises: Identifying the building blocks of an effective response system. *J. Contingencies Crisis Manag.* **2010**, *18*, 195–207. [CrossRef]
2. Shoss, M. Occupational health psychology research and the COVID-19 pandemic. *J. Occup. Health Psychol.* **2021**, *26*, 259–260. [CrossRef] [PubMed]
3. Cascio, W.F.; Montealegre, R. How technology is changing work and organizations. *Annu. Rev. Organ. Psychol. Organ. Behav.* **2016**, *3*, 349–375. [CrossRef]
4. Clauson, M. The future of work. In *The Cambridge Handbook of the Changing Nature of Work*; Hoffman, B., Shoss, M., Wegman, L., Eds.; Cambridge University Press: New York, NY, USA, 2020; pp. 555–582.
5. Shoss, M.; Eisenberger, R.; Lee, J.; Lewis, B.A.; Manteethai, D.; Wen, X.; Yu, J.; Zheng, J. Implications of the changing nature of work for the employee-organization relationship. In *The Cambridge Handbook of the Changing Nature of Work*; Hoffman, B., Shoss, M., Wegman, L., Eds.; Cambridge University Press: New York, NY, USA, 2020.
6. White, J.; Behrend, T.; Sideritis, I. Changes in technology. In *The Cambridge Handbook of the Changing Nature of Work*; Hoffman, B., Shoss, M., Wegman, L., Eds.; Cambridge University Press : New York, NY, USA, 2020; pp. 69–100.
7. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef] [PubMed]
8. Howard, J. Nonstandard work arrangements and worker health and safety. *Am. J. Ind. Med.* **2017**, *60*, 1–10. [CrossRef]
9. Ray, T.K.; Tat'Yana, A.K.; Pana-Cryan, R. Employment arrangement, job stress, and health-related quality of life. *Saf. Sci.* **2017**, *100*, 46–56. [CrossRef] [PubMed]
10. Allen, T.D.; Johnson, R.C.; Kiburz, K.M.; Shockley, K.M. Work–family conflict and flexible work arrangements: Deconstructing flexibility. *Pers. Psychol.* **2013**, *66*, 345–376. [CrossRef]
11. Society for Human Resource Management. Full Poll Results: Telework in the Time of Covid-19. SHRM. Available online: https://www.shrm.org/hr-today/news/hr-news/pages/poll-telework-coronavirus-full-results.aspx (accessed on 7 July 2021).
12. Meister, J. Flexible Workspaces: Employee Perk or Business Tool to Recruit Top Talent? Forbes. Available online: https://www.forbes.com/sites/jeannemeister/2013/04/01/flexible-workspaces-another-workplace-perk-or-a-must-have-to-attract-top-talent/?sh=531a99132ce7 (accessed on 1 April 2013).
13. Kurtzberg, T.R. Feeling creative, being creative: An empirical study of diversity and creativity in teams. *Creat. Res. J.* **2005**, *17*, 51–65. [CrossRef]
14. Morrison-Smith, S.; Ruiz, J. Challenges and barriers in virtual teams: A literature review. *SN Appl. Sci.* **2020**, *2*, 1–33. [CrossRef]
15. U.S. Bureau of Labor Statistics. *29 Percent of Wage and Salary Workers Could Work at Home in Their Primary Job in 2017–18*; U.S. Bureau of Labor Statistics: Washington, DC, USA. Available online: https://www.bls.gov/opub/ted/2019/29-percent-of-wage-and-salary-workers-could-work-at-home-in-their-primary-job-in-2017-18.htm (accessed on 30 September 2019).
16. Gariety, B.S.; Shaffer, S. Wage differentials associated with working at home. *Mon. Labor Rev.* **2007**, *130*, 61–67.
17. Waizenegger, L.; McKenna, B.; Cai, W.; Bendz, T. An affordance perspective of team collaboration and enforced working from home during COVID-19. *Eur. J. Informat. Syst.* **2020**, *29*, 429–442. [CrossRef]
18. Winger, A.R. Face-to-face communication: Is it really necessary in a digitizing world? *Busi. Horiz.* **2005**, *48*, 247–253. [CrossRef]
19. van der Meulen, N.; van Baalen, P.; van Heck, E.; Mülder, S. No teleworker is an island: The impact of temporal and spatial separation along with media use on knowledge sharing networks. *J. Inf. Technol.* **2019**, *34*, 243–262. [CrossRef]
20. Toscano, F.; Zappalà, S. Social isolation and stress as predictors of productivity perception and remote work satisfaction during the COVID-19 pandemic: The role of concern about the virus in a moderated double mediation. *Sustainability* **2020**, *12*, 9804. [CrossRef]
21. Wang, W.; Albert, L.; Sun, Q. Employee isolation and telecommuter organizational commitment. *Empl. Relat. Int. J.* **2020**, *42*, 609–625. [CrossRef]

22. Rognes, J. Telecommuting resistance, soft but strong: Development of telecommuting over time, and related rhetoric. *SSE/EFI Work. Pap. Ser. Bus. Adm.* **2002**, *2002*, 1–16.
23. McDonald, P.; Bradley, L.; Brown, K. Visibility in the workplace: Still an essential ingredient for career success? *Int. J. Hum. Resour. Manag.* **2008**, *19*, 2198–2215. [CrossRef]
24. Maruyama, T.; Tietze, S. From anxiety to assurance: Concerns and outcomes of telework. *Pers. Rev.* **2012**, *41*, 450–469. [CrossRef]
25. Serrat, O. Managing virtual teams. In *Knowledge Solutions*; Springer: Berlin/Heidelberg, Germany, 2017; pp. 619–625.
26. U.S. Bureau of Labor Statistics. *Supplemental Data Measuring the Effects of the Coronavirus (COVID-19) Pandemic on the Labor Market*; U.S. Bureau of Labor Statistics: Washington, DC, USA. Available online: https://www.bls.gov/cps/effects-of-the-coronavirus-covid-19-pandemic.htm (accessed on 10 August 2021).
27. Feitosa, J.; Salas, E. Today's virtual teams: Adapting lessons learned to the pandemic context. *Organ. Dyn.* **2020**, 10077. [CrossRef]
28. Pettijohn, N. Can We Just Work from Home Forever? Available online: https://www.forbes.com/sites/nathanpettijohn/2020/05/20/can-we-just-work-from-home-forever/#2f5673e13d95 (accessed on 27 October 2020).
29. Thompson, C. What If Working from Home Goes on . . . Forever? Available online: https://www.nytimes.com/interactive/2020/06/09/magazine/remote-work-covid.html (accessed on 27 October 2020).
30. Saad, L.; Jones, J.M. Seven in 10 U.S. White-Collar Workers Still Working Remotely. *Gallup.com*. Available online: https://news.gallup.com/poll/348743/seven-u.s.-white-collar-workers-still-working-remotely.aspx (accessed on 16 August 2021).
31. Harvard Business School. *Survey Shows Professionals Excelled While Working from Home*; Harvard Business School: Boston, MA, USA. Available online: https://online.hbs.edu/blog/post/future-of-work-from-home (accessed on 25 March 2021).
32. U.S. Bureau of Labor Statistics. *Labor Force Statistics from the Current Population Survey*; U.S. Bureau of Labor Statistics: Washington, DC, USA. Available online: https://www.bls.gov/cps/cpsaat18.htm (accessed on 30 July 2021).
33. Levy, A. Tech Companies are Ending Leases and Consolidating Offices as Remote Work is Here to Stay. *CNBC*, 13 July 2020.
34. Stoller, K. Never Want to Go Back to the Office? Here's Where you Should Work. *Forbes*. Available online: https://www.forbes.com/sites/kristinstoller/2021/01/31/never-want-to-go-back-to-the-office-heres-where-you-should-work/?sh=2056cc146712 (accessed on 20 April 2021).
35. Maurer, R. Half of Workers Wish to Remain Remote Permanently. *SHRM*. Available online: https://www.shrm.org/hr-today/news/hr-news/pages/shrm-half-workers-wish-remain-remote-permanently.aspx (accessed on 6 July 2021).
36. Dey, M.; Frazis, H.; Loewenstein, M.A.; Sun, H. Ability to work from home. *Mon. Labor Rev.* **2020**, *7*, 1–19.
37. Torpey, E.; Hogan, A. Working in a Gig Economy: Career Outlook. U.S. Bureau of Labor Statistics. Available online: https://www.bls.gov/careeroutlook/2016/article/what-is-the-gig-economy.htm (accessed on 27 August 2021).
38. U.S. Bureau of Labor Statistics. *(2018, June 7). Contingent and Alternative Employment Arrangements Summary*; U.S. Bureau of Labor Statistics: Washington, DC, USA. Available online: https://www.bls.gov/news.release/conemp.nr0.htm (accessed on 7 June 2018).
39. DePillis, L. There Are Fewer Gig Jobs than You Think. Economists Walk Back Study that Showed Huge Increase. *CNN*. Available online: https://www.cnn.com/2019/01/07/economy/gig-economy-katz-krueger/index.html (accessed on 10 January 2019).
40. Murphy, K.R.; Tierney, W. What Has Changed and What Has Not? In *The Cambridge Handbook of the Changing Nature of Work*; Hoffman, B., Shoss, M., Wegman, L., Eds.; Cambridge University Press: New York, NY, USA, 2020; pp. 42–66.
41. Hagel, J.; Schwartz, J.; Bersin, J. Navigating the future of work. *Deloitte Rev.* **2017**, *21*, 27–45.
42. Storey, D.; Davis, C. How the Gig Economy Is Changing the Workforce. *EY*. Available online: https://www.ey.com/en_us/tax/how-the-gig-economy-is-changing-the-workforce (accessed on 20 November 2018).
43. DePillis, L. Gig Economy Jobs Aren't Really Taking Over America's Workforce. *CNNMoney*. Available online: https://money.cnn.com/2018/06/07/news/economy/contingent-workers-bls-gig-economy/index.html (accessed on 7 June 2018).
44. Park, J.; Han, B.; Park, J.S.; Park, E.J.; Kim, Y. Nonstandard workers and differential occupational safety and health vulnerabilities. *Am. J. Ind. Med.* **2019**, *62*, 701–715. [CrossRef]
45. McFeely, S.; Pendell, R. What Workplace Leaders Can Learn from the Real Gig Economy. *Gallup.com*. Available online: https://www.gallup.com/workplace/240929/workplace-leaders-learn-real-gig-economy.aspx (accessed on 16 August 2018).
46. Bussewitz, C.; Olson, A. Gig Workers Face Shifting Roles, Competition in Pandemic. *AP NEWS*. Available online: https://apnews.com/article/understanding-the-outbreak-virus-outbreak-us-news-ap-top-news-ca-state-wire-ebc223c6d783c49feca6ffb27af6264b (accessed on 4 July 2020).
47. Yohn, D.L. How Airbnb Survived the Pandemic-and How you Can Too. *Forbes*. Available online: https://www.forbes.com/sites/deniselyohn/2020/11/10/how-airbnb-survived-the-pandemic--and-how-you-can-too/?sh=27d6fb359384 (accessed on 10 November 2020).
48. Trentmann, N. Airbnb Adapts to the Post-Pandemic Traveler-and Host. *The Wall Street Journal*. Available online: https://www.wsj.com/articles/airbnb-post-pandemic-travel-11623429935 (accessed on 11 June 2021).
49. Roose, K. The Robots are Coming for Phil in Accounting. *The New York Times*. Available online: https://www.nytimes.com/2021/03/06/business/the-robots-are-coming-for-phil-in-accounting.html?searchResultPosition=10 (accessed on 6 March 2021).
50. Hasija, S.; Padmanabhan, V.; Rampal, P. Will the Pandemic Push Knowledge Work into the Gig Economy? *Harvard Business Review*. Available online: https://hbr.org/2020/06/will-the-pandemic-push-knowledge-work-into-the-gig-economy (accessed on 1 June 2020).

51. Baker, M. 9 Future of Work Trends Post-COVID-19. Smarter with Gartner. Available online: https://www.gartner.com/smarterwithgartner/9-future-of-work-trends-post-covid-19/ (accessed on 8 June 2020).
52. Autor, D.; Reynolds, E. The Nature of Work after the COVID Crisis: Too Few Low-Wage Jobs. Available online: https://www.brookings.edu/wp-content/uploads/2020/08/AutorReynolds_LO_FINAL.pdf (accessed on 27 August 2021).
53. Bapuji, H.; Patel, C.; Ertug, G.; Allen, D.G. Corona crisis and inequality: Why management research needs a societal turn. *J. Manag.* **2020**, *46*, 1205–1222. [CrossRef]
54. Liu, J. "I Simply won't be Able to Meet My Day-to-Day Living Expenses": How Coronavirus is Impacting Gig Workers. *CNBC*, 12 January 2021.
55. Purkayastha, D.; Vanroelen, C.; Bircan, T.; Vantyghem, M.A.; Gantelet Adsera, C. Work, Health and Covid-19: A Literature Review. ETUI Research Paper-Report. 2021. Available online: https://www.etui.org/sites/default/files/2021-03/Work%2C%20health%20and%20Covid-19%20a%20literature%20review_2021_WEB.pdf (accessed on 27 August 2021).
56. Wulfhorst, E. Driving in Storm of Coronavirus, U.S. Gig Workers Face Risks. *Reuters*. Available online: https://www.reuters.com/article/us-health-coronavirus-gigeconomy-trfn/driving-in-storm-of-coronavirus-u-s-gig-workers-face-risks-idUSKBN20R39Q (accessed on 4 March 2020).
57. Pardes, A. Is It Ethical to Order Delivery during a Pandemic? *Wired*. Available online: https://www.wired.com/story/coronavirus-food-delivery-gig-economy/ (accessed on 11 March 2020).
58. Mull, A. American Shoppers Are a Nightmare. *The Atlantic*. Available online: https://www.theatlantic.com/health/archive/2021/08/pandemic-american-shoppers-nightmare/619650/ (accessed on 5 August 2021).
59. Vigdor, N. Restaurant Shuts Down for a "Day of Kindness" after Customers Make Its Staff Cry. *The New York Times*. Available online: https://www.nytimes.com/2021/07/14/us/apt-cape-cod-restaurant-workers-covid.html?campaign_id=154&emc=edit_cb_20210714&instance_id=35347&nl=coronavirus-briefingi_id=92462106&segment_id=63476&te=1&user_id=d4895de9a7206ce834e77386d46d793d (accessed on 14 July 2021).
60. Reder, L.; Steward, S.; Foster, N. Designing Portable Benefits: A Resource Guide for Policymakers. *The Aspen Institute*. Available online: https://www.aspeninstitute.org/wp-content/uploads/2019/06/Designing-Portable-Benefits_June-2019_Aspen-Institute-Future-of-Work-Initiative.pdf (accessed on 24 September 2021).
61. Kuhn, P.J. Losing Work, Moving on: International Perspectives on Worker Displacement. W. E. Upjohn Institute for Employer Research. Available online: https://doi.org/10.17848/9781417505333 (accessed on 27 August 2021).
62. Frey, C.B.; Osborne, M. *The Future of Employment*; University of Oxford: Oxford, UK. Available online: https://sep4u.gr/wp-content/uploads/The_Future_of_Employment_ox_2013.pdf (accessed on 27 August 2021).
63. Rifkin, J. *End of Work*; Pacifica Radio Archives: New York, NY, USA, 1996.
64. Schwab, K. The Fourth Industrial Revolution: What It Means and How to Respond. *World Economic Forum*. Available online: https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/?fbclid=IwAR1Np1fXQagtCF8ivsGTyWW-op1LlBdzHzvPmzdsoPVDd1v4l0bHEvJBMzQ (accessed on 14 January 2016).
65. U.S. Bureau of Labor Statistics. *Civilian Unemployment Rate*; U.S. Bureau of Labor Statistics: Washington, DC, USA. Available online: https://www.bls.gov/charts/employment-situation/civilian-unemployment-rate.htm (accessed on 27 August 2021).
66. U.S. Bureau of Labor Statistics. *Alternative Measures of Labor Underutilization for States*; U.S. Bureau of Labor Statistics: Washington, DC, USA. Available online: https://www.bls.gov/lau/stalt.htm (accessed on 23 July 2021).
67. Federal Reserve Bank of, St. Louis. Labor Force Participation Rate. Federal Reserve Economic Data. Available online: https://fred.stlouisfed.org/series/CIVPART (accessed on 6 August 2021).
68. U.S. Bureau of Labor Statistics. *Alternative Measures of Labor Underutilization for States, 2015 Annual Averages*; U.S. Bureau of Labor Statistics: Washington, DC, USA. Available online: https://www.bls.gov/lau/stalt15q4.htm (accessed on 10 March 2016).
69. U.S. Bureau of Labor Statistics. *Alternative Measures of Labor Underutilization for States, 2019 Annual Averages*; U.S. Bureau of Labor Statistics: Washington, DC, USA. Available online: https://www.bls.gov/lau/stalt19q4.htm (accessed on 31 January 2020).
70. U.S. Bureau of Labor Statistics. *Alternative Measures of Labor Underutilization for States, Third Quarter of 2020 through Second Quarter of 2021 Averages*; U.S. Bureau of Labor Statistics: Washington, DC, USA. Available online: https://www.bls.gov/lau/stalt.htm (accessed on 23 July 2021).
71. Nunn, R.; Parsons, J.; Shambaugh, J. Race and Underemployment in the US Labor Market. *Brookings*. Available online: https://www.brookings.edu/blog/up-front/2019/08/01/race-and-underemployment-in-the-u-s-labor-market/ (accessed on 1 August 2019).
72. U.S. Bureau of Labor Statistics. *Current Employment Statistics Highlights*; U.S. Bureau of Labor Statistics: Washington, DC, USA. Available online: https://www.bls.gov/ces/publications/highlights/2020/current-employment-statistics-highlights-03-2020.pdf (accessed on 3 April 2020).
73. Alon, T.; Doepke, M.; Olmstead-Rumsey, J.; Tertilt, M. *The Impact of COVID-19 on Gender Equality (No. w26947)*; National Bureau of Economic Research: Cambridge, MA, USA, 2020.
74. Kurtz, A. The US Economy Lost 140,000 Jobs in December. All of Them Were Held by Women. *CNN*. Available online: https://www.cnn.com/2021/01/08/economy/women-job-losses-pandemic/index.html (accessed on 9 January 2021).
75. Mahajan, D.; White, O.; Madgavkar, A.; Krishnan, M. Don't Let the Pandemic Set Back Gender Equality. *Harvard Business Review*. Available online: https://hbr.org/2020/09/dont-let-the-pandemic-set-back-gender-equality (accessed on 1 February 2021).

76. Zalis, S. Effects of the Pandemic: The Gender Gap Grew by 36 Years in Just 12 Months. *Forbes*. Available online: https://www.forbes.com/sites/shelleyzalis/2021/04/26/effects-of-the-pandemic--the-gender-gap-grew-by-36-years-in-just-12-months/?sh=2d2f02395f51 (accessed on 26 April 2021).
77. Young, M.C. Gender differences in precarious work settings. *Relat. Ind./Ind. Relat.* **2010**, *65*, 74–97.
78. Karageorge, E.X. COVID-19 Recession is Tougher on Women. Available online: https://www.bls.gov/opub/mlr/2020/beyond-bls/covid-19-recession-is-tougher-on-women.htm (accessed on 27 August 2021).
79. Landivar, L.C.; Ruppanner, L.; Scarborough, W.J.; Collins, C. Early signs indicate that COVID-19 is exacerbating gender inequality in the labor force. *Socius* **2020**, *6*, 2378023120947997. [CrossRef] [PubMed]
80. Miller, C.C. Return to Work? Not with Child Care Still in Limbo, Some Parents Say. *The New York Times*. Available online: https://www.nytimes.com/2021/08/05/upshot/covid-child-care-schools.html?fbclid=IwAR2KfEWHPzNBiVbNqd-IW6Q-klk2KnROzQ80-nPBLWHwdix0tSJuSCc4sS0#FB (accessed on 5 August 2021).
81. Cooper, D. The effect of unemployment duration on future earnings and other outcomes. *Fed. Reserve Bank Boston Work. Pap.* **2013**, *13*, 1–33. [CrossRef]
82. Davis, S.J.; Von Wachter, T.M. *Recessions and the Cost of Job Loss*; Working Paper Series; National Bureau of Economic Research: Cambridge, MA, USA, 2011; p. w17638.
83. Feeding America. The Impact of Coronavirus on Food Insecurity. Available online: https://www.feedingamerica.org/sites/default/files/2021-03/National%20Projections%20Brief_3.9.2021_0.pdf (accessed on 9 March 2021).
84. Balch, B. 54 Million People in America Face Food Insecurity during the Pandemic. It Could Have Dire Consequences for Their Health. *AAMC*. Available online: https://www.aamc.org/news-insights/54-million-people-america-face-food-insecurity-during-pandemic-it-could-have-dire-consequences-their (accessed on 15 October 2020).
85. Suliman, A. Apple to Delay Office Return until January 2022. *The Washington Post*. Available online: https://www.washingtonpost.com/nation/2021/08/20/covid-delta-variant-live-updates/#link-T2GTGKDDSNGFXDQTO3C55GZBC4 (accessed on 20 August 2021).
86. Duffy, R.D.; Blustein, D.L.; Diemer, M.A.; Autin, K.L. The psychology of working theory. *J. Couns. Psychol.* **2016**, *63*, 127–148. [CrossRef]
87. Andel, S.A.; Shen, W.; Arvan, M.L. Depending on your own kindness: The moderating role of self-compassion on the within-person consequences of work loneliness during the COVID-19 pandemic. *J. Occup. Health Psychol.* **2021**, *26*, 276–290. [CrossRef]
88. Shockley, K.M.; Gabriel, A.S.; Robertson, D.; Rosen, C.C.; Chawla, N.; Ganster, M.L.; Ezerins, M.E. The fatiguing effects of camera use in virtual meetings: A within-person field experiment. *J. Appl. Psychol.* **2021**, *106*, 1137–1155. [CrossRef]
89. Ammar, A.; Brach, M.; Trabelsi, K.; Chtourou, H.; Boukhris, O.; Masmoudi, L.; Bouaziz, B.; Bentlage, E.; How, D.; Ahmed, M.; et al. ECLB-COVID19 Consortium. Effects of COVID-19 home confinement on eating behaviour and physical activity: Results of the ECLB-COVID19 international online survey. *Nutrients* **2020**, *12*, 1583. [CrossRef]
90. Hertel, G.; Geister, S.; Konradt, U. Managing virtual teams: A review of current empirical research. *Hum. Resour. Manag. Rev.* **2005**, *15*, 69–95. [CrossRef]
91. Ravid, D.M.; Tomczak, D.L.; White, J.C.; Behrend, T.S. EPM 20/20: A Review, Framework, and Research Agenda for Electronic Performance Monitoring. *J. Manag.* **2020**, *46*, 100–126. [CrossRef]
92. Woo, E.H.C.; White, P.; Lai, C.W.K. Ergonomics standards and guidelines for computer workstation design and the impact on users' health—A review. *Ergonomics* **2016**, *59*, 464–475. [CrossRef]
93. Angelucci, M.; Angrisani, M.; Bennett, D.M.; Kapteyn, A.; Schaner, S.G. *Remote Work and the Heterogeneous Impact of Covid-19 on Employment and Health (No. w27749)*; National Bureau of Economic Research: Cambridge, MA, USA, 2020.
94. Allan, B.A.; Autin, K.L.; Wilkins-Yel, K.G. Precarious work in the 21st century: A psychological perspective. *J. Vocat. Behav.* **2021**, *126*, 103491. [CrossRef]
95. Lobell, K.O. How Hospitality Employers Are Ramping Up Recruiting Efforts. *SHRM*. Available online: https://www.shrm.org/resourcesandtools/hr-topics/employee-relations/pages/how-hospitality-employers-are-ramping-up-recruiting-efforts-.aspx (accessed on 7 June 2021).
96. Chapin, A. What Happens When All Your Co-Workers Quit? *The Cut*. Available online: https://www.thecut.com/2021/08/workers-left-behind-by-the-great-resignation.html?utm_source=pocket-newtab (accessed on 18 August 2021).
97. Spiggle, T. What Does a Worker Want? What the Labor Shortage Really Tells Us. *Forbes*. Available online: https://www.forbes.com/sites/tomspiggle/2021/07/08/what-does-a-worker-want-what-the-labor-shortage-really-tells-us/?sh=6cd8e127539d (accessed on 8 July 2021).
98. Taylor, K. A Labor Shortage is Forcing Chains Like Subway and Dunkin' to Cut Hours, Close Dining Rooms, and Push Employees to Work Harder than Ever. *Business Insider*. Available online: https://www.businessinsider.com/mcdonalds-subway-struggle-to-find-workers-forcing-changes-2021-4 (accessed on 17 April 2021).
99. Yamauchi, T.; Yoshikawa, T.; Takamoto, M.; Sasaki, T.; Matsumoto, S.; Kayashima, K.; Takeshima, T.; Takahashi, M. Overwork-related disorders in Japan: Recent trends and development of a national policy to promote preventive measures. *Ind. Health* **2017**, *55*, 293–302. [CrossRef] [PubMed]
100. Sirola, N.; Pitesa, M. Economic downturns undermine workplace helping by promoting a zero-sum construal of success. *Acad. Manag. J.* **2017**, *60*, 1339–1359. [CrossRef]

101. de Macêdo, T.A.M.; Cabral, E.L.D.S.; Silva Castro, W.R.; de Souza Junior, C.C.; da Costa Junior, J.F.; Pedrosa, F.M.; da Silva, A.B.; de Medeiros, V.R.F.; de Souza, R.P.; Cabral, M.A.L.; et al. Ergonomics and telework: A systematic review. *Work* **2020**, *66*, 777–788. [CrossRef]
102. Almoqbel, M.Y.; Wohn, D.Y. Individual and collaborative behaviors of rideshare drivers in protecting their safety. *Proc. ACM Hum.-Comput. Interact.* **2019**, *217*, 1–21. [CrossRef]
103. Christie, N.; Ward, H. The health and safety risks for people who drive for work in the gig economy. *J. Transp. Health* **2019**, *13*, 115–127. [CrossRef]
104. Probst, T.M.; Petitta, L.; Barbaranelli, C.; Lavaysse, L.M. Moderating effects of contingent work on the relationship between job insecurity and employee safety. *Saf. Sci.* **2018**, *106*, 285–293. [CrossRef]
105. De Cuyper, N.; Sora, B.; De Witte, H.; Caballer, A.; Peiró, J.M. Organizations' use of temporary employment and a climate of job insecurity among Belgian and Spanish permanent workers. *Econ. Ind. Democr.* **2009**, *30*, 564–591. [CrossRef]
106. Tran, M.; Sokas, R.K. The gig economy and contingent work: An occupational health assessment. *J. Occup. Environ. Med.* **2017**, *59*, 63–66. [CrossRef]
107. Del Boca, D.; Oggero, N.; Profeta, P.; Rossi, M. Women's and men's work, housework and childcare, before and during COVID-19. *Rev. Econ. Househ.* **2020**, *18*, 1001–1017. [CrossRef] [PubMed]
108. Zamarro, G.; Prados, M.J. Gender differences in couples' division of childcare, work and mental health during COVID-19. *Rev. Econ. Househ.* **2021**, *19*, 11–40. [CrossRef] [PubMed]
109. Nunley, J.M.; Pugh, A.; Romero, N.; Seals, R.A. The effects of unemployment and underemployment on employment opportunities: Results from a correspondence audit of the labor market for college graduates. *ILR Rev.* **2017**, *70*, 642–669. [CrossRef]
110. Sun, X.; McHale, S.M.; Crouter, A.C. Perceived underemployment and couple relationships among African American parents: A dyadic approach. *Cult. Divers. Ethn. Minority Psychol.* **2020**, *26*, 82–91. [CrossRef]
111. Henrickson, M. Kiwis and COVID-19: The aotearoa New Zealand response to the global pandemic. *Int. J. Community Soc. Dev.* **2020**, *2*, 121–133. [CrossRef]
112. Parker, R.W. Why America's Response to the COVID-19 Pandemic Failed: Lessons from New Zealand's Success. *Adm. Law Rev.* **2021**, *73*, 77.
113. Charoensukmongkol, P.; Phungsoonthorn, T. The interaction effect of crisis communication and social support on the emotional exhaustion of university employees during the COVID-19 crisis. *Int. J. Bus. Commun.* **2020**, 2329488420953188. [CrossRef]
114. Manyika, J.; Lund, S.; Chui, M.; Bughin, J.; Woetzel, J.; Batra, P.; Ko, R.; Sanghvi, S. *Jobs Lost, Jobs Gained: What the Future of Work will Mean for Jobs, Skills, and Wages*; McKinsey & Company: New York, NY, USA. Available online: https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages (accessed on 28 November 2017).
115. OECD. The Future of Work: What do WE Know? OECD Employment Outlook 2019: The Future of Work: Oecd iLibrary. The Future of Work: What Do We Know? | OECD Employment Outlook 2019: The Future of Work | OECD iLibrary. Available online: https://www.oecd-ilibrary.org/sites/ef00d169-en/index.html?itemId=%2Fcontent%2Fcomponent%2Fef00d169-en (accessed on 27 August 2021).
116. James, P. Sick Pay, Compensation and the Future of Work. Phil James: Sick Pay, Compensation and the Future of Work. Available online: https://www.ilo.org/global/topics/safety-and-health-at-work/events-training/events-meetings/world-day-for-safety/33thinkpieces/WCMS_681613/lang--en/index.htm (accessed on 26 March 2019).
117. U.S. Department of Labor. *What's the Difference? Paid Sick Leave, FMLA, and Paid Familiy and Medical Leave*. Available online: https://www.dol.gov/sites/dolgov/files/OASP/legacy/files/PaidLeaveFinalRuleComparison.pdf (accessed on 27 August 2021).
118. U.S. Department of Labor. *Hazard Pay*; United States Department of Labor: Washington, DC, USA. Available online: https://www.dol.gov/general/topic/wages/hazardpay (accessed on 27 August 2021).
119. Centers for Disease Control and Prevention. *Priority Areas and Emerging Issues*; The National Institute for Occupational Safety and Health (NIOSH): Washington, DC, USA. Available online: https://www.cdc.gov/niosh/twh/priority.html (accessed on 4 August 2021).
120. Jiang, L. Changes in Organizational Income Inequality. In *The Cambridge Handbook of the Changing Nature of Work*; Hoffman, B., Shoss, M., Wegman, L., Eds.; Cambridge University Press: New York, NY, USA, 2020.
121. Hogler, R. The Rise and Decline of Organized Labor in the United States. In *The Cambridge Handbook of the Changing Nature of Work*; Hoffman, B., Shoss, M., Wegman, L., Eds.; Cambridge University Press: New York, NY, USA, 2020.
122. Federal Reserve Bank of Atlanta. *Wage Growth Tracker*; Federal Reserve Bank of Atlanta: Atlanta, GA, USA. Available online: https://www.atlantafed.org/chcs/wage-growth-tracker (accessed on 27 August 2021).
123. Economomic Policy Institue. Nomimal Wage Tracker. 2020. Available online: https://www.epi.org/nominal-wage-tracker/ (accessed on 27 August 2021).
124. Benson, W.L.; Probst, T.M.; Jiang, L.; Olson, K.J.; Graso, M. Insecurity in the Ivory Tower: Direct and indirect effects of pay stagnation and job insecurity on faculty performance. *Econ. Ind. Democr.* **2020**, *41*, 693–708. [CrossRef]
125. Richardson, T.; Elliott, P.; Roberts, R. The relationship between personal unsecured debt and mental and physical health: A systematic review and meta-analysis. *Clin. Psychol. Rev.* **2013**, *33*, 1148–1162. [CrossRef]
126. Sinclair, R.R.; Allen, T.; Barber, L.; Bergman, M.; Britt, T.; Butler, A.; Ford, M.; Hammer, L.; Kath, L.; Probst, T.; et al. Occupational Health Science in the Time of COVID-19: Now More Than Ever. *Occup. Health Sci.* **2020**, *4*, 1–22. [CrossRef]

127. Norman. Four in 10 Workers Think They're Underpaid. 2018. Available online: https://news.gallup.com/poll/241682/four-workers-think-underpaid.aspx (accessed on 27 August 2021).
128. Mishel, L.; Kandra, J. *CEO Compensation Surged 14% in 2019 to $21.3 Million*; Economic Policy Institute: Washington, DC, USA, 2020.
129. Jiang, L.; Probst, T.M. The rich get richer and the poor get poorer: Country- and state-level income inequality moderates the job insecurity-burnout relationship. *J. Appl. Psychol.* **2017**, *102*, 672–681. [CrossRef] [PubMed]
130. Kawachi, I.; Kennedy, B.P. Socioeconomic determinants of health: Health and social cohesion: Why care about income inequality? *BMJ* **1997**, *314*, 1037. [CrossRef] [PubMed]
131. PayScale. The Impact of the Current Economy on Wage Growth. 2020. Available online: https://www.payscale.com/content/whitepaper/The-Impact-of-Current-Economy-on-Wage-Growth.pdf (accessed on 27 August 2021).
132. PayScale. 2021 Q2The PayScale Index | United States. PayScale. 2021. Available online: https://www.payscale.com/content/report/Index-US-2021-Q2.pdf (accessed on 27 August 2021).
133. Sternberg, D.; Gustafson, S. Small Business Work Trends in the Quarantine Economy, June 20. Available online: https://gusto.com/company-news/small-business-workforce-trends-in-the-quarantine-economy-june-20 (accessed on 15 July 2020).
134. U.S. Department of Labor. *Family and Medical Leave Act*; United States Department of Labor: Washington, DC, USA. Available online: https://www.dol.gov/agencies/whd/fmla (accessed on 27 August 2021).
135. Simonetta, J. *Family and Medical Leave in 2012: Technical Report*; U.S. Department of Labor: Washington, DC, USA. Available online: https://www.dol.gov/sites/dolgov/files/OASP/legacy/files/FMLA-2012-Technical-Report.pdf (accessed on 18 April 2014).
136. Code of Federal Regulations. Title 5 | Administrative Personnel. Available online: https://www.govinfo.gov/content/pkg/CFR-2012-title5-vol1/pdf/CFR-2012-title5-vol1.pdf (accessed on 1 January 2012).
137. Code of Federal Regulations. 5 CFR Ch. I (1–1–02 Edition). Available online: https://www.govinfo.gov/content/pkg/CFR-2002-title5-vol1/pdf/CFR-2002-title5-vol1-sec550-905.pdf (accessed on 27 August 2021).
138. Bureau of Labor Statistics | U.S. Department of Labor. 94 Percent of Managers, 56 Percent of Construction and Extraction Workers Had Paid Sick Leave. 2019. Available online: https://www.bls.gov/opub/ted/2020/94-percent-of-managers-56-percent-of-construction-and-extraction-workers-had-paid-sick-leave.htm (accessed on 5 March 2020).
139. Bureau of Labor Statistics | U.S. Department of Labor. Access to Paid and Unpaid Family Leave in 2018. Available online: https://www.bls.gov/opub/ted/2019/access-to-paid-and-unpaid-family-leave-in-2018.htm#:~{}:text=Paid%20family%20leave%20was%20available,access%20to%20unpaid%20family%20leave (accessed on 27 February 2019).
140. Bureau of Labor Statistics | U.S. Department of Labor. Racial and Ethnic Disparities in Access to and Use of Paid Family and Medical Leave: Evidence from Four Nationally Representative Datasets. Available online: https://www.bls.gov/opub/mlr/2019/article/racial-and-ethnic-disparities-in-access-to-and-use-of-paid-family-and-medical-leave.htm (accessed on 27 August 2021).
141. Boesch, D. *The Uneven Expansion of Access to Paid Sick Days*; Center for American Progress: Washington, DC, USA; Available online: https://www.americanprogress.org/issues/women/news/2018/08/30/457309/uneven-expansion-access-paid-sick-days/ (accessed on 30 August 2018).
142. Institute for Women's Policy Research. Paid Sick Day Access Rates by Gender and Race/Ethnicity. 2010. Available online: https://iwpr.org/iwpr-general/paid-sick-day-access-rates-by-gender-and-race-ethnicity-2010/#iLightbox[gallery25460]/0 (accessed on 14 March 2011).
143. Institute for Women's Policy Research. Paid Sick Days Access and Usage Rates Vary by Race/Ethnicity, Occupation, and Earnings. Available online: https://iwpr.org/wp-content/uploads/2020/08/B356-paid-sick-days.pdf (accessed on 27 August 2021).
144. National Partnership for Women Families. Paid Family and Medical Leave: Busting 10 Common Myths with Facts and Evidence. Available online: https://www.nationalpartnership.org/our-work/resources/economic-justice/paid-leave/paid-family-and-medical-leave-busting-10-common-myths-with-facts-and-evidence.pdf (accessed on 27 August 2021).
145. National Partnership for Women and Families. *Fathers Need Paid Family and Medical Leave*; National Partnership for Women and Families: Washington, DC, USA. Available online: https://www.nationalpartnership.org/our-work/resources/economic-justice/paid-leave/fathers-need-paid-family-and-medical-leave.pdf (accessed on 27 August 2021).
146. U.S. Department of Labor. *Temporary Rule: Paid Leave under the Families First Coronavirus Response Act*; U.S. Department of Labor: Washington, DC, USA. Available online: https://www.dol.gov/agencies/whd/ffcra (accessed on 27 August 2021).
147. U.S. Department of Labor. U.S. Department of Labor Blog. New COVID-19 Unemployment Benefits: Answering Common Questions | U.S. Department of Labor Blog. Available online: https://blog.dol.gov/2021/01/11/unemployment-benefits-answering-common-questions (accessed on 27 August 2021).
148. Department of Industrial Relations. CA COVID-19 Supplemental Paid Sick Leave for Non-Food Sector Employees. Available online: https://www.dir.ca.gov/dlse/COVID-19-Non-Food-Sector-Employees-poster.pdf (accessed on 27 August 2021).
149. New York State. New Paid Leave for COVID-19. Available online: https://paidfamilyleave.ny.gov/COVID19 (accessed on 27 August 2021).
150. Department of Vermont Health Acess. Frontline Employees Hazard Pay Grant Program. 2021. Available online: https://dvha.vermont.gov/front-line-employees-hazard-pay-grant-program (accessed on 27 August 2021).
151. JUST Capital. The COVID-19 Corporate Response Tracker: How America's Largest Employers are Treating Stakeholders Amid the Coronavirus Crisis. Available online: https://justcapital.com/reports/the-covid-19-corporate-response-tracker-how-americas-largest-employers-are-treating-stakeholders-amid-the-coronavirus-crisis/ (accessed on 1 June 2020).

152. Holger, D. Coronavirus Fuels Investor Push for Worker Benefits. *The Wall Street Journal*. Available online: https://www.wsj.com/articles/coronavirus-fuels-investor-push-for-worker-benefits-11588794042#:~{}:text=Dieter%20Holger,-Biography&text=Companies%20are%20under%20pressure%20from,shortcomings%20in%20U.S.%20labor%20policy.&text=Issues%20include%20offering%20paid%20sick,option%20to%20work%20from%20home (accessed on 6 May 2020).
153. Peiper, H. At a Glance: What Customers Need to Know about Starbucks Response to COVID-19. *Starbucks Stories News*. Available online: https://stories.starbucks.com/press/2020/what-customers-need-to-know-about-starbucks-response-to-covid-19/#:~{}:text=Social%20distancing%20will%20be%20supported,stores%20and%20on%20our%20patios (accessed on 9 July 2020).
154. Soto, I. State and Local Hazard Pay. *AAF*. Available online: https://www.americanactionforum.org/insight/state-and-local-hazard-pay/ (accessed on 18 March 2021).
155. National Employment Law Project. Silenced about COVID-19 in the Workplace. Available online: https://www.wwdlaw.com/wp-content/uploads/2020/07/Silenced-About-COVID-19-Workplace-Fear-Retaliation-June-2020-2.pdf (accessed on 27 August 2021).
156. Kashen, J.; Glynn, S.J.; Novello, A. How COVID-19 Sent Women's Workforce Progress Backward. Available online: https://www.americanprogress.org/issues/women/reports/2020/10/30/492582/covid-19-sent-womens-workforce-progress-backward/ (accessed on 30 October 2020).
157. Banks, G.C.; Pollack, J.M.; Bochantin, J.E.; Kirkman, B.L.; Whelpley, C.E.; O'Boyle, E.H. Management's Science–Practice Gap: A Grand Challenge for All Stakeholders. *Acad. Manag. J.* **2016**, *59*, 2205–2231. [CrossRef]
158. Senik, C. Income distribution and well-being: What can we learn from subjective data? *J. Econ. Surv.* **2005**, *19*, 43–63. [CrossRef]
159. Stevenson, B.; Wolfers, J. Subjective well-being and income: Is there any evidence of satiation? *Am. Econ. Rev.* **2013**, *103*, 598–604. [CrossRef]
160. Fractl. 2017 Employee Benefits Study. 2017. Available online: www.frac.tl/employee-benefits-study/ (accessed on 1 November 2017).
161. Vives, A.; González, F.; Moncada, S.; Llorens, C.; Benach, J. Measuring precarious employment in times of crisis: The revised Employment Precariousness Scale (EPRES) in Spain. *Gac. Sanit.* **2015**, *29*, 379–382. [CrossRef]
162. National Partnership for Women and Families. *Key Facts: Paid Family and Medical Leave*; National Partnership for Women and Families: Washington, DC, USA; Available online: https://www.nationalpartnership.org/our-work/resources/economic-justice/paid-leave/key-facts-paid-family-and-medical-leave.pdf (accessed on 27 August 2021).
163. Economic Policy Institute. *A Real Agenda for Working People: How to Raise Wages, Protect Workers' Rights, and Fix Our Rigged Economy*; Economic Policy Institute: Washington, DC, USA; Available online: https://www.epi.org/workers-agenda/ (accessed on 27 August 2021).
164. U.S. Department of Labor. *Benefits*; U.S. Department of Labor: Washington, DC, USA. Available online: https://www.dol.gov/general/jobs/benefits (accessed on 27 August 2021).
165. The National Institute for Occupational Safety and Health (NIOSH). *Organization of Work: Measurement Tools for Research and Practice*; The National Institute for Occupational Safety and Health (NIOSH): Washington, DC, USA. Available online: https://www.cdc.gov/niosh/topics/workorg/default.html (accessed on 14 June 2017).
166. Chen, R.; Sun, C.; Chen, J.J.; Jen, H.J.; Kang, X.L.; Kao, C.C.; Chou, K.R. A large-scale survey on trauma, burnout, and posttraumatic growth among nurses during the COVID-19 pandemic. *Int. J. Ment. Health Nurs.* **2021**, *30*, 102–116. [CrossRef] [PubMed]
167. Killgore, W.D.; Cloonan, S.A.; Taylor, E.C.; Miller, M.A.; Dailey, N.S. Three months of loneliness during the COVID-19 lockdown. *Psychiatry Res.* **2020**, *293*, 113392. [CrossRef] [PubMed]
168. Shimazu, A.; Nakata, A.; Nagata, T.; Arakawa, Y.; Kuroda, S.; Inamizu, N.; Yamamoto, I. Psychosocial impact of COVID-19 for general workers. *J. Occup. Health* **2020**, *62*, e12132. [CrossRef]
169. Grzywacz, J.; Carlson, D. Conceptualizing Work–Family Balance: Implications for Practice and Research. *Adv. Dev. Hum. Resour.* **2007**, *9*, 455–471. [CrossRef]
170. Greenhaus, J.H.; Beutell, N.J. Sources and conflict between work and family roles. *Acad. Manag. Rev.* **1985**, *10*, 76–88. [CrossRef]
171. Allen, T.D. The work-family role interface: A synthesis of the research from industrial and organizational psychology. In *Handbook of Psychology: Industrial and Organizational Psychology*; Schmitt, N.W., Highhouse, S., Weiner, I.B., Eds.; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2013; pp. 698–718.
172. Byron, K. A meta-analytic review of work–family conflict and its antecedents. *J. Vocat. Behav.* **2005**, *62*, 169–198. [CrossRef]
173. Powell, G.N.; Greenhaus, J.H. Sex, gender, and the work-to-family interface: Exploring negative and positive interdependencies. *Acad. Manag. J.* **2010**, *53*, 513–534. [CrossRef]
174. Dean, H. Flexibility or flexploitation? Problems with work-life balance in a low-income neighbourhood. *SOCIAL POLICY REVIEW-HARLOW-* **2008**, *20*, 113.
175. Bolhari, A.; Rezaeean, A.; Bolhari, J.; Bairamzadeh, S.; Soltan, A.A. The Relationship between Quality of Work Life and Demographic Characteristics of Information Technology Staffs. 2011. Available online: http://www.ipcsit.com/vol5/67-ICCCM2011-C009.pdf (accessed on 16 September 2021).
176. Leslie, L.M.; Manchester, C.F. Work–family conflict is a social issue not a women's issue. *Ind. Organ. Psychol.* **2011**, *4*, 414–417. [CrossRef]
177. De Sivatte, I.; Guadamillas, F. Antecedents and outcomes of implementing flexibility policies in organizations. *Int. J. Hum. Resour. Manag.* **2013**, *24*, 1327–1345. [CrossRef]

178. Drouin, R.; Potter, M. Flexible Scheduling: Exploring the benefits and the limitations. *AJN Am. J. Nurs.* **2005**, *105*, 72E–72F. [CrossRef]
179. Foucreault, A.; Ollier-Malaterre, A.; Ménard, J. Organizational culture and work–life integration: A barrier to employees' respite? *Int. J. Hum. Resour. Manag.* **2018**, *29*, 2378–2398. [CrossRef]
180. Kossek, E.E.; Lautsch, B.A. Work–life flexibility for whom? Occupational status and work–life inequality in upper, middle, and lower level jobs. *Acad. Manag. Ann.* **2018**, *12*, 5–36. [CrossRef]
181. Beers, T.M. Flexible schedules and shift work: Replacing the 9-to-5 workday. *Mon. Lab. Rev.* **2000**, *123*, 33.
182. U.S. Bureau of Labor Statistics. *Job Flexibilities and Work Schedules—2017–2018 Data from the American Time Use Survey*; U.S. Bureau of Labor Statistics: Washington, DC, USA, 2019. Available online: https://www.bls.gov/news.release/flex2.nr0.htm (accessed on 27 August 2021).
183. U.S. Bureau of Labor Statistics. *National Compensation Survey: Employee Benefits in the United States, March 2012*; U.S. Bureau of Labor Statistics: Washington, DC, USA, 2012. Available online: https://www.bls.gov/ncs/ebs/benefits/2012/ebbl0050.pdf (accessed on 27 August 2021).
184. U.S. Bureau of Labor Statistics. *National Compensation Survey: Employee Benefits in the United States, March 2018*; U.S. Bureau of Labor Statistics: Washington, DC, USA, 2018. Available online: https://www.bls.gov/ncs/ebs/benefits/2018/ownership/civilian/table32a.pdf (accessed on 27 August 2021).
185. Ray, T.K.; Pana-Cryan, R. Work Flexibility and Work-Related Well-Being. *Int. J. Environ. Res. Public Health* **2021**, *18*, 3254. [CrossRef]
186. Malik, R.; Hamm, K.; Novoa, C.; Workman, S.; Jessen-Howard, S. *America's Child Care Deserts in 2018*; Center for American Progress: Washington, DC, USA, 2018. Available online: https://www.americanprogress.org/issues/early-childhood/reports/2018/12/06/461643/americas-child-care-deserts-2018/ (accessed on 16 September 2021).
187. U.S. Bureau of Labor Statistics. *Average Weekly Hours (Seasonally Adjusted)*; U.S. Bureau of Labor Statistics: Washington, DC, USA. Available online: https://www.bls.gov/webapps/legacy/cesbtab7.htm (accessed on 27 August 2021).
188. Zhang, S.; Moeckel, R.; Moreno, A.T.; Shuai, B.; Gao, J. A work-life conflict perspective on telework. *Transp. Res. Part A Policy Pract.* **2020**, *141*, 51–68. [CrossRef]
189. Hammonds, C.; Kerrissey, J.; Tomaskovic-Devey, D. *Stressed, Unsafe, and Insecure: Essential Workers Need a New, New Deal*; UMass Amherst Labor Center: Amherst, MA, USA, 2020.
190. Chang, S.; Pierson, E.; Koh, P.W.; Gerardin, J.; Redbird, B.; Grusky, D.; Leskovec, J. Mobility network models of COVID-19 explain inequities and inform reopening. *Nature* **2021**, *589*, 82–87. [CrossRef]
191. Milligan, W.R.; Fuller, Z.L.; Agarwal, I.; Eisen, M.B.; Przeworski, M.; Sella, G. Impact of essential workers in the context of social distancing for epidemic control. *PLoS ONE* **2021**, *16*, e0255680. [CrossRef] [PubMed]
192. Hawkins, D. Differential occupational risk for COVID-19 and other infection exposure according to race and ethnicity. *Am. J. Ind. Med.* **2020**, *63*, 817–820. [CrossRef]
193. Dubay, L.; Aarons, J.; Brown, K.S.; Kenney, G.M. *How Risk of Exposure to the Coronavirus at Work Varies by Race and Ethnicity and How to Protect the Health and Well-Being of Workers and Their Families*; Research Report; Health Policy Center: Washington, DC, USA, December 2020.
194. Silver, S.R.; Li, J.; Boal, W.L.; Shockey, T.L.; Groenewold, M.R. Prevalence of underlying medical conditions among selected essential critical infrastructure workers—Behavioral risk factor surveillance system, 31 states, 2017–2018. *Morb. Mortal. Wkly. Rep.* **2020**, *69*, 1244–1249. [CrossRef] [PubMed]
195. Roberts, J.D.; Dickinson, K.L.; Koebele, E.; Neuberger, L.; Banacos, N.; Blanch-Hartigan, D.; Welton-Mitchell, C.; Birkland, T.A. Clinicians, cooks, and cashiers: Examining health equity and the COVID-19 risks to essential workers. *Toxicol. Ind. Health* **2020**, *36*, 689–702. [CrossRef] [PubMed]
196. Aaronson, D.; Hu, L.; Rajan, A. Did Covid-19 disproportionately affect mothers' labor market activity? *Chic. Fed Lett.* **2021**, *450*, 1–5.
197. Lofton, O.; Petrosky-Nadeau, N.; Seitelman, L. *Parents in a Pandemic Labor Market*; Federal Reserve Bank of San Francisco: San Francisco, CA, USA, February 2021.
198. U.S. Bureau of Labor Statistics. *Employment Characteristics of Families Summary*; U.S. Bureau of Labor Statistics: Washington, DC, USA, 2021. Available online: https://www.bls.gov/news.release/famee.nr0.htm (accessed on 27 August 2021).
199. Robinson, L.J.; Engelson, B.J.; Hayes, S.N. Who Is Caring for Health Care Workers' Families Amid COVID-19? *Acad. Med.* **2021**, *96*, 1254–1258. [CrossRef]
200. Substance Abuse and Mental Health Services Administration. *Key Substance Use and Mental Health Indicators in the United States: Results from the 2019 National Survey on Drug Use and Health (HHS Publication No.PEP20-07-01-001, NSDUH Series H-55)*; Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration: Rockville, MD, USA, 2020. Available online: https://www.samhsa.gov/data/ (accessed on 27 August 2021).
201. Ferneini, E.M.; Ferneini, A.M. Physician Burnout: On the Rise! *Am. J. Cosmet. Surg.* **2016**, *33*, 57. [CrossRef]
202. Genly, B. Safety and job burnout: Understanding complex contributing factors. *Prof. Saf.* **2016**, *61*, 45–49.
203. Kraft, S. Companies are Facing an Employee Burnout Crisis. *CNBC*. Available online: https://www.cnbc.com/2018/08/14/5-ways-workers-can-avoid-employee-burnout.html (accessed on 28 August 2018).

204. National Safety Council. NSC Releases Second Report in Workplace Fatigue Series. Available online: https://www.safetyandhealthmagazine.com/articles/17137-nsc-releases-second-report-in-workplace-fatigue-series (accessed on 14 June 2018).
205. Occupational Safety and Health Administration. *Long Work Hours, Extended or Irregular Shifts, and Worker Fatigue*; Occupational Safety and Health Administration: Washington, DC, USA. Available online: https://www.osha.gov/worker-fatigue/hazards (accessed on 27 August 2021).
206. American Heart Association CEO Roundtable. Mental Health. A Workforce Crisis. 2019. Available online: https://ceoroundtable.heart.org/wp-content/uploads/2018/12/Mental-Health-Full-Report-March-25-2019.pdf (accessed on 27 August 2021).
207. Bush, D.M.; Lipari, R.N. *The CBHSQ Report: Substance Use and Substance Use Disorder, by Industry*; Substance Abuse and Mental Health Services Administration, Center for Behavioral Health Statistics and Quality: Rockville, MD, USA, 2015.
208. Agovino, T. Companies Seek to Boost Low Usage of Employee Assistance Programs. *SHRM*. 2019. Available online: https://www.shrm.org/hrtoday/news/hr-magazine/winter2019/pages/companies-seek-to-boost-lowusage-of-employee-assistance-programs (accessed on 27 August 2021).
209. Miller, S. Perk Up: 6 Benefit Trends to Watch in 2020. *SHRM*. Available online: https://www.shrm.org/resourcesandtools/hr-topics/benefits/pages/perk-up-six-key-benefit-trends-to-watch-in-2020.aspx (accessed on 2 January 2020).
210. Linnan, L.A.; Cluff, L.; Lang, J.E.; Penne, M.; Leff, M.S. Results of the Workplace Health in America Survey. *Am. J. Health Promot.* **2019**, *33*, 652–665. [CrossRef]
211. Statistics of, U.S. Businesses [SUSB]. 2018 SUSB Annual Data Tables by Establishment Industry. 2021. Available online: https://www.census.gov/data/tables/2018/econ/susb/2018-susb-annual.html (accessed on 18 August 2021).
212. Ettman, C.K.; Abdalla, S.M.; Cohen, G.H.; Sampson, L.; Vivier, P.M.; Galea, S. Prevalence of depression symptoms in US adults before and during the COVID-19 pandemic. *JAMA Netw. Open* **2020**, *3*, e2019686. [CrossRef]
213. Czeisler, M.É.; Lane, R.I.; Petrosky, E.; Wiley, J.F.; Christensen, A.; Njai, R.; Weaver, M.D.; Robbins, R.; Facer-Childs, E.R.; Barger, L.K.; et al. Mental health, substance use, and suicidal ideation during the COVID-19 pandemic—United States, June 24–30, 2020. *Morb. Mortal. Wkly. Rep.* **2020**, *69*, 1049. [CrossRef] [PubMed]
214. Czeisler, M.É.; Lane, R.I.; Wiley, J.F.; Czeisler, C.A.; Howard, M.E.; Rajaratnam, S.M. Follow-up survey of US adult reports of mental health, substance use, and suicidal ideation during the COVID-19 pandemic, September 2020. *JAMA Netw. Open* **2021**, *4*, e2037665. [CrossRef] [PubMed]
215. McKay, D.; Asmundson, G.J. Substance use and abuse associated with the behavioral immune system during COVID-19: The special case of healthcare workers and essential workers. *Addict. Behav.* **2020**, *110*, 106522. [CrossRef] [PubMed]
216. Carli, L.L. Women, Gender equality and COVID-19. *Gend. Manag. Int. J.* **2020**, *35*, 647–655. [CrossRef]
217. Carvalho, V.S.; Santos, A.; Ribeiro, M.T.; Chambel, M.J. Please, Do Not Interrupt Me: Work–Family Balance and Segmentation Behavior as Mediators of Boundary Violations and Teleworkers' Burnout and Flourishing. *Sustainability* **2021**, *13*, 7339. [CrossRef]
218. Koohsari, M.J.; Nakaya, T.; McCormack, G.R.; Shibata, A.; Ishii, K.; Oka, K. Changes in Workers' Sedentary and Physical Activity Behaviors in Response to the COVID-19 Pandemic and Their Relationships with Fatigue: Longitudinal Online Study. *JMIR Public Health Surveill.* **2021**, *7*, e26293. [CrossRef]
219. Sasangohar, F.; Jones, S.L.; Masud, F.N.; Vahidy, F.S.; Kash, B.A. Provider burnout and fatigue during the COVID-19 pandemic: Lessons learned from a high-volume intensive care unit. *Anesth. Analg.* **2020**. [CrossRef]
220. Wilson, J. I Work in Restaurants and I've Never Felt So Disrespected. *Grub Street*. Available online: https://www.grubstreet.com/2020/08/the-emotional-toll-of-working-in-restaurants-during-covid-19.html (accessed on 20 August 2020).
221. Alharbi, J.; Jackson, D.; Usher, K. The potential for COVID-19 to contribute to compassion fatigue in critical care nurses. *J. Clin. Nurs.* **2020**. [CrossRef]
222. Martichoux, A. Why Some Doctors, Nurses Are Warning of 'COMPASSION FATIGUE' IN COVID-19 Crisis. *CBS17.com*. Available online: https://www.cbs17.com/community/health/coronavirus/why-some-doctors-nurses-are-warning-of-compassion-fatigue-in-covid-19-crisis/ (accessed on 15 August 2021).
223. Brooks, C.D.; Ling, J. "Are We Doing Enough": An Examination of the Utilization of Employee Assistance Programs to Support the Mental Health Needs of Employees during the COVID-19 Pandemic. *J. Insur. Regul.* **2020**, *39*, 1–34.
224. Canady, V.A. CDC examines MH impact on public health workers amid COVID. *Ment. Health Wkly.* **2021**, *31*, 7–8.
225. Koonin, L.M.; Hoots, B.; Tsang, C.A.; Leroy, Z.; Farris, K.; Jolly, B.; Antall, P.; McCabe, B.; Zelis, C.B.; Tong, I.; et al. Trends in the use of telehealth during the emergence of the COVID-19 pandemic—United States, January–March 2020. *Morb. Mortal. Wkly. Rep.* **2020**, *69*, 1595. [CrossRef] [PubMed]
226. Qualtrics//April 14. (2020, 20). Confronting Mental Health Crisis Stemming from the COVID-19 Pandemic. *Qualtrics*. Available online: https://www.qualtrics.com/blog/confronting-mental-health/ (accessed on 20 April 2020).
227. Autin, K.L.; Blustein, D.L.; Ali, S.R.; Garriott, P.O. Career development impacts of COVID-19: Practice and policy recommendations. *J. Career Dev.* **2020**, *47*, 487–494. [CrossRef]
228. Blau, F.D.; Koebe, J.; Meyerhofer, P.A. Essential and Frontline Workers in the Covid-19 Crisis. *Econofact*, 30 April 2020.
229. Groenewold, M.R.; Burrer, S.L.; Ahmed, F.; Uzicanin, A.; Free, H.; Luckhaupt, S.E. Increases in health-related workplace absenteeism among workers in essential critical infrastructure occupations during the COVID-19 pandemic—United States, March–April 2020. *Morb. Mortal. Wkly. Rep.* **2020**, *69*, 853. [CrossRef] [PubMed]

230. Gwynn, R.C. Health Inequity and the Unfair Impact of the COVID-19 Pandemic on Essential Workers. *Am. J. Public Health* **2021**, *111*, 1459–1461. [CrossRef] [PubMed]
231. Centers for Disease Control and Prevention. Know Your Risk for Heart Disease. Heart Disease. Available online: https://www.cdc.gov/heartdisease/risk_factors.htm (accessed on 13 September 2021).
232. Hjálmsdóttir, A.; Bjarnadóttir, V.S. I have turned into a foreman here at home": Families and work–life balance in times of COVID-19 in a gender equality paradise. *Gend. Work. Organ.* **2021**, *28*, 268–283. [CrossRef]
233. Hsu, A. As the Pandemic RECEDES, Millions of Workers are Saying 'I QUIT'. *NPR*. Available online: https://www.npr.org/2021/06/24/1007914455/as-the-pandemic-recedes-millions-of-workers-are-saying-i-quit (accessed on 24 June 2021).
234. Franciosi, E.B.; Tan, A.J.; Kassamali, B.; Leonard, N.; Zhou, G.; Krueger, S.; Rashighi, M.; LaChance, A. The Impact of Telehealth Implementation on Underserved Populations and No-Show Rates by Medical Specialty during the COVID-19 Pandemic. *Telemed. e-Health* **2021**. [CrossRef]
235. Zhou, X.; Snoswell, C.L.; Harding, L.E.; Bambling, M.; Edirippulige, S.; Bai, X.; Smith, A.C. The role of telehealth in reducing the mental health burden from COVID-19. *Telemed. e-Health* **2020**, *26*, 377–379. [CrossRef]
236. Thompson, C.A.; Beauvais, L.L.; Lyness, K.S. When work–family benefits are not enough: The influence of work–family culture on benefit utilization, organizational attachment, and work–family conflict. *J. Vocat. Behav.* **1999**, *54*, 392–415. [CrossRef]
237. Kossek, E.E.; Lee, K.H. *The Coronavirus Work–Life Inequality: Three Evidence-Based Initiatives to Update US Work–Life Employment Policies*; Behavioral Science Policy: Durham, NC, USA, 2020.
238. Wels, J. The Contribution of Labour Unions in Fostering Access to Flexible Work Arrangements in Britain. *METICES Discuss Pap. Ser.* **2021**, *1*, 23.
239. Debus, M.E.; Probst, T.M.; König, C.J.; Kleinmann, M. Catch me if I fall! Enacted uncertainty avoidance and the social safety net as country-level moderators in the job insecurity–job attitudes link. *J. Appl. Psychol.* **2012**, *97*, 690. [CrossRef] [PubMed]
240. Streit, J.M.; Felknor, S.A.; Edwards, N.T.; Howard, J. Leveraging Strategic Foresight to Advance Worker Safety, Health, and Well-Being. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8477. [CrossRef] [PubMed]

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Abstract: Background: The ways workers interface with their workplace and work are changing. These changes provide challenges and opportunities for health and safety professionals attempting to improve worker wellbeing for the future of work. For many workers, the morning commute, an activity typically outside the scope of workplace policies, is the most hazardous portion of the day. The hazard increases if workers are required to drive during winter weather or in other hazardous conditions in order to adhere to strict workplace start times. This research describes the role winter weather plays during the morning commute, demonstrating the need for organizational design and work arrangements that improve safety during the commute to work. Methods: Crash data from the Iowa Department of Transportation for the years 2013–2017 was linked to county level characteristics from the American Community Survey. Crashes were characterized by 30-min time intervals. The likelihood of the crash involving winter weather as a contributing circumstance was compared across time-intervals. Results: Winter weather was more likely to contribute to crashes during the commuting hours compared to 11:00 to 11:59 am. Winter weather was most frequently a contributing circumstance during 8:00–8:29 a.m. (OR = 2.21 95% CI: 1.93–2.52). Conclusions: Winter weather plays a role in crashes during commuting hours. Workplaces can adopt policies for flexible work start times or for telecommuting to empower workers to avoid hazardous driving conditions.

Keywords: Total Worker Health; traffic safety; crash; wellness; commute

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1. Introduction

Workers are often required to commute to work and arrive at a specific start time. Many workers lack the flexibility of deciding when they start their commute to work. While drivers do choose to delay or forgo driving in poor weather conditions [1,2], reduced driving is less apparent during the peak driving hours of 6:00 to 9:00 a.m., the common time period for the daily commute to work [1]. The commute to work is a significant source of employee injury, with motor vehicle crashes occurring most frequently during the morning and evening hours [3,4]. Although injury during a commute to work is not considered a work-related injury in the United States (OSHA 29 CFR 1904.5(b)(2)), the National Institute for Occupational Safety and Health (NIOSH) has expanded current injury and illness prevention efforts to non-occupational sources of increased risk in order to promote overall worker wellbeing through the concept of Total Worker Health® (TWH) [5].

Approaches to TWH have evolved to include issues related to commuting, such as reducing stress and injury prevention [6]. Workplace policies and research about commuting have focused on driving after shift work [7], the stress caused by long commutes [8], and encouraging active travel [9–12]. Previous studies have not evaluated how flexible schedules or allowances for working remotely (telecommuting, alternative work arrangements) can impact driver safety. Recognizing the evolving relationship between workers and their workplace, NIOSH has developed priority topics through the Future of Work Initiative [13]. The commute to work is directly related to several of the topics and subtopics outlined

in the initiative. Most directly, the safety of the commute can be improved through organizational design encouraging autonomy, stress prevention, and job flexibility, as well as through work arrangements that reconceptualize where and when work is completed. While the commute itself is not a job task and not the responsibility of the employer, the employer can directly affect the safety of the commute using the principles outlined in TWH and the Future of Work.

A renewed focus on worker wellbeing through job flexibility and alternative work arrangements should include consideration for reducing traveling to work during adverse weather conditions. Adverse weather conditions contribute to 16% of all fatal crashes in the United States [14]. Analysis matching time-periods of snowfall with non-snowfall periods [15–17] and evaluation of increasing snowfall [18,19] have found that snowfall increases the rate of motor vehicle crashes. With a typical commute for US drivers lasting 27 min [20], many opportunities exist for an adverse weather-related related crash during the commute.

In this study, we evaluated the likelihood that a crash was winter weather-related throughout the morning commuting hours. Using state crash data, we separated the time of crash into 30-min intervals and calculated the odds of winter weather being a reason for the crash. We hypothesized that winter weather is more likely a factor in crashes during the most common commute times compared to times with less commuter traffic.

2. Materials and Methods

2.1. Study Design and Data Sources

Iowa Department of Transportation (DOT) crash data was used to identify all crashes occurring in Iowa between midnight (12:00 a.m.) and 11:59 a.m. for drivers aged 16 through 64 during the years of 2013 to 2017. The Iowa DOT crash data is publicly available as the Iowa Crash Analysis Tool [21]. The tool provides information on all crashes that resulted in an injury or fatality or resulted in estimated property damage of $1500 or more. Information about morning commute activity at the county level is also publicly available in the American Community Survey (ACS) [22]. The ACS was used to identify characteristics of a commute at the county level for each year. Conditions identified included mean travel time, traffic density during specific times, and the total number of drivers commuting. Traffic density was derived from the ACS question asking commuters what time they typically left for work. Additionally, the number of total drivers was determined as those who indicated that they typically drive to work. These two measures together describe how many drivers are expected to be on the road at a given time. These conditions were linked to the crash data based on the county and time of the crash.

We used a cross-sectional design to identify the increased odds of winter weather contributing to the crash (winter weather-related) throughout various times during the morning commute with 11:00 to 11:59 a.m. as a referent category.

The analysis of these publicly available datasets was reviewed by the University of Iowa Institutional Review Board and determined to not be human subject research.

2.2. Winter Weather-Related Crash and Any Weather-Related Crash

A winter weather-related crash was defined as a crash with any of the following: a contributing circumstance of “wet, icy”; surface conditions of “blowing snow,” “freezing rain/drizzle,” “sleet, hail,” or “snow”; surface conditions of “ice/frost,” “snow,” or “slush”. The days between 23 December and 2 January were excluded to remove days with uncharacteristic commute conditions due to anticipated winter vacations. We also identified any weather-related crash as defined as a crash with a contributing circumstance of “Weather conditions” listed in the environmental contributing circumstances field of the crash data. The analysis of any weather-related crash used all months during the year.

2.3. Crash Characteristics and Injury Severity

Crash characteristics were identified from the Iowa DOT crash data. The following crash characteristics were collected and described in this analysis: day of the week, road system, speed limit, paved road, and drug- or alcohol-related. The road system variable had the following classifications: construction (construction zone), farm to market (route to allow flow of commodities from rural areas to towns and terminals), interstate (highway), local road (public roads to assure connection of parcels of land), Iowa route, and US routes. The speed limit variable was the statuary or posted maximum speed for the area in miles per hour (MPH). Unpaved roads included gravel and dirt roads as opposed to paved surfaces.

Injury characteristics were also described using the Iowa DOT crash data. Whether or not any injury occurred as a result of the crash, multicar crash (one or more cars), and the amount of property damage were described for drivers with and without winter weather-related crashes.

2.4. Data Analysis

Odds ratios and 95% confidence intervals were calculated for the increased odds of a crash being winter weather or any weather-related during the morning commute time categories (12:00–04:59 a.m., 5:00–5:29 a.m., 5:30–5:59 a.m., 6:00–6:29 a.m., 6:30–6:59 a.m., 7:00–7:29 a.m., 7:30–7:59 a.m., 8:00–8:29 a.m., 8:30–8:59 a.m., 9:00–9:29 a.m., 9:30–9:59 a.m., 10:00–10:29 a.m., 10:30–10:59 a.m.) compared to 11:00–11:59 a.m. The odds of a winter weather-related crash to non-winter weather-related crash occurring during the times categories was compared with the odds of a winter weather-related crash to non-winter weather-related crash occurring during 11:00 a.m. to 11:59 a.m. using logistic regression. The same methods were used for any weather-related crash. For both winter weather-related crashes and any weather-related crash, we only included crashes occurring during Monday–Friday to reflect the typical work week. For the analysis of winter weather-related crashes, analysis was restricted to the months of November to February. We also evaluated the odds ratio of winter weather-related and any weather-related crashes occurring for female drivers compared to male drivers and across age groups using logistic regression. Conditions of the commute were controlled for in the logistic model by including variables of mean travel time, traffic density, and the total number of commuting drivers in the county where the crash occurred. Characteristics of winter weather-related crashes were compared to characteristics of all other crashes using the Chi-square test. For categorical variables with more than two levels, the presence of the characteristic was compared to the absence of that characteristic across each level of the category. All tests were completed with a significance level of $\alpha = 0.05$.

3. Results

3.1. Comparison of Crash Characteristics

During relevant time-periods and days from 2013 to 2017, there were 85,781 total crashes. Of these crashes, 19.1% met our criteria for winter weather-related crashes. The differences between winter weather and non-winter weather-related crashes are given in Table 1. Winter weather was most frequently a contributing cause of a crash on Monday (n = 2973, 18.2%) and Tuesday (n = 2961, 18.1%). Winter weather-related crashes were less likely to occur for the days Thursday through Saturday. For Sundays, there was no difference in the likelihood of the crash being winter weather-related or non-winter weather-related. The type of road system where the crash occurred was significantly different between winter weather and non-winter weather crashes for all types of road systems except for construction zones. The biggest difference was for crashes occurring on the interstate, where 18.3% of winter weather-related crashes occurred compared to 12.0% of other crashes ($p < 0.001$). The only other road system with a higher proportion of crashes being winter weather-related was farm to market routes ($p < 0.001$).

Table 1. Crash characteristics for crashes with and without a winter weather-related circumstance.

Variable	Category	All Other Crash		Winter Weather-Related Crash		*p*-Value [1]
		n = 69,403	%	*n* = 16,378	%	
Day of Week	Monday	10,162	14.6	2973	18.2	<0.001
	Tuesday	10,318	14.9	2961	18.1	<0.001
	Wednesday	10,144	14.6	2698	16.5	<0.001
	Thursday	10,481	15.1	1853	11.3	<0.001
	Friday	10,957	15.8	2207	13.5	<0.001
	Saturday	9655	13.9	1906	11.6	<0.001
	Sunday	7686	11.1	1780	10.9	0.449
Road System	Construction	257	0.4	62	0.4	0.876
	Farm to Market Route	13,957	20.1	3520	21.5	<0.001
	Interstate	8308	12.0	2995	18.3	<0.001
	Iowa Route	9335	13.5	1615	9.9	<0.001
	Local Road	24,694	35.6	5394	32.9	<0.001
	US Route	12,852	18.5	2792	17.0	<0.001
Speed Limit	≤25 MPH	16,898	28.5	3927	24.4	0.320
	30–35 MPH	17,131	28.9	3074	19.1	<0.001
	40–45 MPH	5804	9.8	1300	8.1	0.076
	50–55 MPH	13,214	22.3	4308	26.7	<0.001
	60–65 MPH	4002	6.7	2093	13.0	<0.001
	≥70 MPH	2270	3.8	1403	8.7	<0.001
Paved	Paved	65,899	95.3		96.1	
	Unpaved	3247	4.7	642	3.9	<0.001
Drug or Alcohol Related	No	64,276	92.6	15,877	96.9	
	Yes	5127	7.4	501	3.1	<0.001

[1] The *p*-value is calculated using the chi-square test.

The speed limit for the location of the crash was different for all speed limits except for the ≤25 MPH across winter weather-relatedness (Table 1). Winter weather-related crashes were more likely to occur for all speed limits above 50 MPH compared to other crashes. Crashes were less likely to have drug or alcohol involvement if winter weather contributed to the crash (3.1% winter weather-related vs. 7.4% non-winter weather-related, Table 1). The drug or alcohol-related winter weather crashes included 18.6% (*n* = 93) who refused the sobriety test. A similar proportion (19.3%, *n* = 990) of the drug or alcohol-related crashes occurring without winter weather conditions had drivers refusing to test.

3.2. Difference in Winter Weather-Related Crashes across Commuting Times

The odds ratios for a crash occurring during a given time compared to the time of 11:00 a.m. to 11:59 a.m. are shown in Table 2. Except for the earliest morning hours (00:00 midnight to 04:59 a.m.) all periods were significantly more likely to have a winter weather-related crash. The distribution of crash odds ratios was bimodal, with crash odds peaking during 5:30–5:59 a.m. (OR = 1.62 95% CI: 1.37–1.91) and 8:00–8:29 a.m. (OR = 2.21 95% CI: 1.93–2.52) compared to 11:00–11:59 am. Analysis was also completed for crashes with any weather-related cause throughout the entire year. The odds ratio for an any weather-related crash remained elevated through the morning hours, but began to taper after 8:00–8:29 a.m. (OR = 2.24 95% CI: 1.96–2.57). From the ACS survey results, 79% of Iowans reported beginning their commute before 9:00 a.m. Of the half-hour commute periods asked about in the ACS, drivers most frequently reported leaving between 7:30 and 8:00 a.m. (15.4%, data not shown). There was no difference in the odds of a winter weather-related crash for female drivers compared to male drivers. However, in the analysis of the entire year, female drivers were less likely to be involved in an any weather-related crash. There was an overall decrease in the odds of a winter weather-related crash for the three age groups

of drivers over the age of 35. The lowest odds of a winter weather-related crash were calculated for drivers in the oldest age group, that being 55–64 years old. Drivers aged 55–64 were also less likely to be involved in an any weather-related crash compared to 16 to 24 year-old drivers.

Table 2. Odds Ratios for time period having a winter weather-related and any weather-related circumstance during the work week.

Variable	Winter Weather-Related Crash [1]			Any Weather-Related Crash [2]	
	Case/Control [3]	OR [4]	95% CI	OR [4]	95% CI
Time of Day					
00:00–04:59	893/1994	0.78	(0.67, 0.90)	1.11	(0.97, 1.28)
05:00–05:29	207/312	1.34	(1.10, 1.63)	1.99	(1.68, 2.36)
05:30–05:59	362/488	1.62	(1.37, 1.91)	2.62	(2.25, 3.05)
06:00–06:29	389/740	1.25	(1.07, 1.48)	2.22	(1.89, 2.61)
06:30–06:59	652/1147	1.51	(1.26, 1.80)	2.65	(2.21, 3.16)
07:00–07:29	752/1194	1.75	(1.46, 2.11)	2.35	(1.95, 2.83)
07:30–07:59	1291/1861	1.91	(1.60, 2.28)	2.12	(1.77, 2.54)
08:00–08:29	1238/1350	2.21	(1.93, 2.52)	2.24	(1.96, 2.57)
08:30–08:59	857/966	1.92	(1.70, 2.17)	1.83	(1.62, 2.08)
09:00–09:29	619/732	1.81	(1.58, 2.06)	1.61	(1.41, 1.85)
09:30–09:59	588/748	1.67	(1.46, 1.91)	1.52	(1.32, 1.74)
10:00–10:29	557/817	1.44	(1.26, 1.65)	1.44	(1.26, 1.66)
10:30–10:59	479/826	1.24	(1.08, 1.42)	1.25	(1.09, 1.45)
11:00–11:59	927/1976	Ref		Ref	
Female	4043/6286	0.98	(0.93, 1.03)	0.87	(0.82, 0.91)
Male	5396/8395	Ref		Ref	
Age					
16–24	2696/3684	Ref		Ref	
25–34	2459/3628	0.94	(0.88, 1.02)	1.03	(0.96, 1.11)
35–44	1773/2798	0.87	(0.80, 0.94)	0.93	(0.86, 1.00)
45–54	1613/2682	0.82	(0.76, 0.89)	0.93	(0.86, 1.01)
55–64	1270/2359	0.73	(0.67, 0.79)	0.81	(0.74, 0.88)

[1] A winter weather-related crash was defined as a crash with any of the following: a contributing circumstance of "wet, icy"; surface conditions of "blowing snow," "freezing rain/drizzle," "sleet, hail," or "snow"; surface conditions of "ice/frost," "snow," or "slush". Analysis was restricted to November through February and the typical work week of Monday-Friday. [2] Any weather-related crash as defined as a crash with a contributing circumstance of "Weather conditions." Analysis was restricted to Monday-Friday. [3] Case was defined as a winter weather-related crash. Crashes that were not winter weather-related were controls. [4] Model includes county level categorical variables for mean travel time, traffic density, and the total number of commuting drivers.

3.3. Injury and Crash Severity

The severity of winter weather-related crashes was compared with all other crashes (Table 3). Winter weather-related crashes had lower fatality (0.4% vs. 0.7%, $p < 0.001$) and were less likely to result in any injury (24.0% vs. 27.4%, $p < 0.001$) when compared to other crashes. This may be partially explained by weather-related crashes less frequently resulting in a multicar crash compared to other crashes (54.2% vs. 61.9%, $p < 0.001$). Winter weather-related and non-winter weather-related crashes resulted in similar amounts of property damage.

Table 3. Crash severity for crashes with and without a winter weather-related circumstance.

Variable	Category	All Other Crash		Winter Weather-Related Crash		*p*-Value [1]
		n = 69,403	%	*n* = 16,378	%	
Crash Severity	Fatal Crash	514	0.7	60	0.4	<0.001
	Possible/Unknown Injury Crash	10,758	15.5	2405	14.7	0.009
	Property Damage Only	50,056	72.1	12,412	75.8	<0.001
	Suspected Minor Injury Crash	6364	9.2	1228	7.5	<0.001
	Suspected Serious Injury Crash	1711	2.5	273	1.7	<0.001
Any Injury	No Injury	50,369	72.6	12,445	76.0	
	Injury	19,034	27.4	3933	24.0	<0.001
Multicar Crash	No	26,424	38.1	7499	45.8	
	Yes	42,979	61.9	8879	54.2	<0.001
Property Damage	Median	4500	-	4500	-	

[1] The *p*-value is calculated using the chi-square test.

4. Discussion

We found that the likelihood of winter weather-related crashes was higher during the commuting hours compared to 11:00 to 11:59 a.m. We examined how this increased risk changes throughout the morning. The role of adverse winter weather conditions in crashes did not subside until well after most people would have completed their morning commute. Winter weather was most likely to play a role in crashes occurring between 7:30 and 9:00 a.m. While it was uncommon for drivers to begin their commute after 9:00 a.m., winter weather-related crashes were more likely during the commute times between 9:00 and 11:00 a.m. compared to the 11:00 to 11:59 a.m. time period.

An important mechanism to reduce the likelihood of winter weather-related crashes during the commute is to allow more flexibility for when workers are required to physically be at work. Through alternative work arrangements or flexible work hours, employers can reduce the frequency of employees driving in poor conditions. Additionally, flexible work schedules reduce the need for a driver to be on the road at specific times, allowing for the improvement of the surface conditions through plowing and application of anti-icing agents. Flexible work hours and alternative work arrangements are subtopics of the Future of Work Initiative [13]. In addition to the many ways that these programs can improve worker wellbeing, as outlined in the initiative, the reduced stress from driving in adverse conditions and the improved safety from reduced crash risk further justifies adoption of these programs.

Several studies support that proposition that driving in snowy conditions increases the risk of a crash [15–19,23]. Despite the known risk, there is a lack of guidance on how to reduce injuries to workers occurring during their commute, and no evaluations of policies that allow for flexible work start times or required work from home when adverse conditions are present. Other risk factors for a crash that can be influenced by workplace polices have been evaluated. Shift work and extended work shifts have both been identified as increasing the risk for a crash [7,24]. These risk factors can be mitigated through policies requiring a minimum amount of time between shifts and limiting the number of hours or number of extended shifts. Similarly, the increased risk from driving in adverse conditions can be reduced through policies allowing for alternative work arrangements.

Workplace programs such as flexible scheduling options and telecommuting are less likely to be available for employees of low-paying jobs [25,26]. Programs that allow for flexible start times or the option to work from home when adverse weather conditions are present are likely to have similar disparities in application. Many low-paying jobs in sectors such as customer service, retail, manufacturing, and food service have set time periods requiring employees to be present onsite to complete job requirements. Employers of these

jobs may find it more difficult to implement policies for flexible start times. However, our work provides evidence of the risk of crash resulting from driving in poor weather conditions. Implementing flexible start time and telecommuting programs could help reduce this risk. The benefits of these programs should be considered even if implementation is difficult. Other studies of work commute have shown that changes in the commute time can reduce job strain and burnout [27,28]. Improved job satisfaction should be evaluated in future studies of flexible start time and telecommuting programs as additional benefits beyond the reduced risk of injury from motor vehicle crashes.

Winter weather-related crashes more frequently occurred at the beginning of the workweek and on high speed, interstate roadways. These crashes were less likely to occur with a report of alcohol or drug involvement. Similarly, a study of the Fatality Analysis Reporting System (FARS), a national system that collects data about crashes that occur on public roads in the US, found that fatal crashes that occurred with an adverse weather event were less likely to involve drug or alcohol use compared to other fatal crashes [14]. The decreased contribution of alcohol and drugs in winter weather-related crashes suggests modification of these risk factors alone will not sufficiently improve driving safety in poor conditions.

Road conditions are a major factor in winter weather-related crashes. Methods to improve conditions, such as salting, sanding, and plowing have been shown to decrease the risk of motor vehicle crashes [29]. Based on the road system, improving surface conditions can increase road safety [30]. We found that a larger proportion of winter weather-related crashes occurred on interstates compared to other types of crashes. Improvements to surface conditions and road safety features of interstates should be prioritized in areas with many commuters and frequent winter weather conditions.

In previous research, female drivers have been identified as having a higher likelihood of being in an injurious crash during commuting hours [4]. We found that female drivers and male drivers had a similar likelihood of having a winter weather-related crash. However, male drivers did have a higher likelihood of fatal winter weather-related crashes than female drivers. The similar winter weather-related crash risk suggests female drivers and male drivers are facing similar demands to drive in adverse winter weather-related conditions. The likelihood of winter weather-related crash was lower for older age groups. We suspect these drivers have more flexibility in their work start time and are more frequently avoiding driving in adverse winter weather conditions. The assumed increased flexibility of these older drivers may change with a shift in the underlying worker population demographics. The job requirements of current older workers may differ from the job requirements of future older workers as they make up a larger proportion of the workforce. This change may limit older worker flexibility in the future if employers don't adopt flexible work arrangements. Additional research about work start time flexibility across age groups is needed to further understand the potential impact to further reduce crash risk.

Winter weather-related crashes, in our study, were less likely to result in injuries or death compared to non-winter weather-related crashes. In a previous study of Iowa interstate highway crashes during a snow event, crashes were less likely to result in an injury when compared to crashes occurring during non-snow events [31]. Multi-car crashes were less frequent among the winter weather-related crashes in our study. We believe this played a role in crashes being less severe since only one car was involved.

A limitation of this study is our inability to determine traffic flow during snowfall. Traffic flow decreases during hours of heavy snowfall [1,2]. However, decreased traffic flow has been shown to be less impacted at peak hours, such as during the morning commute [1]. This is supported by our findings of an over-representation of winter weather-related crashes occurring during most common commute times. Another limitation was our reliance on county-level data to control for differences in traffic density, the total number of drivers, and travel time. This may not accurately reflect the conditions at the time of the crash. However, it allowed us to generally identify driving conditions that may

have contributed to the crash. Additionally, the use of county-level data provides an example of how the ACS can be used at the ecological level to control for different driving conditions. This study only provides suggestive evidence of an over-representation of winter weather-related crashes occurring during commute hours. The setting for this study is a midwestern state with heavy snowfall. The specific weather conditions of a location should be considered when creating programs that address flexibility around the commute to work. Our secondary analysis found an increased likelihood of any weather-related crash during the commute hours, so we suggest other weather conditions be included in policies allowing for flexible works schedules and alternative work arrangements. Most commuters in Iowa do not use public transportation to travel to work. Safe and affordable public transportation systems can allow drivers to avoid driving in hazardous conditions. If workplaces are in areas with public transportation infrastructure, employers and safety managers could support employee use of these modes of transportation as another means of reducing the worker exposure to hazardous driving conditions. TWH research of workplace programs should include organizational and worker- level measurements to fully understand the impact of such programs [32]. More comprehensive research is needed to determine the impact of specific workplace programs that allow for flexible start times and alternative work arrangement to reduce driving in hazardous conditions.

5. Conclusions

We found that drivers were more likely to be involved in a winter weather-related crash during typical commute times. If drivers are given greater flexibility to avoid driving during adverse conditions, weather-related crashes could be reduced. Current commuting practices of self-restriction of driving are not mitigating the risk posed by driving in adverse weather conditions. An emphasis for employers and researchers tasked with improving the safety of a workplace commute has been reducing drowsy driving for shift work employees [7]. The reduction of drowsy driving through workplace policy is an example of how TWH principals can be applied to a driver's commute. Even more drivers would potentially be affected by policies allowing for flexible travel times or working remotely, as most workers are not exposed to shift work. While not possible for all workplaces, the dangers of a commute should be considered whenever possible to improve the overall health of employees. States can use crash data along with the ACS survey to assess how well drivers are avoiding hazardous driving conditions and if weather-related crashes are overrepresented during typical work commute hours.

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Informed Consent Statement: Not applicable.

Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found here: https://icat.iowadot.gov/ (accessed on 10 May 2020) and https://www.census.gov/acs/www/data/data-tables-and-tools/subject-tables/ (accessed on 10 May 2020).

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References

1. Hanbali, R.M.; Kuemmel, D.A. *Traffic Volume Reductions Due to Winter Storm Conditions*; National Research Council: Washington, DC, USA, 1993; pp. 159–164.
2. Knapp, K.K.; Smithson, L.D. Winter storm event volume impact analysis using multiple-source archived monitoring data. *Transp. Res. Rec* **2000**, *1700*, 10–16. [CrossRef]
3. Salminen, S. Seriousness of traffic accidents during work and commuting. *Percept. Mot. Ski.* **2003**, *97*, 147–150. [CrossRef]
4. Camino Lopez, M.A.; Gonzalez Alcantara, O.J.; Fontaneda, I. Gender Differences in Commuting Injuries in Spain and Their Impact on Injury Prevention. *Biomed. Res. Int.* **2017**, *2017*, 3834827. [CrossRef] [PubMed]
5. NIOSH. *National Occupational Research Agenda (NORA)/National Total Worker Health®Agenda (2016–2026): A National Agenda to Advance Total Worker Health®Research, Practice, Policy, and Capacity*; Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health: DHHS Cincinnati, OH, USA, 2016.
6. Tamers, S.L.; Chosewood, L.C.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.C. Total Worker Health((R)) 2014(-)2018: The Novel Approach to Worker Safety, Health, and Well-Being Evolves. *Int J. Env. Res. Public Health* **2019**, *16*, 321. [CrossRef] [PubMed]
7. Lee, M.L.; Howard, M.E.; Horrey, W.J.; Liang, Y.; Anderson, C.; Shreeve, M.S.; O'Brien, C.S.; Czeisler, C.A. High risk of near-crash driving events following night-shift work. *Proc. Natl. Acad. Sci. USA* **2016**, *113*, 176–181. [CrossRef] [PubMed]
8. Clark, B.; Chatterjee, K.; Martin, A.; Davis, A. How commuting affects subjective wellbeing. *Transportation* **2020**, *47*, 2777–2805. [CrossRef]
9. Tran, M.; Forst, L.; Buchanan, S. Not on the Radar: Active Commuting as a Workplace Wellness Issue. *J. Occup. Env. Med.* **2015**, *57*, e91–e92. [CrossRef]
10. Petrunoff, N.; Wen, L.M.; Rissel, C. Effects of a workplace travel plan intervention encouraging active travel to work: Outcomes from a three-year time-series study. *Public Health* **2016**, *135*, 38–47. [CrossRef]
11. Page, N.C.; Nilsson, V.O. Active Commuting: Workplace Health Promotion for Improved Employee Well-Being and Organizational Behavior. *Front. Psychol* **2016**, *7*, 1994. [CrossRef]
12. Kaczynski, A.T.; Bopp, M.J.; Wittman, P. Association of workplace supports with active commuting. *Prev. Chronic. Dis.* **2010**, *7*, A127.
13. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
14. Saha, S.; Schramm, P.; Nolan, A.; Hess, J. Adverse weather conditions and fatal motor vehicle crashes in the United States, 1994–2012. *Environ. Health A Glob. Access Sci. Source* **2016**, *15*, 104. [CrossRef] [PubMed]
15. Andrey, J. Long-term trends in weather-related crash risks. *J. Transp. Geogr.* **2010**, *18*, 247–258. [CrossRef]
16. Black, A.W.; Mote, T.L. Effects of winter precipitation on automobile collisions, injuries, and fatalities in the United States. *J. Transp. Geogr.* **2015**, *48*, 165–175. [CrossRef]
17. Mills, B.N.; Andrey, J.; Hambly, D. Analysis of precipitation-related motor vehicle collision and injury risk using insurance and police record information for Winnipeg, Canada. *J. Saf. Res.* **2011**, *42*, 383–390. [CrossRef] [PubMed]
18. Khattak, A.J.; Knapp, K.K. Snow event effects on interstate highway crashes. *J. Cold Reg. Eng.* **2001**, *15*, 219–229. [CrossRef]
19. Seeherman, J.; Liu, Y. Effects of extraordinary snowfall on traffic safety. *Accid. Anal. Prev.* **2015**, *81*, 194–203. [CrossRef] [PubMed]
20. U.S. Census Bureau. 2018 American Community Survey 1-Year Estimates. 2019. Available online: https://data.census.gov/cedsci/table?q=S0801&tid=ACSST1Y2018.S0801 (accessed on 10 May 2020).
21. Iowa DOT. Iowa Crash Analysis Tool 2020. Available online: https://icat.iowadot.gov/ (accessed on 10 May 2020).
22. U.S. Census Bureau. 2013–2017 American Community Survey 5-Year Estimate. 2018. Available online: https://data.census.gov/cedsci/table?q=S0801&tid=ACSST5Y2017.S0801 (accessed on 10 May 2020).
23. Qiu, L.; Nixon, W.A. Effects of Adverse Weather on Traffic Crashes Systematic Review and Meta-Analysis. *Transp. Res. Rec.* **2008**, *2055*, 139–146. [CrossRef]
24. Barger, L.K.; Cade, B.E.; Ayas, N.T.; Cronin, J.W.; Rosner, B.; Speizer, F.E.; Czeisler, C.A.; Harvard Work Hours, H.; Safety, G. Extended work shifts and the risk of motor vehicle crashes among interns. *N. Engl. J. Med.* **2005**, *352*, 125–134. [CrossRef]
25. Miller, T.I. The effects of employer-sponsored child care on employee absenteeism, turnover, productivity, recruitment or job satisfaction: What is claimed and what is known. *Pers. Psychol.* **1984**, *37*, 277–289. [CrossRef]
26. Glass, J.; Fujimoto, T. Employer Characteristics and the Provision of Family Responsive Policies. *Work Occup.* **1995**, *22*, 380–411. [CrossRef]
27. Amponsah-Tawiah, K.; Annor, F.; Arthur, B.G. Linking commuting stress to job satisfaction and turnover intention: The mediating role of burnout. *J. Workplace Behav. Health* **2016**, *31*, 104–123. [CrossRef]
28. Evans, G.W.; Wener, R.E. Rail commuting duration and passenger stress. *Health Psychol.* **2006**, *25*, 408–412. [CrossRef] [PubMed]
29. Fu, L.; Perchanok, M.S.; Moreno, L.F.M.; Shah, Q.A. Effects of winter weather and maintenance treatments on highway safety. In Proceedings of the TRB 2006 Annual Meeting, Washington, DC, USA, 22–26 January 2006.
30. Usman, T.; Fu, L.; Miranda-Moreno, L.F. Quantifying safety benefit of winter road maintenance: Accident frequency modeling. *Accid. Anal. Prev.* **2010**, *42*, 1878–1887. [CrossRef] [PubMed]

31. Khattak, A.J.; Knapp, K.K. Interstate highway crash injuries during winter snow and nonsnow events. *Transp. Res. Rec. J. Transp. Res. Board* **2001**, *1746*, 30–36. [CrossRef]
32. Tamers, S.L.; Goetzel, R.; Kelly, K.M.; Luckhaupt, S.; Nigam, J.; Pronk, N.P.; Rohlman, D.S.; Baron, S.; Brosseau, L.M.; Bushnell, T.; et al. Research Methodologies for Total Worker Health(R): Proceedings From a Workshop. *J. Occup. Env. Med.* **2018**, *60*, 968–978. [CrossRef]

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Understanding Worker Well-Being Relative to High-Workload and Recovery Activities across a Whole Day: Pilot Testing an Ecological Momentary Assessment Technique

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Abstract: Occupational health and safety is experiencing a paradigm shift from focusing only on health at the workplace toward a holistic approach and worker well-being framework that considers both work and non-work factors. Aligned with this shift, the purpose of this pilot study was to examine how, within a person, frequencies of high-workload and recovery activities from both work and non-work periods were associated with same day well-being measures. We analyzed data on 45 workers with type 1 diabetes from whom we collected activity data 5–6 times daily over 14 days. More frequent engagement in high-workload activities was associated with lower well-being on multiple measures including higher stress. Conversely, greater recovery activity frequency was mostly associated with higher well-being indicated by lower stress and higher positive affect. Overall, our results provide preliminary validity evidence for measures of high-workload and recovery activity exposure covering both work and non-work periods that can inform and support evaluations of worker well-being.

Keywords: workload; recovery; ecological momentary assessment; type 1 diabetes; workweek; healthy work design and well-being; future of work

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1. Introduction

The future of work is projected to bring with it several novel and complex concerns, prompting the National Institute for Occupational Safety and Health (NIOSH) to develop and promote holistic and transdisciplinary approaches to worker health and well-being [1]. Advances in technology are expected to continue influencing how workers engage in work and their workplace, including an increased frequency of remote work [2] and a greater degree of job automation [3]. The COVID-19 pandemic has drastically increased the pace at which remote working arrangements have been adopted, with roughly 35% of employees working from home at the height of the pandemic [4]. Anticipated consequences of these changes include blurring of work–life boundaries, greater expectation of work availability outside of standard hours, and increased potential for isolation [3,5]. To address these consequences, NIOSH implemented the Total Worker Health® (TWH) program, which aims to protect workers from work-related safety and health hazards while also promoting their health more generally [6]. NIOSH also proposed a new worker well-being framework that reflects this holistic paradigm shift and supports consideration of non-work factors that could impact worker health [7]. This expanded approach to worker well-being integrates work and non-work health promotion, acknowledging that both personal and occupational risk factors may contribute in an additive fashion to health and safety outcomes [8].

Workload and recovery are frequent areas of worker health research that could benefit from this more holistic and integrated perspective on supporting worker health and well-being. Workload is most commonly associated with working adults, who are exposed to higher amounts of workload from their paid employment [9,10] than are other populations, such as retirees [11]. However, workload can be more broadly considered as the cost (e.g., fatigue, stress, illness) of performing any tasks [12], whereby high-workload activities can be experienced in both work and non-work times. For instance, caregiving is a potential source of non-work, high workload [13]. Recovery is the process that repairs the negative strain effects stemming from exposure to stressors [14], a concept that is often applied to leisure time or sleep but can also be found in activities throughout a workday. Although workload and recovery apply to both work and non-work activities that individuals engage in throughout a day, prior studies have typically partitioned the investigation of exposures by examining high workload at work [15] and recovery during non-work time [10]. As such, excessive exposure to high-workload tasks from work has frequently been associated with poorer psychological and physical well-being [15–17], while greater engagement in recovery after work has been associated with positive health and well-being outcomes [18].

Despite conceptual support using a siloed approach, the TWH philosophy and emerging holistic frameworks indicate that worker well-being may best be understood by examining activity engagement across both contexts to more fully capture the combined effects of workload and recovery [8]. That is, just as breaks taken during work are likely important to consider as part of total recovery, high-workload engagements during non-work time are also likely essential for measuring total workload.

We are, in essence, suggesting the need for an expanded scope within the Effort-Recovery model that accounts for both work and non-work activity engagements. According to this model, which was in part based on exercise literature, exerting effort (i.e., exposure to workload) during work leads to load reactions, acute changes to psychobiological systems that are adaptive in the short term in that they help in meeting task demands [9]. Adequate time for recovery, defined as return of psychobiological systems to baseline after exertion ceases, allows for reversal of the load reactions and a return of psychobiological systems to pre-demand levels [9]. With sufficient recovery, fatigue and other manifestations of load reactions are reduced [19]. Insufficient recovery however can lead to impaired well-being [19]. Much work has been investigating the nuances of the relationships between effort/recovery and well-being. For instance, job autonomy, role clarity, and social support have been theorized as potential moderators of the link between workload and well-being [20]. Here, however, we focus on the assertion that while the Effort-Recovery model traditionally focuses on work contexts, consideration of both work and non-work activity engagements may be needed to capture full exposure to effort (i.e., workload) and recovery. This would create a fuller picture of how well-being emerges compared to a siloed approach, where part of the picture is missing.

The purpose of this pilot study was to examine the feasibility of ecological momentary assessment (EMA), i.e., repeated sampling of behaviors and experiences in real time and in natural environments [21], as a method for investigating worker health and well-being as part of this expanded scope. Specifically, we collected EMA data five to six times a day for 14 days to examine how the frequencies of workers' exposure to high-workload and recovery activities, across both work and non-work periods over whole days, were associated with same day well-being measures. As shown in Table 1, we expected that valid EMA data would result in the following: (1) frequency of high-workload activities across a whole day would be positively associated with end of day workload [9] and negatively associated with well-being [15], and (2) frequency of recovery activities across a whole day would be negatively associated with workload [9] and positively associated with well-being [22,23].

Table 1. Hypothesized intra-person correlations between relative activity frequency and measures of workload and well-being.

	Workload				Well-Being		
	Overall Task Load	Work Hours	Stress	Fatigue	Pain	Positive Affect	Negative Affect
High workload activity frequency	+	+	+	+	+	−	+
Recovery activity frequency	−	−	−	−	−	+	−

−: negative correlation; +: positive correlation.

2. Materials and Methods

2.1. Study Overview

We analyzed data collected as part of a multisite study investigating the relationship between function, emotion, and blood glucose in adults with type 1 diabetes (T1D), described in greater detail in the published study methodology paper [24]. Participants aged 18–75 with T1D were recruited from three clinical sites, two in Los Angeles and one in New York, through mailings, phone calls, email invitations, and health provider referrals. Due to similarities in the implications of having chronic conditions, we anticipated that our T1D population may be somewhat similar to other worker populations with chronic conditions, thereby increasing the potential generalizability of our results (discussed further in Section 4.3). Only participants that identified as workers were included in analyses. Participants completed a baseline survey battery, 14 days of EMA data collection with 5–6 surveys per day, and a follow-up survey battery. The data collection procedures were approved by the University of Southern California Institutional Review Board. Subjects provided informed consent to participate in the study electronically through the REDCap e-consent framework [25].

2.2. Measures

For approximately two weeks, EMA surveys were administered on smartphones with up to 6 momentary surveys per day at 3-h intervals, using the Mobile EMA application (mEMA: ilumivu.com). Relative to other data collection methods such as end of day surveys or time diaries, an advantage of EMA is reduced recall bias since data are reported immediately after experiences of interest have occurred [21]. At each time point, participants identified the type of activity they were presently engaging in and rated state-level indicators of well-being, and, at the last assessment of each day a subjective assessment of overall workload was obtained (Table 2). Note that measures listed in Table 2 are only a subset used for analyses in this paper. For a full list of the items administered, please refer to the methods paper for the overarching study [24].

Table 2. Ecological momentary assessment measures administered over up to 14 days of data collection.

Construct	Item(s)	Response Option(s) [1]	Time
Activity			
Activity type	What were you doing right before starting this survey?	• Work/school activities (e.g., paid labor, volunteer work, and studying) • Traveling (e.g., driving, riding in a car, walking) • Relaxing/chilling (e.g., passive leisure like watching Netflix, listening to music) • Sleeping/napping • Socializing (e.g., talking with friends/family) • Caring for myself (e.g., eating, dressing, bathing, toileting, personal grooming) • Caring for others (e.g., caring for your children and pets, if you're caring for others as part of work this counts as "work") • Doing housework/errands (e.g., paying bills, washing dishes and clothes, exercising for health) • Fun/play/leisure activities (e.g., active leisure like exercising for fun, video games, reading for fun) • Other (If chosen, please specify)	All survey times

Table 2. *Cont.*

Construct	Item(s)	Response Option(s) [1]	Time
Well-Being			
Stress	How stressed are you right now?	0 (Not at all stressed) to 100 (Extremely stressed)	All survey times
Fatigue	At this moment, how tired do you feel?	0 (Not at all) to 100 (Extremely)	All survey times
Pain	At this moment, how much bodily pain do you have?	0 (None) to 100 (Extreme pain)	All survey times
Positive affect	4 items: Average of mood ratings for "happy", "content", "enthusiastic", "excited"	For each mood, 0 (not at all) to 100 (extremely)	All survey times
Negative affect	4 items: Average of mood ratings for "tense", "upset", "sad", "disappointed"	For each mood, 0 (not at all) to 100 (extremely)	All survey times
Workload			
Task Load	Average of 6 NASA-TLX items asking about mental demand, physical demand, time pressure, effort, performance satisfaction, and frustration for activities over the whole day.	0 to 100 sliding scale for each item, and the overall task load score	End of day
Work hours	(If worked) About how many hours did you work?	Hours, whole number, 0 to 24	End of day

[1] Activity examples were not in the actual item, but were explained during training and listed in a manual provided to participants.

2.2.1. Activity Exposure

At the beginning of every EMA survey, participants indicated the activity in which they were engaged immediately before the survey (sampling approach) [21] as opposed to reporting an activity that was engaged in for the greatest length of time in the hours prior (coverage) [21]. They were forced to choose only one activity option and prompted to choose the main or most important activity if several of them were being engaged in simultaneously. The sampling approach was used rather than a coverage method to minimize subjective selection of activities by the participants and further reduce recall bias. The activity question was adapted from a prior EMA study [26]. Possible activity responses were based on a taxonomy of activities created by occupational therapists based on their practice framework [27] and decided upon with expert review by occupational scientists. During baseline training, participants were given examples of types of activities within each category; these detailed examples were not presented with the answer choices to reduce word clutter on the phone screen.

The responses were conceptually sorted into the two primary constructs of high-workload and recovery based on inferences made from prior literature, the former including both work and non-work strenuous activities and the latter including leisure and rest activities. To do so, we emulated an approach used in prior studies where activities are sorted into categories based on their typical characteristics (e.g., watching television typically represents a "sedentary" behavior) [28].

High-workload tasks included "work/school" and "caring for others". "Work/school" was placed in this category because of the large body of literature conceptualizing work as a demanding task that requires recovery [9,10]. Caregiving is one of the few sources of non-workplace demands that has been frequently investigated [13]. While many studies report adverse effects of caregiving [29,30], others have highlighted the benefits [31,32]. One broadly supported idea is that caregiving may have positive effects as long as workload is not too excessive (e.g., time demands being too high) [29,33]. We argued that given how often caregiving is conceptualized as a demand source that requires recovery periods [34], it conceptually belongs to the high-workload category. This classification was not meant to ignore the potential positive aspects of caregiving such as companionship and a sense of fulfillment [31], but to acknowledge the demands that often come with providing care for other individuals.

Recovery activities included "fun/play/leisure", "socializing", "relaxing/chilling", and "sleeping/napping". "Relaxing/chilling", and "sleeping/napping" were counted as recovery because both are often accompanied by increases in parasympathetic activity, which has been conceptualized as a defining feature of rest [35]. "Fun/play/leisure" and

"socializing" were also subsumed under recovery because both are forms of leisure [36], which is an often-cited form of recovery [10].

Any activity choice that did not fit into high-workload or recovery groupings was placed into an "unclassified" category. "Doing housework/errands" was one activity placed into this category because there is limited published research to provide a clear interpretation of these tasks. For example, "cleaning" is considered restful by some and demanding by others, making it difficult to define as either high-workload or recovery without further understanding an individual's context. Participants also had an option to specify "other activities" not covered by the a priori activity response options using an open-ended response. These responses were assigned to one of the three categories during a post hoc review process. For example, an open-ended response "vigorous exercise" would fit under "high-workload" because of the short-term demand, though it may have a long-term benefit.

2.2.2. Perceived Workload

We administered additional measures explicitly tapping participants' perceptions of workload at the end of each day to validate that our EMA derived high-workload and recovery activity frequency measures had the expected associations with end-of-day workload measures. Survey questions were selected from validated global measures or those that had been used successfully in previous EMA studies. Task load is the level of difficulty an individual encounters when executing tasks [37] and was assessed with an adapted version of the National Aeronautics and Space Administration Task Load Index (NASA-TLX) [38]. Like the original TLX, we also used six items addressing different contributors to task load, but changed the period being inquired about to a whole day rather than a particular task. In the nursing literature, there has been some evidence supporting the validity of use of the TLX items to cover entire periods instead of particular tasks, specifically whole work shifts [39]. The NASA-TLX provides an overall task load score based on the summation (or equivalently, averaging) of an individual's perception of mental demand, physical demand, temporal demand, performance, effort, and frustration level [12]. While a weighting scheme accounting for individual variation in the extent to which each dimension of demands contributes to overall task load was utilized for the original TLX, a review found that raw sums (or equivalently, simple average) appeared just as valid [12]. Total hours worked served as a behavioral measure of general workload over the day.

2.2.3. Well-Being Experiences

Participants' momentary well-being experiences were measured using a variety of state-level factors including affect, working memory, stress, fatigue, and pain—all of which are core well-being concepts encapsulated in the health status section of NIOSH's new Worker Well-being Questionnaire (NIOSH WellBQ) [40]. For positive and negative affect, items were taken from the "Stress and Working Memory" (SAWM) study [41], which were adapted from the Positive and Negative Affect Schedule (PANAS) [42] by changing the period referenced (e.g., asking about emotions in the moment) and the mood items used. The items for fatigue and pain were taken from prior a EMA study [43], where they were derived from the Brief Fatigue Inventory [44] and Brief Pain Inventory, respectively [45]. Our item for stress was used in a prior EMA study [46].

2.2.4. Scoring of Measures

Various scoring approaches were used for different measures. For single item assessments of stress, fatigue, pain, and work hours, there was no score calculation step. The workload, affect, and activity exposure measures however did involve the calculation steps described prior. Scoring algorithms for workload, positive/negative affect, and high workload activity frequency were decided prior to reviewing the dataset. For calculation of recovery frequency however, prior to looking at the data, a scoring approach was used

where "relaxing" and "leisure" were treated as separate forms of recovery. After review of the initial draft, one of the co-authors commented that collapsing relaxing and leisure under the umbrella of recovery made more sense. Thus, scoring for recovery exposure was changed to include both relaxing and leisure activities.

2.3. Statistical Analyses

To calculate daily activity frequencies within the high-workload and recovery categories, we divided the number of times people reported engaging in a particular activity type by the number of EMA assessments taken [47]. For example, if a participant completed six surveys in a day and reported engaging in activities within the high-workload category during three surveys, then the relative frequency of high-workload for that day would be 3/6 = 0.5. Frequencies were only calculated for days where participants completed four or more surveys.

We conducted intra-person correlational tests to investigate the associations of our EMA derived daily activity frequencies with end of day workload and well-being measures. In addition to daily activities, we hypothesized that weekends would have lower high-workload and higher recovery activity frequencies than did days during a traditional 5-day work week. Mixed-effects modeling was used with day of the week as the only predictor, the intercept as the dependent variable's random effect, and frequency of activity groupings (e.g., high-workload and recovery) as the dependent variable. Models were run with the "lme4" package in the statistical software R [48]. Mixed modeling was used to account for the nested nature of the data (multiple days nested in an individual) while testing hypotheses involving multilevel categorical predictors (e.g., day of week) [49]. We chose Sunday as the reference for ease of comparison, as we anticipated that it would have the greatest frequency of recovery and lowest frequency of high-workload activities. Given that p values of parameters from mixed models may be biased because of the inherent uncertainty in the degrees of freedom to specify for calculations [50], especially when the data structure is complex or the dataset is unbalanced, we used bootstrapping to derive standard errors for the parameters and perform significance testing [50,51]. Bootstrapping was also used to account for potential non-normality in the mixed model residuals using the "method = boot" argument available in the "lme4" package. The decision to perform mixed models was done a priori, to allow for comparison of the mean values of high workload and recovery across different days of the week, and have a corresponding indication of statistical significance. The initial plan was to just present mean values of high workload/recovery/unclassified by day of week, but it seemed unsatisfactory to not be able to comment on statistical significance of the differences.

The "power.rmcorr" function in R was used to estimate the statistical power to detect repeated measures correlations [52]. Based on prior daily diary research, we assumed an intraclass coefficient of 0.5 for the nesting of repeated observations in individuals [53,54] for the power calculations. A priori sample size calculations suggested that a sample size of 30 with 13 observations per individual would yield 82% power to detect within-person effect sizes of 0.15 with $\alpha = 0.05$ (a small effect as per Cohen's conventions [55].

3. Results

Analyses were conducted on data from a total of 45 participants from the multisite study who identified as workers. The participants primarily worked full-time, had an average age of 40.1 (SD = 12.7) years, and were heterogenous with respect to gender, ethnicity, education, and annual income (Table 3). Participants were not required to report their vocations, but occupations reported include lawyer, engineer, housekeeper, teacher, and security guard. The median EMA completion percentage was 92%, and four or more EMA surveys were completed on 83% of all data collection days across the participants. The average number of days meeting the minimum threshold for inclusion of four EMA surveys was 12.5 days per participant. The final dataset included a total of 3352 EMA datapoints across 564 valid days. In post hoc power analyses, our sample of 45 participants

with 12.5 observations per individual yielded 84% power to detect within-person effect sizes of 0.13 with $\alpha = 0.05$.

Table 3. Demographic characteristics of our working sample ($n = 45$).

Characteristic	*n*	Mean (SD) or Percent (%)
Age (years)	45	40.1(12.7)
Gender		
Male	21	47%
Female	24	53%
Ethnicity		
White	20	44%
Latino/x	10	22%
African American	7	16%
Multi-ethnic	4	9%
Other	4	9%
Employment status		
Full-time	35	78%
Part-time	10	22%
Education		
High school grad or less	5	11%
Some college, no degree	6	13%
Associate's degree	1	2%
Bachelor's degree	18	40%
Graduate degree	15	33%
Annual household income		
<$50,000	9	20%
$50,000–$99,999	10	23%
≥$100,000	15	34%
Do not wish to provide	8	18%
Do not know	3	7%

The distribution of responses within each of the activity types is provided in Table 4. Approximately half of the datapoints were equally split between work/school (25.8%) and relaxing/chilling (22.0%). One-third of the responses were split between sleeping/napping (13.0%), housework/errands (11.8%), and self-care activities (11.2%). A total of 920 responses were categorized as high-workload, 1452 as recovery, and 980 as unclassified. High-workload activities had a lower average daily relative frequency (0.28, SD = 0.25) compared to the average daily relative frequency of recovery activities (0.43, SD = 0.25).

Table 4. Frequency distribution of activity types across all datapoints ($n = 3352$).

Activity Type	Frequency (%)
Work/school activities	866 (25.8%)
Relaxing/chilling	739 (22.0%)
Sleeping/napping	437 (13.0%)
Doing housework/errands	396 (11.8%)
Caring for myself	374 (11.2%)
Fun/play/leisure activities	191 (5.7%)
Traveling	160 (4.8%)
Socializing	85 (2.5%)
Caring for others	54 (1.6%)
Other	50 (1.5%)

Full between and in-person correlation matrices are shown in Appendices A and B respectively. Note that the correlations shown in Table 5 are only the subset of associations from Appendix A that were of interest in this paper, along with their confidence intervals.

We did not address between-person correlations in this paper, as the within-person context was of interest, and we only had sufficient power to investigate within-person questions and not between-person ones. Thus, between-person associations shown in Appendix A should be cautiously interpreted, and were included to highlight the distinction among between- and within-person relationships.

Table 5. Within-person correlations among daily frequency of activity categories and measures of workload and well-being. Values in parentheses represent 95% confidence intervals.

	Overall Task Load	Work Hours	Stress	Fatigue	Pain	Positive Affect	Negative Affect
High workload activity frequency	0.42, (0.34, 0.49)	0.31, (0.21, 0.4)	0.34, (0.26, 0.41)	0.11, (0.03, 0.2)	0.02, (−0.07, 0.11)	−0.15, (−0.23, −0.07)	0.21, (0.13, 0.29)
Recovery activity frequency	−0.37, (−0.44, −0.29)	−0.14, (−0.25, −0.04)	−0.34, (−0.41, −0.26)	−0.10, (−0.19, −0.01)	−0.06, (−0.14, 0.03)	0.14, (0.06, 0.23)	−0.22, (−0.3, −0.13)
Unclassified	−0.08, (−0.16, 0.01)	−0.17, (−0.27, −0.07)	−0.02, (−0.11, 0.07)	−0.02, (−0.11, 0.06)	0.04, (−0.04, 0.13)	0.02, (−0.07, 0.1)	−0.01, (−0.1, 0.08)

Except for pain, all associations among the daily relative frequencies for high-workload and recovery activities with measures of workload and well-being were in line with our hypotheses (Table 5). High-workload activity frequency had a moderate positive association with overall task load (r = 0.42), work hours (r = 0.31), and stress (r = 0.34), whereas recovery activity frequency had a moderate negative association with overall task load (r = −0.37) and stress (r = −0.34). Fatigue, positive affect, and negative affect were weakly associated with the two categories, and the two groupings had opposite directions for each. Unclassified activity frequency had only a weak negative association with work hours (r = −0.17), with no other associations with workload or well-being.

The daily relative frequencies of high-workload and recovery activities had nearly opposite patterns when examining their distributions across days of the week (Figure 1). Recovery activities accounted for a clear majority of the activities (i.e., >0.50) on the weekend and were slightly more prevalent than high-workload activities on Mondays and Fridays. High-workload and recovery activity frequencies were balanced through the middle of the week. Mixed model results for the daily activity frequency measures were consistent with our hypotheses. High-workload activities were more frequent on weekdays compared to Sunday, and recovery activities were less frequent on weekdays compared to Sunday (Table 6). The mean frequency of unclassified activities was only different from Sunday on Monday through Wednesday.

Table 6. Day-of-week differences in activity frequencies. Values in parentheses represent 95% confidence intervals.

Day	Number of Observations	High-Workload Frequency Beta, (95% CI)	Recovery Frequency Beta, (95% CI)	Unclassified Frequency Beta, (95% CI)
Sunday	89	Reference	Reference	Reference
Monday	87	0.24, (0.18, 0.29)	−0.16, (−0.22, −0.1)	−0.08, (−0.14, −0.02)
Tuesday	106	0.29, (0.23, 0.34)	−0.21, (−0.28, −0.15)	−0.07, (−0.13, −0.02)
Wednesday	105	0.32, (0.26, 0.38)	−0.24, (−0.3, −0.18)	−0.09, (−0.14, −0.03)
Thursday	107	0.26, (0.19, 0.31)	−0.2, (−0.26, −0.14)	−0.05, (−0.11, 0.01)
Friday	104	0.22, (0.16, 0.28)	−0.17, (−0.22, −0.11)	−0.05, (−0.11, 0.00)
Saturday	78	0.00 (−0.06, 0.06)	0.01, (−0.05, 0.08)	−0.01, (−0.07, 0.05)

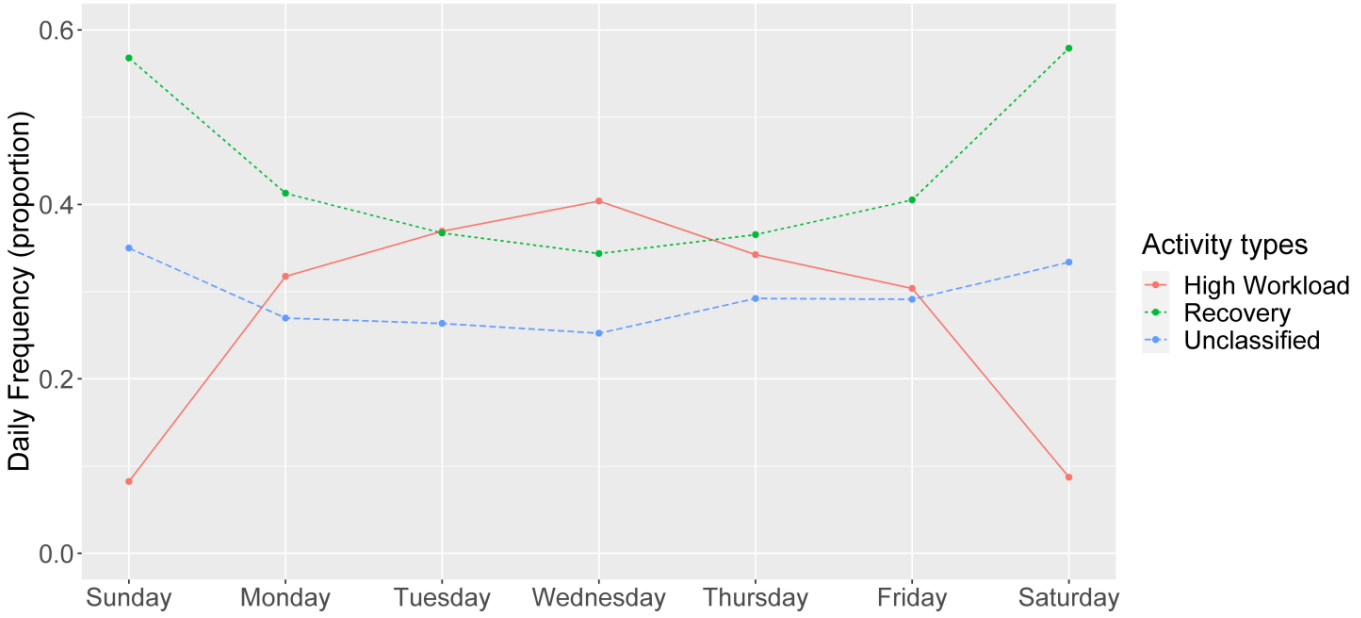


Figure 1. Distribution of activity frequencies, by day of week.

Measures of well-being showed less consistent patterns of mean level differences across the days of the week (Figure 2). Stress was the only state-level well-being measure that demonstrated fluctuations across days of the week, with a pattern comparable to that of high-workload activity frequency. A slight upward trend in fatigue was noted across the week, and participants generally reported low levels of pain, minimal negative affect, and high positive affect, measures that all remained relatively stable across the week.

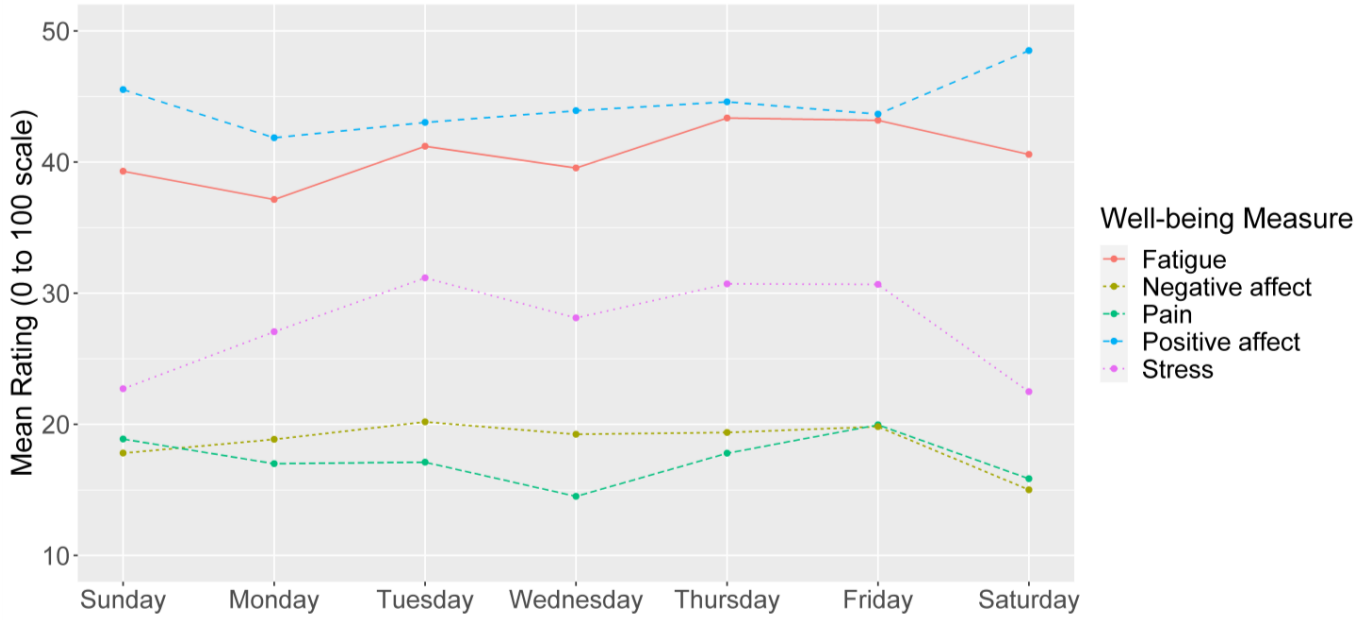


Figure 2. Average ratings of state-level well-being, by day of week.

4. Discussion

4.1. Principal Findings

Our results supported the usefulness of our EMA-derived daily activity frequency measures, with one piece of supporting evidence being our observation of weekend versus weekday differences in theoretically expected directions. Though not hypothesized a

priori, mean high-workload activity frequency steadily increased from Monday to Wednesday and then decreased on Thursday and Friday. Conversely, mean recovery activity frequency steadily decreased from Monday to Wednesday and increased on Thursday. This is consistent with the finding that fatigue, a possible proxy measure of the amount of workload relative to recovery experienced, was found to peak midweek and then decrease for workers [56]. Whole day workload and recovery by day of week has not yet been formally examined.

Results of within-person correlation tests also generally provided evidence supporting the trustworthiness of our daily activity measures. Frequency of unclassified activities had a significant but weak association with work hours ($r = -0.17$, $p = 0.001$). This relationship may have been driven by slight increases in engagement in unclassified activities (e.g., housework/errands) on the weekends when high-workload activities decreased. Despite this association, unclassified activities were not found to be related to measures of task load or any of the well-being factors, further indicating that deeper examination of contextual factors underlying these activities is needed to better understand their impact either on demand or recovery as a component of a worker's day.

In contrast to the lack of association in unclassified activities, daily frequencies of high-workload and recovery activities followed the hypothesized associations with well-being measures. This finding provides preliminary support that an EMA derived whole day metric of activities may be useful for exploring the holistic impact of both work and non-work periods. Across the correlations among high-workload and recovery activities with measures of workload and well-being, 86% were consistent with our hypotheses providing strong evidence of convergent validity. Convergent validity is considered to be adequate if at least 75% of hypothesized correlations are empirically supported [57,58].

Given the number of statistical tests conducted, there is a chance of spurious associations. We conducted approximately 39 statistical tests, which included21 within-person correlation tests and 18 beta parameter tests in mixed models. This total includes tests for unclassified activities that were done for exploratory purposes as opposed to hypothesis testing. Assuming an alpha of 0.05, approximately 2 (39×0.05) of the "significant" findings as per confidence intervals may have been spurious associations. Given how small this number is however relative to the number of associations we found aligned with our hypotheses, the overall findings of this pilot work provide strong preliminary evidence in supporting the evaluation of within-person relationships among workload/recovery across both work and non-work settings and measures of worker well-being.

4.2. Implications for EMA in Worker Health Research

While the relationship between workload/recovery and well-being has long been researched [15,18], the novelty of this study lies in the development of methods to assess high-workload and recovery activity exposure across both work and non-work settings using EMA methods. Studying the experience of high-workload and recovery activities by considering both work and non-work contexts matches well with NIOSH's intent to support workers of the future through its TWH initiative [1,6–8]. When workload and recovery are examined only in work or non-work scenarios, researchers are likely to attain an incomplete picture of total exposure and a fragmented depiction of how well-being outcomes arise. The actual relationships found between whole day activity frequencies and various well-being measures were generally in the expected directions. This provides preliminary evidence that measures with a coverage period comprising both work and non-work can provide meaningful information.

From a psychometric standpoint, no prior studies have formally validated daily activity frequencies calculated from a single EMA activity engagement item. Our results imply that our measurement approach, involving classification of a broad range of activity choices and tallying of the number of reports of particular activities in a day, may be appropriate for specific activity types. Activity frequencies derived from a single EMA activity engagement item would likely be particularly useful in studies already planning to

administer multiple EMA signals daily for several days. With minimal additional burden to participants, adding a single activity engagement item would allow researchers to gauge time use in an activity believed to be relevant to the primary construct of interest. For instance, in EMA studies investigating links between momentary patient reported outcome data and ambulatory physiological measures (e.g., blood pressure, blood glucose) in workers, a single activity item could potentially allow for exploration of questions such as how time spent in particular activities (e.g., work or leisure) is associated with the values of physiological measures on the same day.

EMA based time use measurement can also potentially be used by organizational leadership to approximately gauge time employees spend in high-workload and recovery activities over entire days, especially if they are already using EMA to measure other variables of interest such as ergonomic positioning or mood [59]. For instance, employers can work to identify the circumstances that contribute to excessive exposure to high workload relative to recovery. This imbalance may occur across all workers during certain days of the week or seasons of the year. Employers can also investigate relationships between whole day high workload/recovery and other within person measures of interest such as productivity or frequency of job errors on a particular day.

The utility of measuring daily workload directly (e.g., with the TLX) compared to assessing engagement in high-workload activities through EMA requires further research. Theoretically, the former requires that participants make a judgement of how demanding tasks across the day felt, while the latter requires them to just report activities that they engaged in, from which high workload exposure is calculated. Which is more useful may depend on the research question (e.g., if judgement-based vs. activity- report derived workload ratings are of interest), and which is found to have a greater relationship with the outcome(s) of interest (e.g., stress).

4.3. Limitations and Future Directions

Findings of this study should be considered within the context of this work as a pilot study. This includes an acknowledgement that this work is not intended to indicate conclusive relationships among whole-day exposures and well-being, but to serve as preliminary support for a process that could be used to examine these relationships.

Moreover, it should be noted that data collection was limited to individuals who had type 1 diabetes and were experiencing the COVID-19 pandemic and its associated social distancing requirements during data collection. Replication of this process with larger samples and within other worker populations and settings is needed to confirm our preliminary findings as more conclusive evidence of the relationships suggested in this study. Due to similarities in the implications of having chronic conditions, we anticipate that our T1D population may be somewhat similar to other worker populations with chronic conditions, suggesting the potential for future studies to generalize our study findings. For instance, the Chronic Disease Self-Management program, a widely used intervention for chronic conditions, assumes that patients with different chronic diseases have similar self-management problems and disease related tasks [60], which can include following complex treatment regimens, self-monitoring one's condition(s), and making decisions about when/how to receive professional treatment [61]. All these responsibilities are additional potential sources of workload, which may in part explain why management of chronic conditions in general is frequently perceived as intrusive to people's daily lives [62]. As additional evidence of the commonalities between chronic conditions, research is often conducted on populations with any chronic condition [63,64]. Nearly 45% of all Americans suffer from at least one chronic condition [65]. While our T1D population is potentially similar to populations with chronic conditions generally, they may have more commonalities with people with type 2 diabetes (T2D). Thus, our findings may generalize more easily to people with T2D as compared to populations with chronic conditions generally. T1D and T2D have different etiologies, and T2D is the much more common of the two, with a prevalence of 8.5% in the U.S as of 2017 as compared to 0.5% for

T1D [66]. However, they share similar management approaches (e.g., insulin therapy [67]) which can often serve as sources of distress [68]. In research studies, participants with both T1D and T2D are often pooled together [67,68].

In addition to limitations inherent in a pilot study, because activity engagement was a secondary measure within the primary study, precision for the EMA activity item was perhaps limited. Specifically, to minimize participant burden only nine broad activity choices were provided, and no follow-up questions were asked. The possible realm of activities are likely much more nuanced and capturing contextual factors and relative meaning to each individual might increase the ability to more precisely categorize activities as high-workload or recovery. One approach that may be worth testing in future studies is asking participants to first choose a general category of activities that best matches what they had been doing immediately prior to the survey (e.g., housework), and then use branching logic to ask about the specific activity done (e.g., washing dishes or vacuuming). This would allow for more detailed participant activity reports while reducing screen clutter. An additional semantic differential question allowing participants to rate the activity on a spectrum from high-workload to recovery could begin to fill the gap in understanding individual perspectives on activities, particularly those falling within our unclassified category.

Because the precision for our EMA activity item was limited we could not account for individual variation in context, and misclassification during conceptual sorting of activity types into high workload or recovery may have occured. For instance, if a participant reported "fun/play/leisure" this activity would always fall under the recovery category. However, "fun/play/leisure" in the form of a friendly board game could have been high-stress if it had evolved into cutthroat competition. As such, implicit in our conceptual sorting scheme was a certain degree of error that likely created a deviation from true high-workload/recovery activity exposure. A benefit of this rough sorting heuristicwas that it only required a single EMA item asking about type of activity engagement, and our results indicate that the sorting was good enough to capture relationships with the well-being measures. In future studies, increased accuracy could be achived using a more refined sorting of activities into high-workload and recovery bins may be possible if, in addition to a question about type of activity engaged in, there is also a rating of the workload associted with that activity, as suggested in the prior paragraph. The downside of this approach is the added respondent burden.

EMA measures are not formally validated as often as one time cross-sectional measures [69], so another study limitation to consider is that evidence of validity for EMA assessments used in this paper comes in the less definite forms of being adapted from validated global measures, and/or being successfully used in prior studies. While the approach of arguing for the validity of EMA assessments based on derivation from an establish global measure is often taken [43,70], it is also common for EMA studies to rely on face validity for some items [46,71]. The full versions of global measures often cannot be used in the EMA context due to excessive length, so adaption to shorter versions is often required [70]. While some work has been done to formally validate these shortened versions [72], such efforts often focus on validation in the between-person context and not within-person [69], like in our work.

Worker well-being is a broad multi-dimensional concept, and this pilot study did not address all aspects of well-being. We were limited in our choice of well-being measures to items included as part of the overarching study investigating the relationship between a variety of variables and blood glucose. Well-being variables that were included were general enough to be appliable to a large segment of workers, as evidenced by their inclusion in the NIOSH WellBQ, but do not comprehensively capture well-being. Future studies may be needed to investigate how high-workload and recovery activity exposure over whole days relate to other aspects of well-being (e.g., sleep quality, life satisfaction) not covered in this study.

Two further limitations are noted in our statistical approach. Firstly, within the context of worker well-being, researchers and practitioners are commonly interested in examining between-person questions, such as how workers with different job classifications and/or work schedule arrangements differ in their mean exposure to high workload and recovery activities. This pilot study was designed to provide preliminary support for measuring within-person relationships among activities and well-being, and did not examine between-person contexts in part because we were insufficiently powered to do so. Given that our findings supported general within-person hypotheses, future studies could examine feasibility for using EMA to create between person-level outcomes (e.g., averages over the entire study period) that could support between-person analyses. For instance, future studies might be able to conduct concurrent validity testing of study period averages of the daily activitiy frequencies (between-person metrics) by comparing their values to those attained from full questionnaires, such as the newly released NIOSH WellBQ. Secondly, we used the standard approach in longitudinal data analyses of assuming that our missing data were missing at random [73], which may have biased our results. There is a possibility that data was not missing at random. For instance, high workload engagements may have been undercounted because some participants may be less likely to answer surveys during those activities. Work on modeling data not missing at random in the longitudinal context is ongoing [73].

A final limitations in this pilot work is that our results did not allow us to assess our theoretical assertion that, when workload and recovery are examined only in work or non-work scenarios, researchers are likely to attain an incomplete picture of total exposure and a fragmented depiction of how well-being outcomes arise. Instead, our results provide evidence supporting one potential way to measure workload/recovery across both work and non-work. Future research, posssibly using the EMA assessment used here, is needed to compare how/if whole day and work specific measures of workload/recovery differ in their associations with well-being. Our theoretical assertion would be supported if the whole day version has stronger associations with well-being relative to assessment only of work periods.

5. Conclusions

In this pilot study, we found that measures of the frequency of high-workload and recovery activities over a whole day generally had the expected associations with same day well-being measures. More frequent engagement in high-workload activities was associated with worse well-being experiences including higher stress and lower positive affect. Conversely, greater recovery activity frequency was mostly associated with better well-being including lower stress and higher positive affect. Activity frequency measures also had anticipated associations with day of the week whereby high-workload activities peaked during the middle of the week and recovery activity frequency was more common on the weekends. Our results provide preliminary validity evidence for measures of high-workload and recovery activity exposure across a whole day that covers both work and non-work periods. This assessment of both work and non-work factors may facilitate strategies for identifying job classifications, work schedules, or individual workers who may be most at-risk for negative impacts on well-being. Application of these EMA techniques may serve as a basis for employers to develop policies or programs to support health and well-being across their workforce.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author, R.H., upon reasonable request.

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Appendix A

Table A1. Between-person intercorrelation matrix.

	High Workload Freq.	Recovery Freq.	Un-Classified Freq.	Stress	Fatigue	Pain	Positive Affect	Negative Affect	Task Load	Work Hours
High Workload	1, $p < 0.001$									
Recovery Freq.	−0.36, $p = 0.016$	1, $p < 0.001$								
Un-classified	−0.39, $p = 0.008$	−0.72, $p < 0.001$	1, $p < 0.001$							
Stress	0.44, $p = 0.003$	−0.19, $p = 0.206$	−0.13, $p = 0.377$	1, $p < 0.001$						
Fatigue	0.33, $p = 0.028$	−0.08, $p = 0.621$	−0.17, $p = 0.271$	0.57, $p < 0.001$	1, $p < 0.001$					
Pain	0.22, $p = 0.142$	−0.31, $p = 0.038$	0.14, $p = 0.355$	0.44, $p = 0.003$	0.50, $p < 0.001$	1, $p < 0.001$				
Positive Affect	0.22, $p = 0.140$	0.01, $p = 0.930$	−0.18, $p = 0.240$	−0.10, $p = 0.503$	−0.05, $p = 0.743$	−0.09, $p = 0.560$	1, $p < 0.001$			
Negative Affect	0.32, $p = 0.031$	−0.18, $p = 0.227$	−0.06, $p = 0.711$	0.73, $p < 0.001$	0.40, $p = 0.006$	0.45, $p = 0.002$	−0.11, $p = 0.459$	1, $p < 0.001$		
Task Load	0.51, $p < 0.001$	−0.30, $p = 0.043$	−0.08, $p = 0.610$	0.73, $p < 0.001$	0.34, $p = 0.022$	0.38, $p = 0.010$	0.10, $p = 0.499$	0.49, $p = 0.001$	1, $p < 0.001$	
Work Hours	0.21, $p = 0.172$	0.02, $p = 0.874$	−0.17, $p = 0.260$	0.10, $p = 0.532$	0, $p = 0.988$	−0.11, $p = 0.495$	0.04, $p = 0.793$	−0.05, $p = 0.734$	0.09, $p = 0.576$	1, $p < 0.001$

Appendix B

Table A2. Within-person intercorrelation matrix.

	High Workload Freq.	Recovery Freq.	Un-Classified Freq.	Stress	Fatigue	Pain	Positive Affect	Negative Affect	Task Load	Work Hours
High Workload	1, $p < 0.001$									
Recovery Freq.	−0.67, $p < 0.001$	1, $p < 0.001$								
Un-classified	−0.46, $p < 0.001$	−0.36, $p < 0.001$	1, $p < 0.001$							
Stress	0.34, $p < 0.001$	−0.34, $p < 0.001$	−0.02, $p = 0.621$	1, $p < 0.001$						
Fatigue	0.11, $p = 0.007$	−0.10, $p = 0.017$	−0.02, $p = 0.606$	0.31, $p < 0.001$	1, $p < 0.001$					
Pain	0.02, $p = 0.620$	−0.06, $p = 0.180$	0.04, $p = 0.327$	0.22, $p < 0.001$	0.37, $p < 0.001$	1, $p < 0.001$				
Positive Affect	−0.15, $p < 0.001$	0.14, $p = 0.001$	0.02, $p = 0.683$	−0.42, $p < 0.001$	−0.28, $p < 0.001$	−0.15, $p < 0.001$	1, $p < 0.001$			
Negative Affect	0.21, $p < 0.001$	−0.22, $p < 0.001$	−0.01, $p = 0.829$	0.72, $p < 0.001$	0.29, $p < 0.001$	0.23, $p < 0.001$	−0.54, $p < 0.001$	1, $p < 0.001$		
Task Load	0.41, $p < 0.001$	−0.36, $p < 0.001$	−0.08, $p = 0.069$	0.43, $p < 0.001$	0.23, $p < 0.001$	0.11, $p = 0.007$	−0.13, $p = 0.002$	0.33, $p < 0.001$	1, $p < 0.001$	
Work Hours	0.28, $p < 0.001$	−0.14, $p = 0.007$	−0.17, $p = 0.001$	0.22, $p < 0.001$	0.16, $p = 0.001$	0.08, $p = 0.109$	−0.12, $p = 0.015$	0.12, $p = 0.014$	0.31, $p < 0.001$	1, $p < 0.001$

References

1. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
2. Eurofound; International Labour Office. *Working Anytime, Anywhere: The Effects on the World of Work*; Publications Office of the European Union: Luxembourg; International Labour Office: Geneva, Switzerland, 2017.
3. Gabriel, M.; Pessl, E. Industry 4.0 and sustainability impacts: Critical discussion of sustainability aspects with a special focus on future of work and ecological consequences. *Ann. Fac. Eng. Hunedoara* **2016**, *14*, 131.
4. Brynjolfsson, E.; Horton, J.; Ozimek, A.; Rock, D.; Sharma, G.; TuYe, H.-Y. *COVID-19 and Remote Work: An Early Look at US Data*; Report No.: w27344; National Bureau of Economic Research: Cambridge, MA, USA, 2020; p. w27344. Available online: http://www.nber.org/papers/w27344.pdf (accessed on 17 August 2021).
5. Fukumura, Y.E.; Schott, J.M.; Lucas, G.M.; Becerik-Gerber, B.; Roll, S.C. Negotiating Time and Space When Working from Home: Experiences During COVID-19. *OTJR Occup. Particip. Health* **2021**, *41*, 223–231. [CrossRef]
6. Tamers, S.; Chosewood, L.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.-C. Total Worker Health® 2014–2018: The Novel Approach to Worker Safety, Health, and Well-Being Evolves. *Int. J. Environ. Res. Public Health* **2019**, *16*, 321. [CrossRef]
7. Chari, R.; Chang, C.-C.; Sauter, S.L.; Sayers, E.L.P.; Cerully, J.L.; Schulte, P.; Schill, A.L.; Uscher-Pines, L. Expanding the Paradigm of Occupational Safety and Health a New Framework for Worker Well-Being. *J. Occup. Environ. Med.* **2018**, *60*, 589–593. [CrossRef] [PubMed]
8. Sauter, S.L. Integrative Approaches to Safeguarding the Health and Safety of Workers. *Ind. Health* **2013**, *51*, 559–561. [CrossRef]
9. Meijman, T.F.; Mulder, G. Psychological aspects of workload. In *Handbook of Work and Organizational: Work Psychology*, 2nd ed.; Psychology Press: Hove, UK, 1998; Volume 2, pp. 5–33.
10. Sonnentag, S.; Fritz, C. The Recovery Experience Questionnaire: Development and validation of a measure for assessing recuperation and unwinding from work. *J. Occup. Health Psychol.* **2007**, *12*, 204–221. [CrossRef] [PubMed]
11. Pettican, A.; Prior, S. 'It's a New Way of Life': An Exploration of the Occupational Transition of Retirement. *Br. J. Occup. Ther.* **2011**, *74*, 12–19. [CrossRef]
12. Hart, S.G. NASA-task load index (NASA-TLX) 20 years later. In *In Proceedings of the Human Factors and Ergonomics Society Annual Meeting*; Sage publications: Los Angeles, CA, USA, 2006; pp. 904–908.
13. Dich, N.; Lange, T.; Head, J.; Rod, N.H. Work Stress, Caregiving and Allostatic Load: Prospective results from Whitehall II cohort study. *Psychosom. Med.* **2015**, *77*, 539–547. [CrossRef] [PubMed]
14. Demerouti, E.; Bakker, A.B.; Geurts, S.A.E.; Taris, T.W. Daily Recovery from Work-Related Effort During Non-Work Time. *Res. Occup. Stress Well Being* **2009**, *7*, 85–123.
15. Bowling, N.A.; Alarcon, G.M.; Bragg, C.B.; Hartman, M.J. A meta-analytic examination of the potential correlates and consequences of workload. *Work Stress* **2015**, *29*, 95–113. [CrossRef]
16. Radic, A.; Arjona-Fuentes, J.M.; Ariza-Montes, A.; Han, H.; Law, R. Job demands—Job resources (JD-R) model, work engagement, and well-being of cruise ship employees. *Int. J. Hosp. Manag.* **2020**, *88*, 102518. [CrossRef]
17. Ariza-Montes, A.; Hernández-Perlines, F.; Han, H.; Law, R. Human dimension of the hospitality industry: Working conditions and psychological well-being among European servers. *J. Hosp. Tour. Manag.* **2019**, *41*, 138–147. [CrossRef]
18. Bennett, A.A.; Bakker, A.B.; Field, J.G. Recovery from work-related effort: A meta-analysis. *J. Organ. Behav.* **2018**, *39*, 262–275. [CrossRef]
19. Sonnentag, S. Work, recovery activities, and individual well-being: A diary study. *J. Occup. Health Psychol.* **2001**, *6*, 196. [CrossRef] [PubMed]
20. Bakker, A.B.; Demerouti, E. The Job Demands-Resources model: State of the art. *J. Manag. Psychol.* **2007**, *22*, 309–328. [CrossRef]
21. Shiffman, S.; Stone, A.A.; Hufford, M.R. Ecological momentary assessment. *Annu. Rev. Clin. Psychol.* **2008**, *4*, 1–32. [CrossRef] [PubMed]
22. Pressman, S.D.; Matthews, K.A.; Cohen, S.; Martire, L.M.; Scheier, M.; Baum, A.; Schulz, R. Association of Enjoyable Leisure Activities with Psychological and Physical Well-Being. *Psychosom. Med.* **2009**, *71*, 725–732. [CrossRef]
23. Dababneh, A.J.; Swanson, N.; Shell, R.L. Impact of added rest breaks on the productivity and well being of workers. *Ergonomics* **2001**, *44*, 164–174. [CrossRef]
24. Pyatak, E.A.; Hernandez, R.; Pham, L.; Mehdiyeva, K.; Schneider, S.; Peters, A.; Ruelas, V.; Crandall, J.; Lee, P.-J.; Jin, H.; et al. Function and Emotion in Everyday Life with Type 1 Diabetes (FEEL-T1D): A fully remote intensive longitudinal study of blood glucose, function, and emotional well-being in adults with type 1 diabetes (Preprint). *JMIR Res. Protoc.* 2021. Available online: http://preprints.jmir.org/preprint/30901 (accessed on 10 September 2021).
25. Harris, P.A.; Taylor, R.; Thielke, R.; Payne, J.; Gonzalez, N.; Conde, J.G. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. *J. Biomed. Inform.* **2009**, *42*, 377–381. [CrossRef]
26. Laurenceau, J.-P. *Using Mobile Devices to Study Daily Diabetes Management in Marital*; Context NIDDK/NIH (R21DK098679); University of Delaware: Newark, DE, USA, 2013.
27. American Occupational Therapy Association. Occupational Therapy Practice Framework: Domain and Process—Fourth Edition. *Am. J. Occup Ther.* **2020**, *74*, 7412410010.

28. Tudor-Locke, C.; Washington, T.L.; Ainsworth, B.E.; Troiano, R.P. Linking the American Time Use Survey (ATUS) and the compendium of physical activities: Methods and rationale. *J. Phys. Act. Health* **2009**, *6*, 347–353. [CrossRef]
29. Legg, L.; Weir, C.J.; Langhorne, P.; Smith, L.N.; Stott, D.J. Is informal caregiving independently associated with poor health? A population-based study. *J. Epidemiol. Community Health* **2013**, *67*, 95–97. [CrossRef]
30. Murphy, N.A.; Christian, B.; Caplin, D.A.; Young, P.C. The health of caregivers for children with disabilities: Caregiver perspectives. *Child Care Health Dev.* **2007**, *33*, 180–187. [CrossRef]
31. Cohen, C.A.; Colantonio, A.; Vernich, L. Positive aspects of caregiving: Rounding out the caregiver experience. *Int. J. Geriatr. Psychiatry* **2002**, *17*, 184–188. [CrossRef]
32. Brown, S.L.; Smith, D.M.; Schulz, R.; Kabeto, M.U.; Ubel, P.A.; Poulin, M.; Yi, J.; Kim, C.; Langa, K.M. Caregiving Behavior Is Associated with Decreased Mortality Risk. *Psychol. Sci.* **2009**, *20*, 488–494. [CrossRef] [PubMed]
33. Buyck, J.-F.; Bonnaud, S.; Boumendil, A.; Andrieu, S.; Bonenfant, S.; Goldberg, M.; Zins, M.; Ankri, J. Informal Caregiving and Self-Reported Mental and Physical Health: Results from the Gazel Cohort Study. *Am. J. Public Health* **2011**, *101*, 1971–1979. [CrossRef] [PubMed]
34. Rose, M.S.; Noelker, L.S.; Kagan, J. Improving Policies for Caregiver Respite Services. *Gerontologist* **2015**, *55*, 302–308. [CrossRef] [PubMed]
35. Tindle, J.; Tadi, P. *Neuroanatomy, Parasympathetic Nervous System*; StatPearls Publishing: Treasure Island, FL, USA, 2021. Available online: http://www.ncbi.nlm.nih.gov/books/NBK553141/ (accessed on 24 June 2021).
36. Stebbins, R.A. Casual leisure: A conceptual statement. *Leis. Stud.* **1997**, *16*, 17–25. [CrossRef]
37. Zimmerman, M.E. Task Load. In *Encyclopedia of Clinical Neuropsychology*; Kreutzer, J.S., DeLuca, J., Caplan, B., Eds.; Springer: New York, NY, USA, 2011; pp. 2469–2470. [CrossRef]
38. Hart, S.G.; Staveland, L.E. Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. In *Advances in Psychology*; Elsevier: Amsterdam, The Netherlands, 1988; pp. 139–183. Available online: https://linkinghub.elsevier.com/retrieve/pii/S0166411508623869 (accessed on 24 March 2019).
39. Hoonakker, P.; Carayon, P.; Gurses, A.; Brown, R.; McGuire, K.; Khunlertkit, A.; Walker, J.M. Measuring Workload of ICU Nurses with a Questionnaire Survey: The NASA Task Load Index (TLX). *IIE Trans. Healthc. Syst. Eng.* **2011**, *1*, 131–143. [CrossRef]
40. Chari, R.; Chang, C.-C.; Sauter, S.L.; Sayers, E.L.P.; Huang, W.; Fisher, G.G. *NIOSH Worker Well-Being Questionnaire (WellBQ)*; CDC: Atlanta, GA, USA, 2021.
41. Scott, S.B.; Sliwinski, M.J.; Zawadzki, M.; Stawski, R.S.; Kim, J.; Marcusson-Clavertz, D.; Lanza, S.T.; Conroy, D.E.; Buxton, O.; Almeida, D.M.; et al. A Coordinated Analysis of Variance in Affect in Daily Life. *Assessment* **2020**, *27*, 1683–1698. [CrossRef]
42. Crawford, J.R.; Henry, J.D. The Positive and Negative Affect Schedule (PANAS): Construct validity, measurement properties and normative data in a large non-clinical sample. *Br. J. Clin. Psychol.* **2004**, *43*, 245–265. [CrossRef]
43. Broderick, J.E.; Schwartz, J.E.; Schneider, S.; Stone, A.A. Can end-of-day reports replace momentary assessment of pain and fatigue? *J. Pain* **2009**, *10*, 274–281. [CrossRef]
44. Mendoza, T.R.; Wang, X.S.; Cleeland, C.S.; Morrissey, M.; Johnson, B.A.; Wendt, J.K.; Huber, S.L. The rapid assessment of fatigue severity in cancer patients: Use of the Brief Fatigue Inventory. *Cancer* **1999**, *85*, 1186–1196. [CrossRef]
45. Daut, R.L.; Cleeland, C.S. The prevalence and severity of pain in cancer. *Cancer* **1982**, *50*, 1913–1918. [CrossRef]
46. Dunton, G.F.; Ke, W.; Dzubur, E.; O'Connor, S.G.; Lopez, N.V.; Margolin, G. Within-Subject Effects of Stress on Weight-Related Parenting Practices in Mothers: An Ecological Momentary Assessment Study. *Ann. Behav. Med.* **2018**, *53*, 415–425. [CrossRef] [PubMed]
47. Sonnenberg, B.; Riediger, M.; Wrzus, C.; Wagner, G.G. Measuring Time Use in Surveys—How Valid are Time Use Questions in Surveys? Concordance of Survey and Experience Sampling Measures. *SSRN J.* **2012**, *41*, 1037–1052. Available online: http://www.ssrn.com/abstract=1895307 (accessed on 19 December 2020). [CrossRef]
48. Bates, D.; Mächler, M.; Bolker, B.; Walker, S. Fitting Linear Mixed-Effects Models Using lme4. *J. Stat. Softw.* **2015**, *67*, 1–48. [CrossRef]
49. Bell, B. *433-2013: A Multilevel Model Primer Using SAS® PROC MIXED*; SAS Institute: Cary, NC, USA, 2013; p. 19.
50. Luke, S.G. Evaluating significance in linear mixed-effects models in R. *Behav. Res.* **2017**, *49*, 1494–1502. [CrossRef] [PubMed]
51. Appiah, A.K. *Bootstrap Linear Mixed-Effects Models Using SAS® Procedures*; SAS Institute: Cary, NC, USA, 2018; p. 17.
52. Bakdash, J.Z.; Marusich, L.R. Repeated Measures Correlation. *Front. Psychol.* **2017**, *8*, 456. [CrossRef]
53. Merz, E.L.; Roesch, S.C. Modeling trait and state variation using multilevel factor analysis with PANAS daily diary data. *J. Res. Pers.* **2011**, *45*, 2–9. [CrossRef]
54. Roesch, S.C.; Aldridge, A.A.; Stocking, S.N.; Villodas, F.; Leung, Q.; Bartley, C.E.; Black, L.J. Multilevel Factor Analysis and Structural Equation Modeling of Daily Diary Coping Data: Modeling Trait and State Variation. *Multivar. Behav. Res.* **2010**, *45*, 767–789. [CrossRef]
55. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*; Academic Press: Cambridge, MA, USA, 2013.
56. Rook, J.W.; Zijlstra, F.R.H. The contribution of various types of activities to recovery. *Eur. J. Work Organ. Psychol.* **2006**, *15*, 218–240. [CrossRef]
57. Abma, I.L.; Rovers, M.; van der Wees, P.J. Appraising convergent validity of patient-reported outcome measures in systematic reviews: Constructing hypotheses and interpreting outcomes. *BMC Res Notes* **2016**, *9*, 226. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4837507/ (accessed on 22 March 2021). [CrossRef]

58. Terwee, C.B.; Bot, S.D.M.; de Boer, M.R.; van der Windt, D.A.W.M.; Knol, D.L.; Dekker, J.; Bouter, L.M.; de Vet, H.C.W. Quality criteria were proposed for measurement properties of health status questionnaires. *J. Clin. Epidemiol.* **2007**, *60*, 34–42. [CrossRef] [PubMed]
59. Engelen, L.; Chau, J.Y.; Burks-Young, S.; Bauman, A. Application of ecological momentary assessment in workplace health evaluation. *Health Promot. J. Aust.* **2016**, *27*, 259–263. [CrossRef] [PubMed]
60. Lorig, K.R.; Sobel, D.S.; Stewart, A.L.; Brown, B.W.; Bandura, A.; Ritter, P.; Gonzalez, V.M.; Laurent, D.D.; Holman, H.R. Evidence Suggesting That a Chronic Disease Self-Management Program Can Improve Health Status While Reducing Hospitalization: A Randomized Trial. *Med. Care* **1999**, *37*, 5–14. [CrossRef]
61. Dixon, A.; Hibbard, J.; Tusler, M. How do People with Different Levels of Activation Self-Manage their Chronic Conditions? *Patient Patient-Cent. Outcome Res.* **2009**, *2*, 257–268. [CrossRef] [PubMed]
62. Devins, G.M. Using the Illness Intrusiveness Ratings Scale to understand health-related quality of life in chronic disease. *J. Psychosom. Res.* **2010**, *68*, 591–602. [CrossRef]
63. Keles, H.; Ekici, A.; Ekici, M.; Bulcun, E.; Altinkaya, V. Effect of chronic diseases and associated psychological distress on health-related quality of life. *Intern. Med. J.* **2007**, *37*, 6–11. [CrossRef]
64. Schokker, M.C.; Links, T.P.; Luttik, M.L.; Hagedoorn, M. The association between regulatory focus and distress in patients with a chronic disease: The moderating role of partner support. *Br. J. Health Psychol.* **2010**, *15*, 63–78. [CrossRef]
65. Raghupathi, W.; Raghupathi, V. An Empirical Study of Chronic Diseases in the United States: A Visual Analytics Approach to Public Health. *Int. J. Environ. Res. Public Health* **2018**, *15*, 431. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5876976/ (accessed on 23 March 2021).
66. Xu, G.; Liu, B.; Sun, Y.; Du, Y.; Snetselaar, L.G.; Hu, F.B.; Bao, W. Prevalence of diagnosed type 1 and type 2 diabetes among US adults in 2016 and 2017: Population-based study. *BMJ* **2018**, *362*, k1497. [CrossRef]
67. Davies, M.J.; Gagliardino, J.J.; Gray, L.J.; Khunti, K.; Mohan, V.; Hughes, R. Real-world factors affecting adherence to insulin therapy in patients with Type 1 or Type 2 diabetes mellitus: A systematic review. *Diabet. Med.* **2013**, *30*, 512–524. [CrossRef] [PubMed]
68. Coccaro, E.F.; Lazarus, S.; Joseph, J.; Wyne, K.; Drossos, T.; Phillipson, L.; de Groot, M. Emotional Regulation and Diabetes Distress in Adults with Type 1 and Type 2 Diabetes. *Diabetes Care* **2021**, *44*, 20–25. [CrossRef] [PubMed]
69. Trull, T.J.; Ebner-Priemer, U.W. Ambulatory Assessment in Psychopathology Research: A Review of Recommended Reporting Guidelines and Current Practices. *J. Abnorm. Psychol.* **2020**, *129*, 56–63. [CrossRef] [PubMed]
70. Cranford, J.A.; Shrout, P.E.; Iida, M.; Rafaeli, E.; Yip, T.; Bolger, N. A Procedure for Evaluating Sensitivity to Within-Person Change: Can Mood Measures in Diary Studies Detect Change Reliably? *Pers. Soc. Psychol Bull.* **2006**, *32*, 917–929. [CrossRef]
71. Reichenberger, J.; Pannicke, B.; Arend, A.-K.; Petrowski, K.; Blechert, J. Does stress eat away at you or make you eat? EMA measures of stress predict day to day food craving and perceived food intake as a function of trait stress-eating. *Psychol. Health* **2021**, *36*, 129–147. [CrossRef]
72. Fisher, G.G.; Matthews, R.A.; Gibbons, A.M. Developing and investigating the use of single-item measures in organizational research. *J. Occup. Health Psychol.* **2016**, *21*, 3–23. [CrossRef]
73. Cursio, J.F.; Mermelstein, R.J.; Hedeker, D. Latent trait shared-parameter mixed models for missing ecological momentary assessment data. *Stat. Med.* **2019**, *38*, 660–673. [CrossRef]

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Framing Future of Work Considerations through Climate and Built Environment Assessment of Volunteer Work Practices in the United States Equine Assisted Services

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Abstract: The foundation of healthy workplace design is an understanding of work practices. Volunteers comprise the majority of the workforce in care centers using horses to address human health issues. Documentation is lacking on protections for worker well-being in equestrian microenvironments which are known to have the potential for dust exposures. Climate acts as a master variable in equestrian facility design and ventilation usage to address dust and temperature concerns. Using climate as an independent variable, our objective was to characterize space usage, safety, environmental control, and organizational practices through a national survey of equine assisted programs. We found that more fully enclosed indoor arena spaces were in cold/very cold and mixed-humid climates (p = 0.0114). Annually more volunteers (p = 0.0073) work in these two climate groups averaging 100 volunteers per location. A total of 34% of all facilities, regardless of climate, do not use mechanical ventilation systems (e.g., fans). As volunteer worker time in the arena increased, time in the barn microenvironment tended to decrease (p = 0.0538). We identified facility designs, ventilation usage, and worker arrangements to refine the scalability of future air contaminant monitoring and to provide frameworks for education, workplace design, and prevention of exposure to dust.

Keywords: volunteer workers; workplace design; ventilation; microenvironment; equestrian

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1. Introduction

In Equine Assisted Services (EAS), hippotherapy (HT) and therapeutic riding (TR) are well documented to aid in social, emotional, and behavioral development [1,2]. These programs are primarily offered at non-profit facilities, relying on volunteer workers to fill staffing gaps, and many facilities are mostly or fully volunteer-run. The Professional Association of Therapeutic Horsemanship (PATH) International reported that over 61,600 volunteers contributed an estimated value of more than four billion dollars in volunteer hours in 2017 [3]. These workers are essential in offering safe interventions for individuals with special needs and usually work in teams of three volunteers and one horse (volunteer horse unit; VHU; Figure S1). HT is a physical, occupational, or speech intervention that is delivered by a credentialed therapist and focuses on specific patient outcomes required by a physician. TR is adapted to populations that can have physical, social, or emotional vulnerabilities that the intervention is designed to mitigate [4]. Populations served by these health-based activities are predominantly youth aged 6–18 years with over 37,000 participants internationally in 2017 [3]. Organizations offering HT and TR have expanded rapidly in recent years, thus driving demand for more volunteer hours [5]. Emphasis on participant outcomes has overshadowed volunteers' workplace health and well-being.

The United States Centers for Disease Control and Prevention (CDC) and the National Institute for Occupational Safety and Health (NIOSH) launched their Future of Work (FOW) Initiative in 2020 [6]. Overarching goals of the Initiative include promoting research

concerning new job arrangements (EAS's largely volunteer workforce serves as an obvious example) and connecting trends in workplace and workforce changes to advance worker safety, health, and well-being [6]. The CDC/NIOSH FOW Initiative has adopted a Total Worker Health® (TWH) approach to advance these goals. The TWH program is a holistic model which prioritizes safety and underscores that the design of work conditions focuses on practices that can improve worker health outcomes. These frameworks are important for application in EAS to protect volunteer health, specifically around the need to "increase implementation of evidence-based programs and practices" [7]. Part of NIOSH's TWH program includes the National Occupational Research Agenda (NORA). NORA is a program used to stimulate research and improve workplace practices. Within the FOW initiative and NORA's research priorities, volunteer workers are included in the goal of addressing non-standard work practices and healthy work design. Work practice issues relevant to EAS include prevention and control of dust exposures and defining the built environment. Volunteer workers are recognized as important but are not regulated by standard worker programs. As such, work practices for volunteers are undefined. Workplace conditions including space usage, safety, organization, and environmental control practices need to be defined in EAS. Space usage refers to where volunteers are conducting their activities including time spent in the location, activity in the space, when activities occur, and what else is in the space including horses. Safety practices would include a description of the physical structures, maintenance of the areas, and if there are existing exposure concerns. Organization practices include a description of the EAS programs, who is served, and if there are worker training programs intended to protect health. Finally, environmental control practices are focused on how and when methods are applied to control known or suspected exposures in the environment.

A microenvironment is a location where people spend noteworthy time daily (e.g., work, volunteer, or recreational activities) and includes indoor, semi-indoor, and outdoor settings. Microenvironment exposure analysis can be used to explain exposures across spaces to further describe spatiotemporal and air contamination data [8]. In EAS, the barn and arena are two main microenvironments where people and horses move through daily. The barn is used primarily for horse housing where horses eat, rest, and are prepared for exercise (called "working the horse"). The surfaces in the barn spaces are designed for the comfort of the horses and for people to efficiently clean (e.g., manure removal and sweeping). The arena is the primary location used for horse training and activities. Arenas can consist of fully indoor spaces (roof, four walls, and openings that can be closed; called "indoor arenas"), partial indoor spaces (roof and partial side walls; called "covered arenas"), or flat and open spaces (no structure such as a roof or sidewalls; called "outdoor arenas"). The arena also differs from the barn in that the main floor surface (known as "footing") is specially constructed of materials that maximize horse welfare [9,10]. Indoor arenas may or may not incorporate mechanical ventilation systems [11], thus air quality can vary based on the type of ventilation [12–14]. Because TR and HT services are often offered at low or no cost to participants, many of the TR and HT facilities do not have the resources to implement modern ventilation systems [3].

Climate drives equestrian facility design and ventilation type. In the United States, areas with colder and more inclement climates have equestrian arenas that are more enclosed with four solid walls and a roof [15]. In climates with requirements for greater ventilation to maintain comfort, arenas were more likely to be open with removable or no sidewalls. Research by McGill et al. was the first of its kind to characterize indoor arena design by climate, yet this study did not include sufficient EAS programs to address how non-profit facilities may differ or be similar to for-profit equestrian sport. Extreme weather conditions vary by climate and with more open facility designs, workers are subjected to outdoor conditions. Climate-related occupational hazards relevant to FOW in EAS programs include increased ambient temperatures, air pollution, ultraviolet radiation, and changes in the built environment [16].

Climates that have distinct seasonal changes impacted real-time area particulate concentrations in equestrian microenvironments [12,17,18]. Personal exposures to both respirable dust and respirable crystalline silica were increased when the sand-based footing was dry and external weather conditions were also dry during summer seasons [17]. Conversely, colder months resulted in higher dust production in German indoor arenas [14]. The use of mechanical ventilation improved barn microenvironments in winter seasons, although less so in summer seasons when more natural ventilation (e.g., open doors) was used [12]. The combination of water, ventilation usage, and activity in equine facilities generated a profile of exposure akin to other agricultural activities and should be considered in determining health risks. Previous studies with riding instructors, workers that stand and teach in the indoor arena, reported episodic symptoms of rhinitis and allergic irritation during work activities. Airborne dust exposure was not determined to be a cause of reported symptoms [18]. The permissible exposure limits (PELs) for respirable dust and silica are 50 mg/m^3 and 0.05 mg/m^3 over an 8 h time-weighted average, respectively [19]. Respirable silica concentrations measured during work tasks completed in an indoor arena ranged from 0.01 mg/m^3 to 0.09 mg/m^3 and concentrations exceeding the PELs were observed [17]. Respirable dust concentrations in barn/horse housing have also been reported from less than 1 mg/m^3 to over 15 mg/m^3, with variability impacted by external door positions, method of sampling, time of day, presence of horse feedstuffs, and activity level in the space [12,18].

Despite known workplace hazards in EAS microenvironments, the research community has paid inadequate attention to volunteers moving through these spaces. We suspected that climate was a master variable for defining characteristics of EAS programs and would follow observations of facility design and climate made by McGill et al. [15]. We hypothesized that, at EAS facilities, factors that are related to how space is structured and used (hereafter, "space usage"); factors related to human health and safety (hereafter, "safety"); factors related to organizational management (hereafter, "organization"); and factors related to the environment (hereafter, "environmental control") are not independent of climate. Although it is reasonable that many of the factors that our survey attempted to characterize (e.g., what type of arena ventilation system is employed, if services are offered year-round) are driven by climate, for other factors, the assumption was less reasonable (e.g., what workers were responsible for maintaining arena space?). Given the paucity of data in this domain, we compared factors across climate zones to provide an understanding of volunteer workers and their potential exposure risks in EAS programs. Therefore, the purpose of this study was to: (1) establish baseline space usage, safety, organization, and environmental control practices in EAS programs using volunteer workers to aid in contextualizing future exposure studies (e.g., What happens in the spaces? What organizational or safety practices may contribute to dust exposures?) and (2) determine relationships between space usage, safety, organization, and controls used in EAS and climate designation.

2. Materials and Methods

2.1. Survey Design

We developed a questionnaire with four sections: environmental, program demographics, volunteer workers, and horse. Within each section, topics about factors that would impact air quality and potential dust exposure in offering EAS programs were developed into questions as documented in Table 1. Topics included space usage, safety, organization, and environmental control. Questions about safety and control were adapted from prior research [15]. Questions about space and organization were developed in consultation with selected PATH International Premier Accredited facilities. Selection criteria were specified before distributing the survey. Specifically, we included the surveys when the respondents were at least 18 years of age and facilities had both an indoor or covered arena and volunteer workers delivering EAS.

Table 1. Selected survey topics, questions, and potential answers for each section.

Section 1: Environmental		
Topic	**Question**	**Potential Answers**
Safety	Do you have any concerns about the environment within the indoor arena/activities space?	Yes No
	Do your concerns fall into any of these categories?	Multiple (air movement, moisture, dust, temperature) Temperature Dust
	What is the main component of the surface footing in the indoor arena/activity area?	Dirt/Clay Sand/washed sand Mixed (Wood Chip/Sawdust Textile/fiber) Rubber
	What other materials are in the footing mixture?	Dirt/Clay Sand/washed sand Crushed Rock/Wood Chip Textile/fiber Rubber Waxed Sand Dust suppression additive (Magnesium Chloride)
	Who is responsible for maintaining the arena space?	Volunteers Staff Other (contracted labor; property owners/leased property)
	Is smoking allowed in the indoor arena/activity space?	Yes No
	Please characterize how frequently vehicles are near or in the barn/horse housing area.	Only farm traffic is nearby Access is limited but available to service providers (vets/farriers/feed delivery) Driving and parking next to the area is common practice
Control	Are there temperature/ventilation control methods in the indoor arena?	Fans Heaters Fans and Heaters None
	What type of fans are used?	Box fan Low speed, high velocity (ceiling mounted) Exhaust
	How many fans?	One to three Four to six Six to nine
	When are fans used for ventilation?	Year-round When horses and humans are hot Based on thermometer measurements (set heat limits) When it feels humid in the facility During fly season Multiple (temperature, dust, flies)
Section 2: Program Demographics		
Topic	**Question**	**Potential Answers**
Space Usage	Select the activity for which you utilize your facility space the most.	Adaptive Riding/Therapeutic Riding Hippotherapy Recreational Riding Competition/Boarding
	Which of the following best describes where you conduct the majority of your services?	Covered arena Indoor/partially enclosed arena Indoor/fully enclosed arena Indoor/horse housing (stalls/barn)
	How are services offered year-round at this center?	All seasons All seasons except Winter Other (text entry)
Organization	Which of the following describes your Member Center affiliation?	PATH International/Premier Center Member United States Equestrian Federation American Hippotherapy Association National Council for Therapeutic Recreation Certification Multiple Affiliations (including PATH)
	Which of the following best describes the majority of your participants who engage in your equine assisted activities or equine assisted therapies?	Children under 9 years Children under 18 years Adults above 18 years Other (text entry)

Table 1. *Cont.*

Section 3: Volunteer Workers		
Topic	**Question**	**Potential Answers**
Space Usage	What is the minimal volunteer to participant ratio for the indoor arena/activities space?	1 volunteer to 1 participant 2 volunteers to 1 participant 3 volunteers to 1 participant
	Approximately how many volunteers participate in a typical day at this center?	Less than 10 11–25 26–45
	Annually, how many volunteers participate at this center?	Less than 25 26–50 51–100 more than 100
	If applicable, how long is the volunteer in the indoor arena/activity area on a typical day at this center?	Open ended entry, recoded to: Low (<2 h daily) High (>2 h daily)
	If applicable, how long is a typical volunteer in a barn/horse housing area on a typical day at this center?	Open ended entry recoded to: Low (<2 h daily) High (>2 h daily)
	If applicable, how many hours per week does each volunteer engage in activities offered in the indoor arena/activities space?	Open ended entry recoded to: Low (<2 h weekly) High (>2 h weekly)
Organization	Are you aware if the center volunteers have any of the following respiratory conditions?	Seasonal allergy (pollen primarily) Horse allergy (dander primarily) Grass/hay allergy I am not aware of any health conditions of volunteers
	Do volunteers receive training/education about the following respiratory conditions?	Severe conditions (e.g., Asthma, use of artificial respirators) Mild conditions (e.g., Seasonal, horse, grass/hay allergy) Multiple conditions (Severe and allergy) I am not aware of any volunteer training/education in respiratory conditions
Section 4: Horse		
Topic	**Question**	**Potential Answers**
Space Usage	How many horses or horse-volunteer-participant units are in the arena space at one time?	Less than 2 on average Two to four on average More than four on average
Organization	Are you aware if the center horses involved in activities have any of the following respiratory conditions?	ROA (recurrent airway obstruction) IAD (non-infectious inflammatory airway disease) Seasonal allergy No diagnosed condition, but horses will cough I am not aware of any health conditions of horses
	If horses do not have diagnosed conditions, but will cough, then which of the following do you observe to cause the most coughing in the horses?	When in the stall/barn area During activities in the arena
	If horse coughing is observed in the stall/barn or during activities/interventions in the arena space, which time of year do you notice the majority of the coughing in the horses?	Winter Spring Summer Fall Year round

2.2. Survey Distribution

The survey was distributed over 5 months in two phases: (1) internationally through PATH International distribution lists, and (2) through personal contact with regionally targeted facilities. Respondents were instructed that their participation was voluntary; no incentive was offered for the completion of the survey. Respondents answered questions based on their knowledge of the facility, the volunteers, and how the facility functioned. Respondents were asked to identify their role at the EAS facility (Survey S1). Each response represented a unique facility. The second phase was added in the last two months of distribution because there were no respondents in the states of Illinois, Indiana, Ohio, and Kentucky. Facilities in these four states received a second targeted distribution of the survey with the intent to develop community collaborations for future exposure assessments at facilities in these locales. Respondents were permitted to skip questions except for the age

and volunteer worker criterion. Incomplete surveys were included if primary selection questions of having an indoor/covered space and using volunteers were both satisfied.

2.3. Climate Designation

Climate designation was coded based on climate region guides [20]. The International Energy Conservation Code and American Society of Heating, Refrigerating and Air-Conditioning Engineers utilize climate designations specifically for building and ventilation guidance. There are eight zones in the United States with several states split by climate designation [20]. Alaska is the only state in the sub-arctic climate designation and was not represented in this study. Climate designations were based on heating degree days, average temperatures, and precipitation. By definition, a degree-day measurement is calculated from the mean outdoor temperature and base temperature in a building space over a 24 h period. This measurement reflects changes in the climate and is traditionally used for designing energy demands of buildings such as heating and ventilation. While actual indoor temperatures were not measured in this study, understanding the facility location in these climate designations, and how climate is a major variable in describing workplace factors provided a framework for comparing climate and work practices in EAS. Within the United States Department of Energy document, these climate designations are identifiable to the county level; thus, coding of respondent locale was grouped based on county-level climate designation [20]. Facility latitude and longitude were used to identify the county in which the facility was located. When locations were on the border between two climate designations or were the only representative in that climate designation, the location was combined with the nearest climate designation. For instance, a facility that was in northern Minnesota (very cold designation) was grouped with cold designations as it was the only very cold designation representative.

2.4. Data Coding and Analysis

Three types of indoor spaces were defined within the questionnaire: (1) indoor arena (2) covered arena, and (3) barn (fully enclosed horse housing area with any combination of openings and surface types). We used a median split for time variables and coded the variables into high (more than 2 h) or low categories (less than 2 h) for analyses. The seasonality of offerings was coded into "yes" for including winter and "no" for excluding the winter season. One text entry indicated a future winter offering, so that response was coded as "no" to represent current offerings. Descriptive analyses and frequencies were determined with comparisons of climate made to each of the dependent variables using the Chi-square or Fisher's exact test, as appropriate.

3. Results

3.1. Participants

In Phase 1, 55 individual EAS facilities (10% response rate) were recruited. Following targeted recruitment, 17 more facilities responded (100% response rate). A total of 72 responses were realized (96% domestic United States). Sixty-nine facilities were represented with one respondent from each facility above 18 years. We included facilities that offered EAS and used volunteers (n = 39). Facilities without an indoor arena/covered arena were excluded. Within the original 72 responses, three non-domestic facilities, in Brazil, Hong Kong, and Puerto Rico were eliminated for either not having an indoor arena/covered arena, and/or for not using volunteer workers leaving a data set representing only United States responses. A total of 33 responses were used in the data analysis as shown in Figure 1.

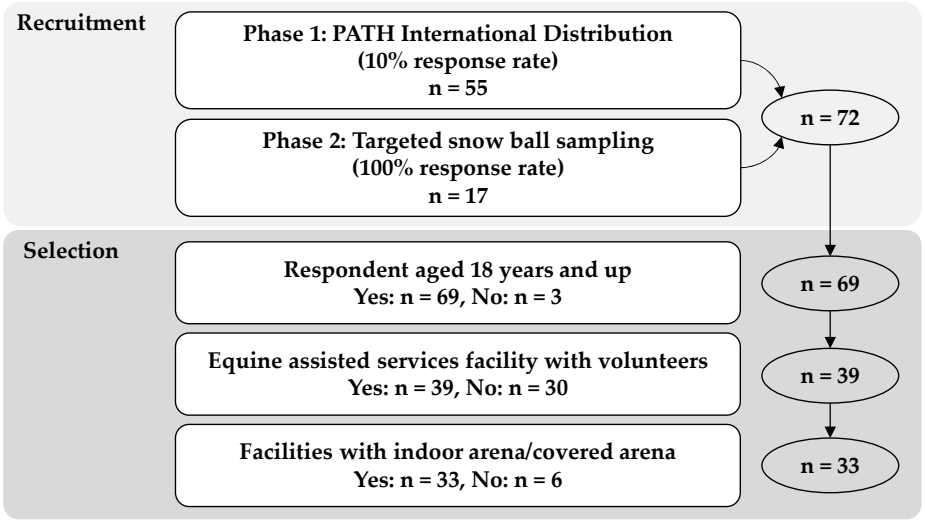


Figure 1. Recruitment flowchart for data analysis.

3.2. Climate Designation

Climate designations were coded based on the location latitude and longitude of the facilities. The four resulting designations were cold/very cold, mixed-humid, hot-humid, and hot-dry/mixed-dry. A total of 21 states were represented in the final data set as shown in Figure 2. Year-round services were offered at 72% (24/33) of facilities with the remaining indicating they stop activities in the winter season or rely on an assessment of weather conditions (Table 2). Facilities in hot dry/mixed dry locations offer 100% (4/4) of services year-round, whereas only 46% (6/13) of facilities in cold/very cold designations offer services year-round ($p = 0.0250$, df = 3, $X^2 = 9.345$). A summary of major findings relevant to the overall goals of the Future of Work Initiative is depicted in Figure 3.

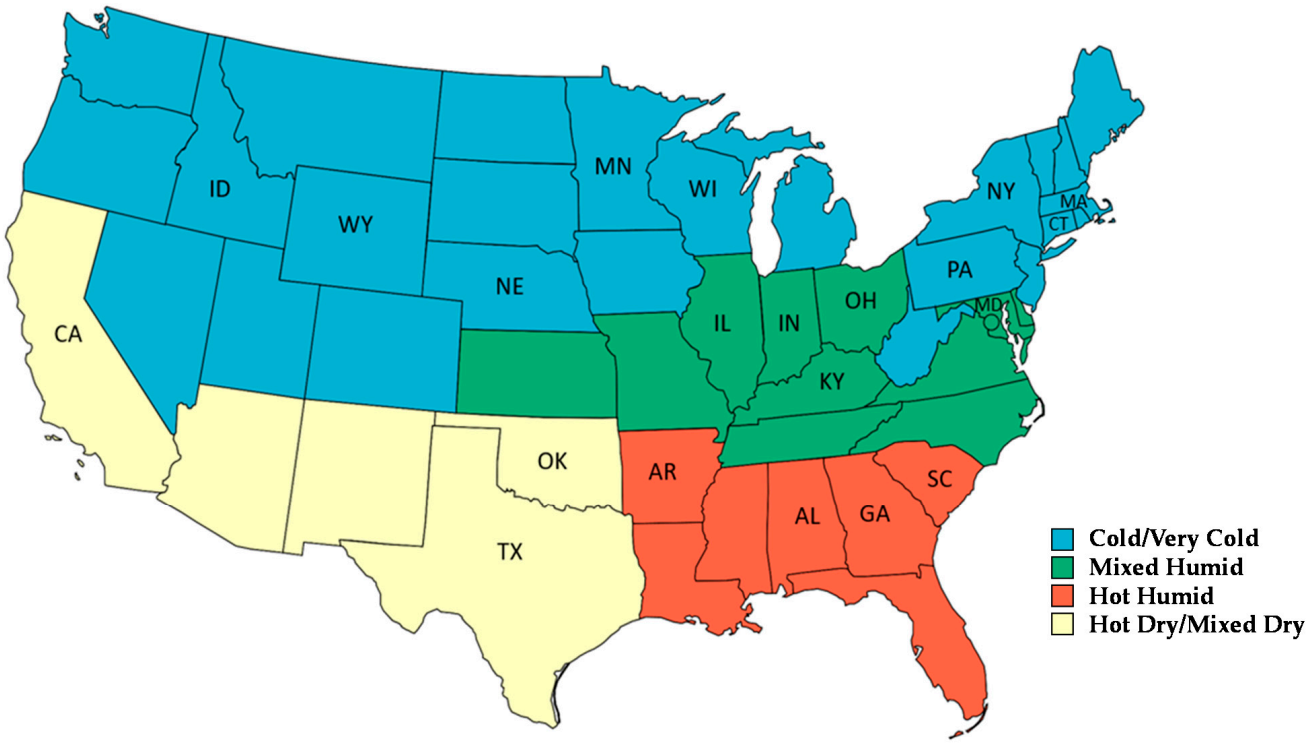


Figure 2. Climate designation and states in which facilities were located.

Table 2. Seasonality of Equine Assisted Services offered by climate designation.

	Cold/Very Cold *n* = 13	Mixed Humid * *n* = 12	Hot Humid *n* = 4	Hot Dry/Mixed Dry * *n* = 4
Year round	46%	92%	67%	100%
Spring, Summer, Fall only	46%	8%	33%	0%
Other (weather dependent)	8%	0%	0%	0%

* An effect of seasonality by climate designation was realized at $p = 0.0250$, df = 3, $X^2 = 9.345$.

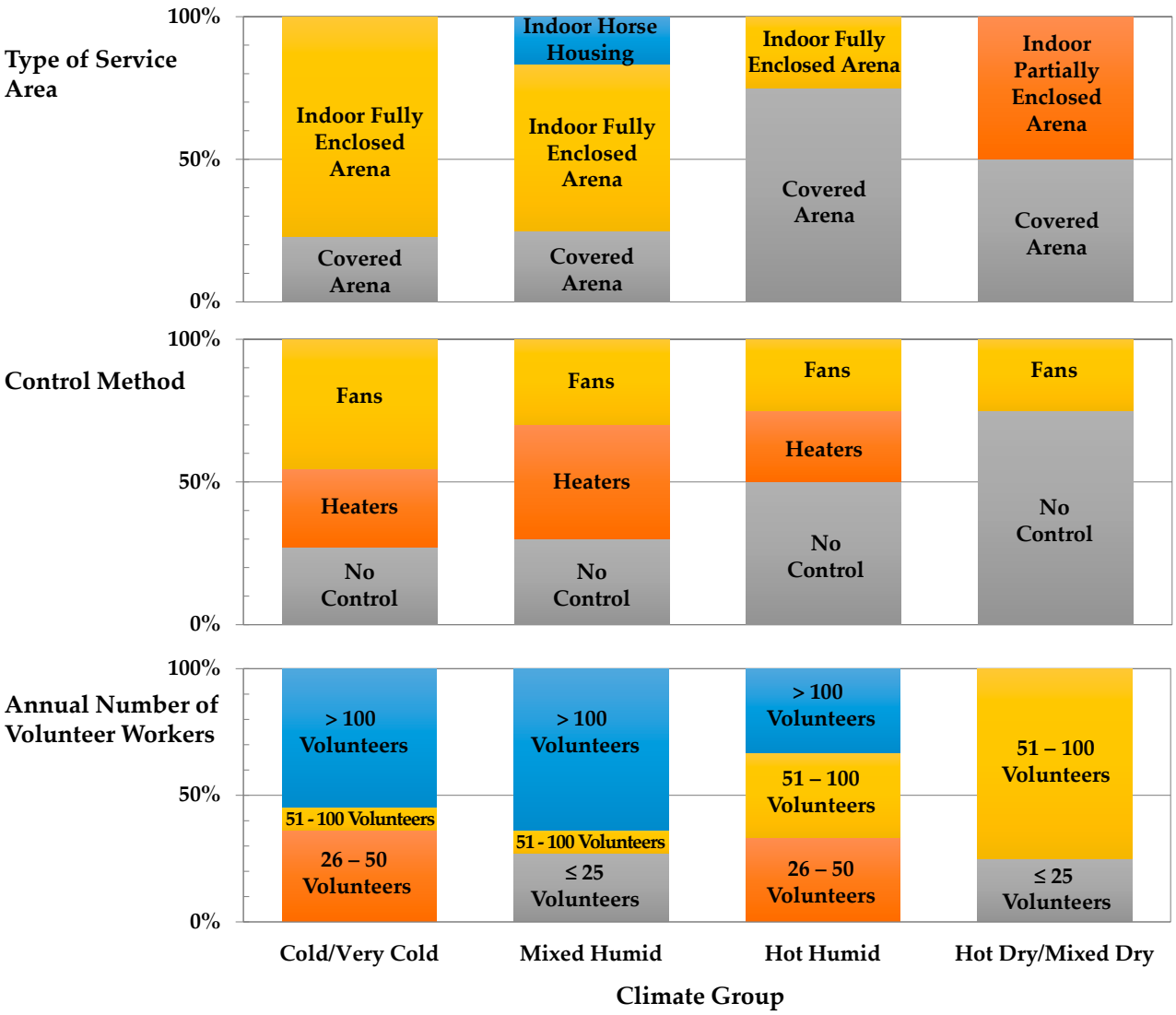


Figure 3. Major findings relevant to goals of the Future of Work Initiative.

3.3. Respondent Demographics

Respondent role in the facility tended to vary by climate designation with more executive directors replying from hot dry/mixed dry and mixed humid locations. The majority of responses were completed by center staff in cold/very cold designations, with an even proportion of roles represented in hot humid designations. Volunteers were represented in both the cold/very cold and hot humid climates. The majority of respondents were female and reported as white/Caucasian as documented in Table 3.

Table 3. Respondent demographics by climate designation.

	Cold/Very Cold $n = 11$	Mixed Humid $n = 9$	Hot Humid $n = 3$	Hot Dry/Mixed Dry $n = 4$
What is your role at this center?				
Center/Executive Director	18%	56%	33%	75%
Center Staff	63%	44%	34%	25%
Volunteer	18%	0%	33%	0%
($p = 0.0907$, df = 9, $X^2 = 15.007$)				
What is your sex?				
Male	0%	0%	0%	25%
Female	91%	100%	100%	75%
Prefer not to answer	0%	0%	0%	0%
($p = 0.4460$, df = 6, $X^2 = 5.800$)				
What is your race?				
White/Caucasian	91%	89%	67%	75%
American Indian/Alaska Native	0%	0%	0%	25%
Prefer not to answer	9%	11%	33%	0%
($p = 0.4400$, df = 6, $X^2 = 5.852$)				

3.4. Space Usage

Facilities in cold/very cold (77%; 10/13) and mixed-humid (58%; 7/12) climates reported indoor arenas that were fully enclosed ($p = 0.0114$, df = 9, $X^2 = 21.297$). Seventy-five percent (3/4) of facilities in the hot-humid climate and 50% (2/4) in hot-dry reported using covered arenas (Table S1). Arena sizes were optionally reported, with the smallest 370.88 m^2 (15.2 m × 24.4 m) and the largest 2613.66 m^2 (38.1 m × 68.6 m). Facility area ranged from 4 acres (0.016 km^2) to over 575 acres (2.33 km^2), with an average of approximately 30 acres (0.12 km^2).

A total of 73% (22/30) of facilities offer TR as their primary EAS activity. There was a tendency ($p = 0.0813$, df = 9, $X^2 = 15.366$) for hot-humid locations to offer the lowest proportion of TR, but they had more private lesson programming (Table S1). To further characterize the number of people in the space over time, we analyzed questions around the numbers and frequency of volunteers moving through the spaces. There was no effect of climate on a minimal volunteer to participant ratio, with responses ranging from 1:1 to 3:1. There was a tendency for more VHU in an arena at one time in cold/very cold climates (more than 4 = 80%; $p = 0.0775$, df = 6, $X^2 = 11.373$). The fewest average VHUs were observed in hot-humid climate facilities (less than 2 at a time = 33%). There was no interaction of how long volunteers work daily by climate designation. A relationship between the number of volunteers and climate designation was observed with cold/very cold (55%; 6/11) and mixed-humid (64%; 7/11) locations reporting more than 100 volunteers annually ($p = 0.0073$, df = 9, $X^2 = 22.552$). To characterize work time, respondents indicated daily and weekly work hours of volunteers. Daily, there was no relationship of time spent in the indoor arena by climate; volunteer workers are in the arena for up to 5 h/day in all climate designations ("High" group). Similarly, there was no relationship of daily time spent in the barn microenvironment by climate designation. Weekly there was no relationship between weekly hours and climate in the indoor arena. There was a relationship of volunteer work in the barn space weekly ($p = 0.0311$, df = 3, $X^2 = 28.870$). Volunteers in the mixed-humid climate more likely worked for greater than 2 h/wk in the barn space. When evaluating the relationship between volunteer worker time in the two spaces, when time in the arena is high, barn time tends to be reduced ($p = 0.0538$).

3.5. Safety

Concerns about the indoor environment in both arena and barn spaces were shared in nearly three-quarters of EAS facilities, and there were no differences based on climate

designation. Facilities in mixed humid, hot humid, and hot dry/mixed dry shared multiple concerns over temperature, dust, humidity/moisture, and ventilation challenges. Dust was a concern in 43% (3/7) of cold/very cold and 50% (2/4) of hot humid locations (Table S2). Airborne dust sources include the footing (soil surface), proximity to vehicles, and cooking, tobacco smoking/vaping, or other aerosol liberation activities. There was no relationship by climate designation of footing (soil surface) selection (Table S2). The majority of facilities had sand as the primary base (63%; 19/30) with mixed types (including fiber, rubber, wood chip) being secondary to sand bases (30%; 9/30). Paid staff maintain the arena footing (e.g., applying water, grooming the surface, and removing manure) in 90% (26/29) of facilities. Vehicle proximity was limited in 60% (15/25) of facilities, preventing exhaust fumes from entering the arena microenvironment. Nearby parking was restricted to individuals having mobility challenges, and facilities indicated that vehicles were not left running. There is no smoking/vaping permitted in any of the indoor microenvironments (arena or barn) in 100% (27/27) of the facilities.

3.6. Organization

There were no differences in affiliation with professional associations by climate designation, although the majority of facilities were associated with PATH International. Collectively, additional affiliations included the Certified Horsemanship Association (10%; 3/33), American Hippotherapy Association (3%; 1/33), National Council for Therapeutic Recreation Certification (3%; 1/33), and United States Equestrian Federation (3%; 1/33). The majority (73%; 24/33) of services are provided to children under 18 years and there were no differences by climate designation in who participates in the EAS (Table S3). Respondents answered questions about their personal awareness of respiratory conditions in volunteers such as allergies, asthma, or bronchitis. Forty-six percent (13/29) responded yes, they had awareness; however, there were no relationships to climate designation by type of condition. Thirty-three percent (1/3) of facilities in hot humid locations indicated they were aware of volunteers having a horse allergy (Table S3). Proportionately, more responses in hot-dry climates were found in the "I am not aware of any health conditions of volunteers" than other climate designations. Only facilities in the mixed humid climate provide education on severe respiratory conditions and treatment (e.g., asthma, and use of respirators), whereas more than 50% (13/25) in cold-very/cold, mixed humid, and hot humid climates provide volunteer training on mild respiratory condition recognition such as seasonal allergies and general irritation (Table S3). Respondents also considered their knowledge of horse respiratory health in these spaces. There were no differences by climate designation, although most respondents indicated "I am not aware of any health conditions of horses". Of those who indicated an answer of "No diagnosed condition, but horses will cough" respondents indicated coughing occurs in the arena 100% of the time in mixed humid, hot humid, and hot dry/mixed dry locations (n = 5). Cold/very cold responses were split evenly between the barn and arena microenvironment, although there were no differences by climate designation and season when horses cough (Table S3).

3.7. Environmental Control

Control topics were assessed through questions on arena ventilation including use of fans or heaters, number and type of fans, and when fans were used for controlling air movement. A total of 34% (10/29) of facilities do not use any type of ventilation system. When considering control methods by climate designation, there were no differences in the usage of fans or heaters. No heaters were reported in hot dry/mixed dry facilities. On average only 38% (11/29) of facilities used fans. Of those locations that used fans, box fans were commonly used in hot dry/mixed dry locations and ceiling mounted low speed, high volume fans were reported in cold/very cold and hot humid locations. In the mixed-humid facilities, both exhaust and combinations of the other fan types (box/high speed) were utilized. There were no differences by climate in the number of fans used, although cold/very cold locations reported more variability in the number of fans than

other climates (Table S4). Facilities chose ventilation methods based primarily on environmental temperature and humidity (Survey S1). There were no differences by climate in when fans were used, although mixed humid locations were the only locations to respond that fans were used year-round. We evaluated time in the arena microenvironment and the relationship to the use of ventilation systems. In hot humid locations, volunteers worked more than 2 h in arena microenvironments that used fans as the primary control method ($p = 0.0507$, df = 1, $X^2 = 3.819$).

4. Discussion

The purpose of this study was to provide baseline characterization of factors that impact volunteer worker health linked to FOW initiative priorities. To achieve this goal we utilized a survey addressing factors in EAS programs and evaluated climate as a master variable to ascertain differences among factors. Based on the analyses, there were effects of climate for many, but not all factors characterized, which supported our hypothesis. For instance, more volunteers work annually in cold/very cold and mixed humid climates than other areas. Conversely, we identified that ventilation control was independent of climate.

There is a paucity of research in EAS which focuses on defining protocols and practices at the organizational level [21]. Participant outcomes that are improved with EAS included somatic awareness, relational experiences, and brain functionality improvement [22–25]. Although, therapeutic interventions vary widely in approach (e.g., mounted or unmounted), delivery (frequency and duration), and measurement (e.g., biometric or psychometric scales). Prior EAS research does not offer a consensus on how to offer services and does not address climate dimensions addressed in our study. As such, this study is the first to establish how volunteer workers interact in equestrian spaces, and how EAS programs offer services related to climate.

Demographics of the respondent roles varied by climate. We expected more executive director responses across all climate designations, however, volunteer respondents were represented equally in the hot-humid climate designation. EAS facilities are primarily non-profit organizations and rely on volunteers to function. In this study, EAS roles were represented at the executive director, staff, and volunteer levels, suggesting that volunteers may have work roles that cross traditional expectations of offering EAS activities. Volunteers who responded to the survey were not asked what they did daily in the EAS organization.

We validated that climate drives facility design and space usage as previously reported in non-EAS equestrian facilities [15]. Facilities in cold/very cold and mixed humid climate designations operated in more enclosed structures representing indoor environments. We found that facilities in hot-dry and hot-humid climates reported more covered spaces that do not have walls; hence these are not true indoor environments. Given these findings, design and modeling of future exposure studies and worker protections should consider facility design and ventilation usage. In more open settings, dust exposure is dependent on natural airflow and arena footing moisture content is different based on footing type, ambient temperature, and moisture [9]. In a prior study, exposure to respirable dust and respirable crystalline silica was increased when conditions external to the arena were dry and no water was applied to the footing surface [17]. Changes in ambient temperature were positively correlated with variability in dust concentrations in barns [26].

Space usage also tended to be higher in cold/very cold climates at a single time point. Prior research indicates that increased activity in indoor arenas is associated with increased dispersion of footing material and subsequent increase in airborne contaminants [9,14]. In the equestrian microenvironment, air contaminants are generally produced by the activities of horses and people. The generation of air contaminants can be affected by occupancy (number of people and horses) [27,28], building characteristics (infiltration, airtightness, and ventilation system) [29–31], and activity type (sweeping, feeding horses, and use of bedding materials) [17]. We found that there was an inverse relationship between volunteer worker time in the arena and barn microenvironments. This finding is

important to understand what activity type volunteers engage in during the offering of EAS programs and provides a baseline for determining the next steps in understanding potential exposure risks.

Despite standards of practice provided for PATH, International [32], volunteer workers' health and safety are not addressed. EAS services are most like self-regulated organizations, where standards and practices are adapted for the delivery of services but worker health is not overseen by external bodies. Oftentimes these self-regulated organizations have complex social and political factors [33]. Because volunteers in EAS do not have the protections normally provided to standard workers, developing more detailed questioning around the adoption of health and safety practices is necessitated. Organizationally, programs hold permanent workers to standards different from temporary or casual workers, thus perpetuating organizational discrimination in health and safety practices between groups of workers [33]. To characterize potential exposure differences between standard workers and volunteers, we established that volunteer workers in EAS do not follow traditional work schedules. Time-weighted averages for exposures in volunteer workers would be based on a 5 h day/20 h workweek. This is different from the standard 8 h day used for traditional workers.

Respondents consistently reported safety concerns that included temperature, moisture/humidity, dust, and airflow. We expected this finding to vary by climate, as the moisture content of arena surfaces affects air contaminants, with wet footing materials having lower airborne dust liberation [10]. Conversely, higher moisture combined with lower ventilation, as measured by air exchange rates, previously resulted in greater mold and bioaerosol contaminates in equestrian microenvironments [13,14]. We also characterized EAS program footing as primarily sand and that footing selection was independent of climate was novel. Prior work suggested that footing surfaces vary by climate [15]. We found that climate impacted the number of volunteers working annually in the indoor arena with the highest number of volunteers in both the cold/very cold and mixed humid climates. What differentiates mixed humid climates from cold/very cold climates is the level of precipitation. Annually mixed humid climates in the United States receive more than 50 cm (20 inches) of precipitation [20]. While not measured in this study the impact of moisture, surface materials, and air exchange rates combined with the number of volunteer workers in various climates requires definition as potential exposure risks for EAS organizations.

Integrating organizational practices which expand approaches to promote health and safety and consider the relationships between workplace and health is core to the FOW Initiative priorities. Organizational practices that support relevant worker protections such as personal protection equipment or the use of environmental controls in the physical work environment are important organizational design factors [6]. Furthermore, climate related hazards such as increased ambient temperature or exposure to air pollution require organizations to enhance risk communications [16]. At the organization level, we expected more evidence of impact on human and horse health based on climate. Interestingly, 44% (12/27) of facilities indicated they were not aware of respiratory conditions. It was also surprising to find horse allergies in a population that works with horses. This is an important finding when considering future studies on lung function. Horse allergen dispersion is related to ventilation patterns in barn microenvironments [34], so further characterization of how and when ventilation is used is needed to better understand the dispersion of allergens in the arena microenvironment. Training on respiratory conditions was independent of climate for mild respiratory conditions such as general respiratory irritation or seasonal allergies. Respondents did not indicate if EAS programs provided training on ventilation usage and recognizing when airborne dust could pose a respiratory risk. Only those facilities in mixed-humid climates reported providing training on severe respiratory conditions including the use of artificial respirators. In horse farm workers, those who never or infrequently used respirators as personal protection equipment were

two times more likely to report respiratory symptoms when in barn microenvironments [35]. This survey did not specifically ask if volunteers used respirators.

Environmental control in the form of mechanical ventilation serves as a primary means to control indoor contaminants, where indoor air is exhausted and clean outside air is brought into the facility. Surprisingly, 34% (10/29) of facilities reported no specific ventilation control and of these responses. Fifty percent were located in the cold/very cold climate. Lack of specific ventilation control in equestrian indoor arenas is not uncommon [13,17], although we expected that facilities in cold/very cold climates would use have more environmental control methods (fans, heaters) than other climates.

Because organizations often rely on volunteer workers to ensure that activities in school and health programs are successful [36,37], findings from this study provide frameworks for FOW considerations of the built environment such as engineering design and ventilation recommendations, as well as addressing factors influencing worker health safety at the organizational leadership level. We successfully engaged facilities from various climate locations and demonstrated a variety of facility structures and ventilation systems. Potential dust exposure risks in indoor arenas include footing surfaces, the interplay between temperature, moisture, and airflow, and who is in the environment (e.g., horses and humans). We validated that most volunteers focused on activities including EAS participants as evidenced by the questions on VHU ratio and time spent in specific spaces. Volunteers did not work on the maintenance of the arena footing. Much of the prior exposure research has focused on activities unrelated to riding or interacting with horses such as using a tractor to drag and water the arena, general facility maintenance, or considered only a single rider in the indoor space [12,14,18]. We did not ask if other maintenance activities such as sweeping, raking, or blowing the spaces were completed by volunteers.

We also considered that seasonality would have a role in air contaminant risks. In winter seasons when barns inlets (e.g., doors, windows, ridge vents) were closed, the use of fans did not decrease respirable dust concentrations [12,13]. In climates experiencing below freezing temperatures, it is impractical to open all external air inlets as temperature control becomes a primary concern. Decreased ventilation use in winter seasons has been associated with human respiratory symptoms [12,17,36]. In our survey, we specifically asked about when fans were used for ventilation and responses of "when horses and humans are hot" and multiple reasons (temperature, dust, flies) predominated. Only those facilities in mixed-humid reported using fans year-round. In cold locations, facilities are generally enclosed with minimal ventilation since exhausted air must be replaced with cold outside air that must be heated, resulting in increased heating costs. Considering there are fewer air exchanges in cold climates to maintain internal temperatures [20], contaminants may accumulate when ventilation rates are low as previously documented [38]. Our survey indicated that EAS programs are offered year-round. Because the ambient temperature and humidity impact equestrian microenvironment air quality [10,18,34], the use of fans needs to be considered along with activity and season of activity offering. In mixed-humid climates and cold/very cold climate facilities, there are over 100 volunteers annually interacting in these spaces. EAS facilities in these two climate designations provide a natural experiment for future exposure studies to evaluate exposures in volunteer workers.

This study has several limitations. The sample size was small and no efforts were made to ensure the pool of respondents was representative of facilities that were affiliated with organizations other than PATH International, besides the regionally sampled facilities. Although demographics of respondents were recorded, demographics of volunteers such as age, sex, race, and ethnicity were not identified. These demographics would aid in further understanding exposure risks to dust exposures. Further understanding of sex and age differences in this non-standard workforce would also contribute to advancing the FOW Initiative priorities. Aging volunteers face challenges of increased risk not only for exposure but musculoskeletal injury [16] especially given differences in surfaces identified in this study. Given the complete absence of literature in this domain, however, we judge our study to be an important proof-of-concept. Our systematic characterization of the

volunteer work practices, facility characterization, and relationships to climate inform the next steps for conducting exposure assessments.

5. Conclusions

In this study, we explored relationships of climate and volunteer worker arrangements in indoor equestrian microenvironments. The FOW Initiative highlights the importance of organizations to provide hazard-free work environments while acknowledging that exactly how these safe environments will be deployed is unclear. The FOW Initiative also designates volunteers as non-standard workers [6] who may be vulnerable to unfair treatment. Volunteers have comprised an important workforce in HT and TR programs. We have defined volunteer work practices that can be relevant to TWH prevention and control guidelines. These results can also be applied to program assessments to make the case for advancements in ventilation and engineering strategies for these non-profit programs to promote healthy workspaces. In climates with more moisture, additional contaminates beyond particulate matter could be potential exposure sources for volunteer workers. We could expect that workers in cold locations might be more exposed to indoor pollutants than workers in hot locations. To evaluate this hypothesis, further study to monitor indoor air contaminants needs to be conducted. The relationships between systems of the built environment, climate, and volunteer worker health aids in understanding potential exposure risks for this unique population. EAS programs have the opportunity to utilize these findings to address volunteer worker safety to ensure the health and well-being of all populations involved in the therapeutic process.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph181910385/s1, Figure S1: Example of a volunteer-horse-unit in a fully enclosed arena (used with permission from Healing Strides of VA, Boone's Mill, VA, USA). Survey S1: Questionnaire utilized. Tables S1–S4 Detailed questionnaire results

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Institutional Review Board Statement: Ethical review and approval were waived for this study because the project did not meet the federal definition of human subjects' research. Questions focused on the facility, program, and observations but not specifically about "living individual about whom an investigator conducting research obtains (1) data through intervention or interaction with the individual, or (2) identifiable private information" [45 CFR 46.102(f)].

Informed Consent Statement: Based on the waiver of ethical review, this study was not considered human subjects research. Therefore, no informed consent was obtained.

Data Availability Statement: Data are contained within the article and the survey provided in the supplements.

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References

1. Burgon, H.; Gammage, D.; Hebden, J. Hoofbeats and heartbeats: Equine-assisted therapy and learning with young people with psychosocial issues—Theory and practice. *J. Soc. Work Pract.* **2017**, *32*, 3–16. [CrossRef]
2. Stergiou, A.; Tzoufi, M.; Ntzani, E.; Varvarousis, D.; Beris, A.; Ploumis, A. Therapeutic Effects of Horseback Riding Interventions: A Systematic Review and Meta-analysis. *Am. J. Phys. Med. Rehabil.* **2017**, *96*, 717–725. [CrossRef] [PubMed]

3. PATH International. 2017 PATH International. Statistics Fact Sheet. 2017. Available online: https://www.pathintl.org/images/pdf/about-narha/documents/2017-fact-sheet.pdf (accessed on 10 June 2021).
4. PATH International. EAS Definitions: Learn about EAAT. Available online: https://www.pathintl.org/resources-education/resources/EAS/193-EAS-definitions (accessed on 10 June 2021).
5. Vogelsang, M.M.; Lazo, M.; Harper, K.; Shehane, M. 132 Equine Assisted and Affiliated Therapies Provide Service-Learning Opportunities For Students. *J. Anim. Sci.* **2016**, *94*, 64. [CrossRef]
6. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flunn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef] [PubMed]
7. Tamers, S.L.; Chosewood, L.C.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.-C. Total Worker Health®2014–2018: The Novel Approach to Worker Safety, Health, and Well-Being Evolves. *Int. J. Environ. Res. Public Health* **2019**, *16*, 321. [CrossRef] [PubMed]
8. Steinle, S.; Reis, S.; Sabel, C.E.; Semple, S.; Twigg, M.M.; Braban, C.; Leeson, S.R.; Heal, M.R.; Harrison, D.; Lin, C.; et al. Personal exposure monitoring of PM 2.5 in indoor and outdoor microenvironments. *Sci. Total Environ.* **2015**, *508*, 383–394. [CrossRef]
9. Riding Arena Footing Material Selection and Management. Available online: https://extension.psu.edu/riding-arena-footing-material-selection-and-management (accessed on 15 June 2021).
10. Claußen, G.; Hessel, E.F. Particulate Matter in Equestrian Stables and Riding Arenas. *J. Equine Vet. Sci.* **2017**, *55*, 60–70. [CrossRef]
11. Hobbs, S.J.; Northrop, A.J.; Mahaffey, C.; Martin, J.H.; Clayton, H.M.; Murray, R.; Roepstorff, L.; Peterson, M.M. Equine Surfaces White Paper. 2015. Available online: https://inside.fei.org/system/files/Equine%20Surfaces%20White%20Paper.pdf (accessed on 15 June 2021).
12. Wålinder, R.; Riihimäki, M.; Bohlin, S.; Hogstedt, C.; Nordquist, T.; Raine, A.; Pringle, J.; Elfman, L. Installation of mechanical ventilation in a horse stable: Effects on air quality and human and equine airways. *Environ. Health Prev. Med.* **2011**, *16*, 264–272. [CrossRef]
13. Bøe, K.E.; Dragsund, G.; Jørgensen, G.H.; Fabian-Wheeler, E. Air Quality in Norwegian Horse Stables at Low Outdoor Temperatures. *J. Equine Vet. Sci.* **2017**, *55*, 44–50. [CrossRef]
14. Lühe, T.; Mielenz, N.; Schulz, J.; Kemper, N.; Dreyer-Rendelsmann, C. Factors associated with dust dispersed in the air of indoor riding arenas. *Equine Vet. J.* **2016**, *49*, 73–78. [CrossRef]
15. McGill, S.; Hayes, M.; Tumlin, K.; Coleman, R. Characterization of Indoor Arenas Through an Anonymous Survey. In Proceedings of the ASABE 2020 Annual International Meeting, Omaha, NE, USA, 13–15 July 2020. [CrossRef]
16. Schulte, P.; Bhattacharya, A.; Butler, C.; Chun, H.; Jacklitsch, B.; Jacobs, T.; Kiefer, M.; Lincoln, J.; Pendergrass, S.; Shire, J.; et al. Advancing the framework for considering the effects of climate change on worker safety and health. *J. Occup. Environ. Hyg.* **2016**, *13*, 847–865. [CrossRef]
17. Bulfin, K.; Cowie, H.; Galea, K.S.; Connolly, A.; Coggins, M.A. Occupational Exposures in an Equestrian Centre to Respirable Dust and Respirable Crystalline Silica. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3226. [CrossRef]
18. Kollar, J.; Swinker, A.; Swinker, M.L.; Irlbeck, N. Dust Exposure and Respiratory Disorders in Equine Instructors. *Prof. Anim. Sci.* **2005**, *21*, 128–132. [CrossRef]
19. National Institute for Occupational Safety and Health. NIOSH Pocket Guide to Chemical Hazards. Available online: https://www.cdc.gov/niosh/npg/npgd0684.html (accessed on 6 June 2021).
20. Baechler, M.C.; Gilbride, T.L.; Cole, P.C.; Hefty, M.G.; Ruiz, K. *Building America Best Practices Series—High Performance Technologies: Guide to Determining Climate Regions by Country*; U.S. Department of Energy: Washington, DC, USA, 2015; Volume 7, p. 3.
21. Fine, A.H.; Andersen, S.J. A Commentary on the Contemporary Issues Confronting Animal Assisted and Equine Assisted Interactions. *J. Equine Vet. Sci.* **2021**, *100*, 103436. [CrossRef] [PubMed]
22. Fry, N.E. Horses in the treatment of trauma. In *Transforming Trauma: Resilience and Healing Through Our Connection with Animals*; Tedeschi, P., Ed.; Purdue University Press: West Lafayette, IN, USA, 2019; pp. 265–298.
23. Blakely, J.M. Critical Aspects of Equine Assisted Therapy: A Qualitative Study. Ph.D. Thesis, University of Colorado, Denver, CO, USA, 2020.
24. Harvey, C.; Jedlicka, H.; Martinez, S. A Program Evaluation: Equine-Assisted Psychotherapy Outcomes for Children and Adolescents. *Child Adolesc. Soc. Work J.* **2020**, *37*, 665–675. [CrossRef]
25. Zhu, X.; Suarez-Jimenez, B.; Zilcha-Mano, S.; Lazarov, A.; Arnon, S.; Lowell, A.L.; Bergman, M.; Ryba, M.; Hamilton, A.J.; Hamilton, J.F.; et al. Neural changes following equine-assisted therapy for posttraumatic stress disorder: A longitudinal multimodal imaging study. *Hum. Brain Mapp.* **2021**, *42*, 1930–1939. [CrossRef] [PubMed]
26. Ivester, K.M.; Smith, K.; Moore, G.E.; Zimmerman, N.J.; Couëtil, L.L. Variability in particulate concentrations in a horse training barn over time. *Equine Vet. J. Suppl.* **2012**, *44*, 51–56. [CrossRef] [PubMed]
27. Claußen, G.; Grau, D.; Hessel, E.F. Determination of the Moisture Content and the Generation of Airborne Particulate Matter From Various Types of Footing From Indoor Riding Arenas Considered to Have Optimal Rideability. *J. Equine Vet. Sci.* **2019**, *79*, 113–120. [CrossRef]
28. Clarke, A.F.; Madelin, T.M.; Allpress, R.G. The relationship of air hygiene in stables to lower airway disease and pharyngeal lymphoid hyperplasia in two groups of Thoroughbred horses. *Equine Vet. J.* **1987**, *19*, 524–530. [CrossRef]
29. Davison, J.A.; Wylie, C.E.; McGLADDERY, C.E.; Fettes, C.; Haggett, E.F.; Ramzan, P.H. Airborne particulate size and concentrations in five Thoroughbred training yards in Newmarket (UK). *Vet. J.* **2019**, *248*, 48–50. [CrossRef]

30. Webster, A.J.; Clarke, A.F.; Madelin, T.M.; Wathes, C.M. Air hygiene in stables 1: Effects of stable design, ventilation and management on the concentration of respirable dust. *Equine Vet. J.* **1987**, *19*, 448–453. [CrossRef] [PubMed]
31. Ivester, K.M.; Couëtil, L.L.; Moore, G.E. An observational study of environmental exposures, airway cytology, and performance in racing thoroughbreds. *J. Vet. Intern. Med.* **2018**, *32*, 1754–1762. [CrossRef] [PubMed]
32. PATH International. Standards Manual. Available online: https://www.pathintl.org/path-intl-membership/my-path-intl-membership/standards-manual (accessed on 15 June 2020).
33. Umeokafor, N.I. Realities of Construction Health and Safety Regulation in Nigeria. Ph.D. Thesis, University of Greenwich, London, UK, 2017.
34. Haeger-Eugensson, M.; Ferm, M.; Elfman, L. Use of a 3-D Dispersion Model for Calculation of Distribution of Horse Allergen and Odor around Horse Facilities. *Int. J. Environ. Res. Public Health* **2014**, *11*, 3599–3617. [CrossRef] [PubMed]
35. Swanberg, J.E.; Clouser, J.M.C.; Gan, W.; Mannino, D.M.; Flunker, J.C. Individual and occupational characteristics associated with respiratory symptoms among latino horse farm workers. *Am. J. Ind. Med.* **2015**, *58*, 679–687. [CrossRef] [PubMed]
36. Stukas, A.; Snyder, M.; Gil Clary, E. Understanding and encouraging volunteerism and community involvement. *J. Soc. Psychol.* **2016**, *156*, 243–255. [CrossRef]
37. Murimi, M.W. Volunteerism: A Win-Win Undertaking. *J. Nutr. Educ. Behav.* **2017**, *49*, 89–90. [CrossRef]
38. Riihimäki, M.; Raine, A.; Elfman, L.; Pringle, J. Markers of respiratory inflammation in horses in relation to seasonal changes in air quality in a conventional racing stable. *Can. J. Vet. Res.* **2008**, *72*, 432–439.

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Article

Evaluation of an Online Training for Supervisors of Young Agricultural Workers

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Abstract: Adolescents and young adults (<25 years) working in agriculture are at greater risk of injury than youth working in other industries. Supervisors play an important role in protecting these young workers who lack workplace experience and whose bodies and brains are still developing. A theoretically based approach was used to develop an online training for supervisors of young agricultural workers. The training addresses an expanded view of occupational safety that not only addresses injury prevention, but also focuses on health promotion and worker well-being using a Total Worker Health approach. A pre-post/post study design was used to evaluate the training. Questionnaires included demographics, workplace characteristics, knowledge, beliefs about protecting young workers, and supervisors' communication behaviors. One-hundred-eighty-two participants completed all parts of the efficacy trial. A post-test administered immediately after completing the training, indicated that supervisors had greater understanding of the risks to young workers and at 3-month follow-up were more likely to engage in communication behaviors to protect the safety and health of young workers. Positive changes in when, how, and under what circumstances supervisors talk about safety and health occurred. Establishing patterns of protective behaviors in the workplace can have lifelong impact, particularly among young workers.

Keywords: agriculture; youth; occupational safety; Total Worker Health; health promotion; intervention; health communication

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1. Introduction

Youth begin working in agriculture work at younger ages and in more hazardous jobs than youth in other industries [1]. In the United States, eighteen percent of all hired farmworkers are under the age of 25 [2]. Half of all fatal injuries to young workers occur in agriculture [3]. Workplace injury and illness can lead to enduring disabilities. Various factors put young workers at increased risk. There are no federal restrictions on the number of hours children can work on the farm, but there are some state restrictions [1]. Moreover, if the farm is owned and operated by relatives, there are no age or work restrictions of any kind [4]. Younger workers face additional challenges, including lack of previous work experience and training that contribute to the inability to recognize hazards, physical and cognitive limitations based on their stage of development, reluctance to ask questions or to admit that they do not understand something, and they are often assigned more physically demanding tasks [5]. Technology use on the job can also impact safety [6]. Off-the job factors impair focus on the job, including family and school demands and stress, risky behaviors (e.g., substance use), fatigue, and sleep [7–14]. Therefore, it is essential for workplaces to protect the well-being of these vulnerable workers.

Interventions that focus on protection from work-related hazards and address health and well-being are more effective than addressing just one [15–19]. This integration of health protection and health promotion is the foundation of the National Institute for Occupational Safety and Health Total Worker Health™ (TWH) Program (http://www.cdc.gov/

niosh/twh, accessed on 31 July 2021) [20]. TWH strategies expand traditional definitions of workplace hazards (e.g., pesticide exposure, unguarded machinery, livestock) to include additional hazards that can also impact health and safety (e.g., stress, fatigue, inexperience). Solutions that impact the workplace (i.e., eliminating hazards, engineering controls, policies, supervisor behaviors) are often more effective and sustainable than those targeting the individual worker (i.e., encouraging health behaviors, use of personal protective equipment (PPE)) [21]. Rather than targeting individual behaviors, the Social Ecological Model (SEM) suggests targeting the environment around the individual, including the interpersonal, organizational, and policy levels of influence [4,22,23]. Young workers in agriculture are influenced by their own knowledge and attitudes, their interactions with supervisors, coworkers, teachers, and workplace policies.

To protect this vulnerable population, an online training using a TWH approach for supervisors of young agricultural workers was developed using several theoretical perspectives to increase its likelihood of efficacy [24]. The goal of this study was to evaluate the training for changes in supervisors' attitudes, knowledge, and behaviors and the stability of these changes over time. A pre-post/post efficacy trial was used to evaluate the impact of an online supervisor training.

2. Materials and Methods

2.1. Participant Recruitment

Recognizing the range of settings where young agricultural workers are employed, "supervisor" included employers, parents, and educators. Adults who hire, teach, or train young workers (less than 21 years of age) were invited to participate in the study. A project website was created with information describing the study and contained a link to the study materials. Recruitment began in October 2017 and continued through August 2019. A multipronged approach was used to recruit participants that included conference presentations and recruitment at events, use of an agricultural list-serv, and targeted emails and social media posts through partner organizations and commodity groups.

2.2. Online Supervisor Training

An online training for supervisors of young agricultural workers was developed using a TWH approach and several theoretical perspectives to increase its likelihood of efficacy [24]. The theories included SEM [4], Social Learning Theory [25], and the Extended Parallel Process Model [26–30]. SEM addresses levels of influence (i.e., supervisors and policy). Social Learning Theory points to the importance of modeling safety behaviors (e.g., supervisors also engaging in behaviors to reduce injury). The EPPM emphasizes the importance of addressing both threat (i.e., the severity and susceptibility of young workers to injury) and efficacy (i.e., skills to perform behaviors to protect young workers and that the recommended solutions will address the problem).

The supervisor training begins by describing the threat to young workers in agriculture. This includes developmental differences (both physical and cognitive), the impact of inexperience, risky behaviors that tend emerge in young adulthood (e.g., substance use), and the difficulties of balancing work, school, and home which impact stress and fatigue. Efficacy was addressed by providing and demonstrating specific skills supervisors can use to reduce threat. These include health communication skills to ensure the delivery of effective occupational safety and health training [31], with a particular focus on using the teach-back method and open-ended questions [32]. These skills are particularly important among supervisors of this population. Young workers may be reluctant to speak up if they are uncertain of the task requirements or if they have a concern. In addition, the training addresses the need for ongoing supervision, and not just when the worker is hired, how to communicate and enforce policies, and the importance of role modeling.

2.3. Instruments

Questionnaires were used at pre-test, immediate post-test, and at a three-month follow-up. The pre-test questionnaire collected information on demographics, workplace characteristics, beliefs about protecting young workers (e.g., "I know what age-appropriate assignments are for the workers I supervise"), and supervisors' communication behaviors (e.g., talking with young workers safety and health issues). A 25-item knowledge pre-test was administered immediately prior to beginning training. Upon completion of each module within the training, changes in knowledge were assessed (immediate post-test). Attitude change was assessed after all training modules were completed. Three months after completing the training, participants were invited to complete a follow-up questionnaire (3-month post-test). This questionnaire included workplace characteristics, knowledge, beliefs, supervisors' communication behaviors, and open-ended questions on training impact. All questionnaires were pilot tested during the development of the training [24].

2.4. Procedures

A pre-post/post design was used to evaluate training efficacy. All study procedures occurred online. Prospective participants were directed to the project website with a link to study materials. Following online consent, participants completed a pre-test questionnaire lasting approximately 15 min. The pre-test questionnaire collected information on demographics, workplace characteristics, beliefs about protecting young workers (e.g., "I know what age-appropriate assignments are for the workers I supervise"), and supervisors' communication behaviors (e.g., talking with young workers about safety and health issues). Supervisor beliefs were assessed using a 5-type Likert scale ranging from "strongly disagree" to "strongly agree." Participants were then directed to the training module, where they completed a 25-item knowledge pre-test prior to beginning the training. The training took approximately 45 min to complete and included knowledge checks throughout. The knowledge checks were used to assess post-training knowledge (immediate post-test). Next, participants completed an immediate post-test questionnaire. Participants received $50 for completing the pre-test questionnaire, training, and immediate post-test questionnaire. Three months after completing the training, participants were invited to complete a follow-up questionnaire, approximately 20 min in length. This questionnaire included workplace characteristics, knowledge, beliefs, supervisors' communication behaviors, and open-ended questions describing how they applied the training. Participants received an additional $50 for completing the 3-month post-test questionnaire. A list of all measures can be found in Table 1. Up to three email reminders were sent to participants at each step of the study. All study procedures were reviewed and approved by the Institutional Review Board at the University of Iowa.

2.5. Statistical Methods

Descriptive statistics were calculated for all measures to characterize demographic and occupational items. McNemar's test was used to examine behavior changes (i.e., frequency of talking to young workers about safety and risk) at baseline and 3-month follow-up. Linear mixed effects models were used to examine the means of variables at different time points regarding changes in beliefs. Data analysis was completed with SAS 9.4 (SAS Institute, Cary, NC, USA). An alpha of 0.05 was used for testing significance.

Table 1. Table of Measures, number of items, and response categories.

Measure	Pre-Test	Immediate Post-Test	3-Month Post-Test
Demographics and workplace characteristics *13 items; Multiple choice and open-ended*	X		
Knowledge of safety and health promotion *25 items; Multiple choice*	X	X	X
Supervisor beliefs (age-appropriate assignments, modeling, workplace policies, regular training, using teach-back, open-ended questions, outside of work factors impacting safety on the job) *11 items; 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree)*	X	X	X
Supervisors' communication behaviors (talk to young workers about safety issues, i.e., PPE, ATV * safety, and other factors that increase risk of injury, i.e., stress, not enough sleep) *2 items; Select all that apply (when they are hired, when you assign a new task, after an injury or near miss, never, once a year, once a month, once a week, everyday)*	X		X

* All-terrain vehicle

3. Results

The analyses that follow include participants that completed all parts of the study.

3.1. Description of Respondents and Response Rates

Three-hundred-ninety-two respondents consented to participate in the study. Of these, 319 completed the pre-test questionnaire, 236 completed the training, 204 completed the immediate post-test questionnaire, and 185 completed the 3-month follow-up questionnaire. One-hundred-eighty-two participants completed all parts of the study. At each successive step, absolute response rates were 81.0%, 74.0%, 86.4%, and 90.7%, respectively. Cumulative response rates were 81.0%, 59.9%, 51.8%, and 47.0%, respectively. Participants represented 31 states, 2 U.S. territories (District of Columbia and Puerto Rico), and 3 provinces in Canada (Alberta, Manitoba, and Saskatchewan) (Figure 1).

3.2. Demographic and Workplace Characteristics

The majority of participants were female and agricultural education teachers. On average, participants had worked in agriculture nearly 18 years. Two-thirds had at least five years of experience supervising young agricultural workers (Table 2). At pre-test, participants reported supervising a median of 22.5 workers between the ages of 14–20 in the previous six months. Fifty percent of participants had supervised between 5 and 75 workers in the previous 6 months. There were no significant differences in demographic characteristics among respondents by occupation (ag teachers versus all other occupations) or study completion (those who completed all parts of the study versus those who dropped out).

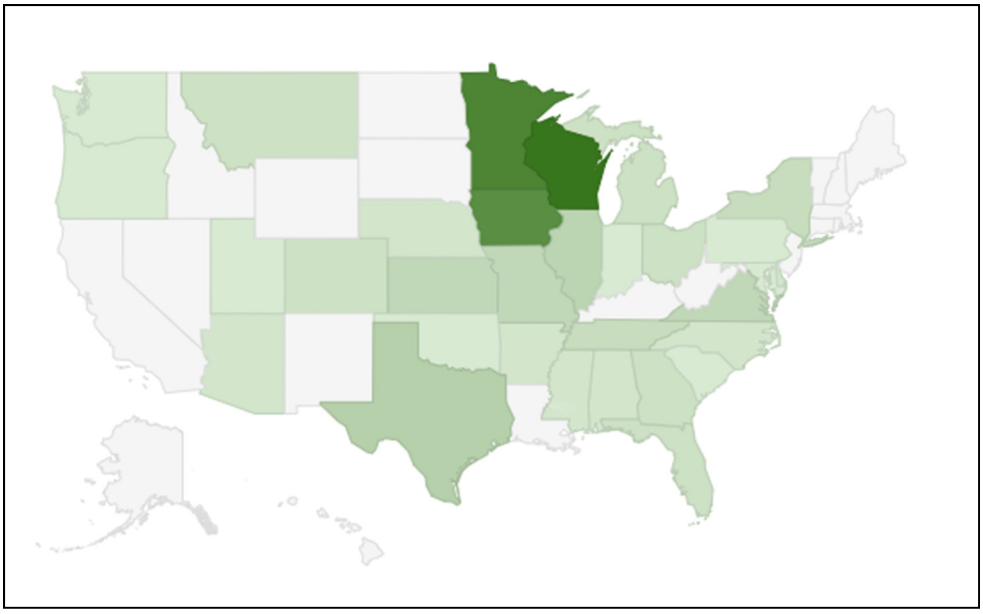


Figure 1. U.S. States with training participants, n = 182. States with no shading (white) had no participants. Darker shading represents a greater number of participants. Participants from Canada and U.S. territories are not included in the figure.

Table 2. Demographic and workplace characteristics.

Item	All (n = 182)	
	Mean or % (n)	Range
Age	35.6	22–71
Gender:		
Female	63.7 (116)	
Male	35.7 (65)	
Other	0.55 (1)	
Years supervising workers under 21:		
≥5	66.5 (121)	
<5	31.9 (58)	
Do not supervise under 21	1.65 (3)	
Occupation *:		
Agricultural Education Teacher	69.2 (126)	
Farmer/Producer	20.3 (37)	
Supervisor	12.6 (23)	
Safety and Health Professional	8.2 (15)	
Other	14.3 (26)	
Years working in agriculture	17.8	0–60
Commodity:		
I do not work on a farm	45.1 (82)	
Livestock (i.e., pork, poultry)	29.1 (53)	
Row crop (i.e., corn, soybeans)	11.5 (21)	
Other	14.3 (26)	

* Percentages do not equal 100 as respondents could select multiple categories.

3.3. Changes in Knowledge

Pre-test knowledge scores were high ($\overline{X}$ = 81.7%) and showed significant improvement immediately following the training. However, knowledge scores decreased at the 3-month follow-up (Table 3).

Table 3. Average percent correct on knowledge questions.

Time	Average Percent Correct (SD)
Pre-test	81.7 (9.57)
Immediate Post-test	89.3 (6.90) *
3-Month Post-test	83.0 (9.79)

* Significant increase at immediate post-test.

3.4. Changes in Beliefs

Supervisors were asked about their beliefs regarding training and other behaviors they can utilize to protect younger workers, including the impact of activities outside of work on workplace safety. Supervisors rated 11 beliefs on a Likert-type scale (1 = strongly disagree to 5 = strongly agree). The teach-back method (*The teach-back method is effective in training workers under the age of 21*) also included the option "I don't know what the teach-back method is." Agreement with the belief statement increased for all items from pre-test to immediate post-test and changes were sustained at the 3-month follow-up. Only two beliefs did not show significant changes following the training (Tables 4 and 5).

Table 4. Changes in supervisor beliefs regarding training and other behaviors they can utilize to protect younger workers and their importance over time.

Time	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree	Pre- to Post-Test Pre- to 3-Month
	% (*n*)	% (*n*)	% (*n*)	% (*n*)	% (*n*)	*p*-Value
I know what age-appropriate assignments are for the workers I supervise.						
Pre-test	1.1 (2)	4.4 (8)	5.5 (10)	42.3 (77)	46.7 (85)	
Post-test	0.0 (0)	2.2 (4)	0.0 (0)	25.3 (46)	72.5 (132)	<0.0001
3-month	0.6 (1)	0.6 (1)	2.8 (5)	34.6 (63)	61.5 (112)	<0.0001
If supervisors and co-workers do safe things, workers under the age of 21 will do safe things.						
Pre-test	1.6 (3)	4.4 (8)	7.1 (13)	44.0 (80)	42.9 (78)	
Post-test	0.0 (0)	1.1 (2)	1.6 (3)	28.6 (52)	68.7 (125)	<0.0001
3-month	0.0 (0)	1.1 (2)	3.8 (7)	39.6 (72)	55.5 (101)	<0.0001
All workers need to know the workplace policies and what will happen if they don't follow the rules.						
Pre-test	1.6 (3)	1.6 (3)	2.2 (4)	9.3 (17)	85.2 (155)	
Post-test	0.0 (0)	0.6 (1)	0.0 (0)	9.9 (18)	89.5 (162)	0.0230
3-month	0.5 (1)	1.1 (2)	0.0 (0)	11.0 (20)	87.4 (159)	0.1965
Workers under the age of 21 need regular training which should be frequently repeated.						
Pre-test	1.1 (2)	2.2 (4)	6.6 (12)	25.3 (46)	64.8 (118)	
Post-test	0.0 (0)	0.6 (1)	0.0 (0)	9.9 (18)	89.5 (162)	<0.0001
3-month	0.5 (1)	0.5 (1)	2.7 (5)	21.4 (39)	74.7 (136)	0.0032
Questions about a task that end with a "yes" or "no" answer will not tell me if a worker under the age of 21 has thought about safety.						
Pre-test	1.6 (3)	9.3 (17)	17.0 (31)	45.1 (82)	26.9 (49)	
Post-test	4.4 (8)	1.1 (2)	1.1 (2)	16.6 (30)	76.8 (139)	<0.0001
3-month	4.4 (8)	3.3 (6)	5.5 (10)	23.1 (42)	63.7 (116)	<0.0001
Training workers about safety is an ongoing process.						
Pre-test	1.1 (2)	0.5 (1)	0.5 (1)	11.0 (20)	86.8 (158)	
Post-test	0.6 (1)	0.0 (0)	0.6 (1)	5.0 (9)	93.9 (170)	0.0518
3-month	0.5 (1)	0.0 (0)	0.0 (0)	9.3 (17)	90.1 (164)	0.2626
Safety is more important than working quickly.						
Pre-test	1.1 (2)	0.0 (0)	2.2 (4)	9.3 (17)	87.4 (159)	
Post-test	0.5 (1)	0.0 (0)	0.5 (1)	6.6 (12)	92.3 (168)	0.0672
3-month	0.0 (0)	0.0 (0)	0.5 (1)	6.6 (12)	92.9 (169)	0.0137

Table 4. *Cont.*

Time	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree	Pre- to Post-Test Pre- to 3-Month
	% (*n*)	% (*n*)	% (*n*)	% (*n*)	% (*n*)	*p*-Value
Talking with workers under the age of 21 frequently can help prevent injuries.						
Pre-test	1.6 (3)	0.5 (1)	3.8 (7)	37.4 (68)	56.6 (103)	
Post-test	0.6 (1)	0.0 (0)	1.7 (3)	15.5 (28)	82.3 (149)	<0.0001
3-month	0.0 (0)	0.5 (1)	1.1 (2)	25.8 (47)	72.5 (132)	<0.0001
Being approachable can help prevent injuries.						
Pre-test	1.1 (2)	0.0 (0)	2.7 (5)	20.9 (38)	75.3 (137)	
Post-test	0.6 (1)	0.0 (0)	0.6 (1)	9.4 (17)	89.5 (162)	0.0003
3-month	0.0 (0)	0.0 (0)	1.1 (2)	11.0 (2)	87.9 (160)	0.0005
Distractions at home, such as stress about friends or homework, can increase the risk of injury at work for workers under the age of 21.						
Pre-test	1.1 (2)	0.0 (0)	2.7 (5)	28.6 (52)	67.6 (123)	
Post-test	0.5 (1)	0.0 (0)	0.0 (0)	7.7 (14)	91.8 (167)	<0.0001
3-month	0.0 (0)	0.5 (1)	0.5 (1)	13.2 (24)	85.7 (156)	<0.0001

Table 5. Changes in supervisor beliefs about teach-back method effectiveness and importance over time.

Time	Do Not Know Teachback Method	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree	Pre- to Post-Test Pre- to 3-Month
	% (*n*)	% (*n*)	% (*n*)	% (*n*)	% (*n*)	% (*n*)	*p*-Value
The teach-back method is effective in training workers under the age of 21.							
Pre-test	49.5 (90)	0.6 (1)	0.6 (1)	5.5 (10)	17.0 (31)	26.9 (49)	
Post-test	4.4 (8)	4.7 (3)	0.0 (0)	0.0 (0)	11.5 (21)	82.4 (150)	<0.0001
3-month	6.0 (11)	0.0 (0)	0.0 (0)	1.1 (2)	14.3 (26)	78.6 (143)	0.0004

3.5. Supervisors' Communication Behavior Changes

We observed an increase in the percentage of supervisors talking to young workers about safety issues at various timepoints: (1) when they start a new task, (2) when they are hired, and, (3) after an injury or near miss between the pre-test and the 3-month post-test (Table 6). Similarly, we observed an increase from pre-test to 3-month post-test in the percentage of supervisors talking to young workers about other factors that increase risk for injury, such as stress or not enough sleep, when they were assigned to a new task or when they were hired. More importantly, we observed more supervisors reporting discussions of safety occurring every day or at least once a week, rather than conversations that are limited to once a month or longer intervals (Table 7). In sum, supervisors are talking about safety and health in more contexts after completing the training (Table 8).

Table 6. Changes in supervisors' frequency of whether they talk to young workers about safety and health issues (yes/no) that impact their risk of injury (n = 182).

Item	Pre-Test	3-Month Post-Test	Pre-Test to 3-Month
	% (n)	% (n)	p-Value
Talk to young workers about safety issues that increase risk of injury *			
When they are hired	48.3 (88)	55.6 (101)	0.5903
When you assign a new task	60.4 (110)	66.5 (121)	0.0002
After an injury or near miss	24.2 (44)	28.0 (51)	<0.001
Do not talk at any of these times	26.9 (49)	23.1 (42)	<0.001
Talk to young workers about health issues that increase risk of injury *			
When they are hired	45.2 (84)	51.7 (94)	0.760
When you assign a new task	40.1 (73)	47.3 (86)	0.077
After an injury or near miss	25.3 (46)	26.4 (48)	<0.0001
Do not talk at any of these times	35.7 (65)	30.8 (56)	<0.0001

* Percentages do not equal 100 as respondents could select multiple categories.

Table 7. Changes in supervisors' frequency of how often they talk to young workers about safety and health issues that impact their risk of injury (n = 182).

Item	Pre-Test	3-Month Post-Test	
	% (n)	% (n)	p-Value
Talk to young workers about safety issues that increase risk of injury			
No answer	40.7 (74)	31.3 (57)	0.0003
Never	0.55 (1)	1.65 (3)	<0.0001
Once a year	13.7 (25)	8.24 (15)	<0.0001
Once a month	12.1 (22)	8.24 (15)	<0.0001
Once a week	13.7 (25)	24.2 (44)	<0.0001
Every day	19.2 (35)	26.4 (48)	<0.0001
Talk to young workers about health issues that increase risk of injury			
No answer	41.2 (75)	34.1 (62)	0.0013
Never	0.0 (0)	0.0 (0)	–
Once a year	14.3 (26)	6.59 (12)	<0.0001
Once a month	15.9 (29)	14.8 (27)	<0.0001
Once a week	14.8 (27)	26.9 (49)	<0.0001
Every day	13.7 (25)	17.6 (32)	<0.0001

Table 8. Changes in the number of contexts that supervisors talk about safety and health (i.e., at hire, when assigning tasks, and/or following a near miss/injury) before and after completing the training (n = 182) *.

Item	Pre-Test	3-Month Post-Test	
	% (n)	% (n)	p-Value
Number of contexts in which supervisors talk to young workers about safety issues that increase risk of injury			
0	26.9 (49)	23.1 (42)	<0.0001
1	28.0 (51)	23.6 (43)	<0.0001
2	30.2 (55)	33.5 (61)	<0.0001
3	14.8 (27)	19.8 (36)	<0.0001

Table 8. *Cont.*

Item	Pre-Test	3-Month Post-Test	
	% (*n*)	% (*n*)	*p*-Value
Number of contexts in which supervisors talk to young workers about health issues that increase risk of injury			
0	35.7 (65)	30.8 (56)	<0.0001
1	28.6 (52)	25.8 (47)	<0.0001
2	24.2 (44)	30.8 (56)	<0.0001
3	11.5 (21)	12.6 (23)	<0.0001

* 0 = supervisors do not talk about safety and health in any context and 3 = talk about safety and health in all contexts.

3.6. Application of the Training: Qualitative Findings

At the 3-month post-test, participants were presented with optional open-ended questions asking how the training helped them and to share a story about a young worker they supervised. Ninety-five percent (n = 172) of participants provided comments; of these, 91% (n = 156) indicated they were more prepared to effectively supervise young workers after taking the training. Of the supervisory practices addressed in the training, teach-back was the most popular, with 23% (n = 40) of participants referencing it in their comment. One participant shared the following story of how they used the teach-back method to ascertain a young worker's understanding of a task:

1. "I had a worker who seemed to know what they were doing. Then when I asked them to talk me through the steps and show me, they didn't know what to do. They said they were embarrassed to admit they didn't know. Now they know the proper procedure."

Another participant provided an example of how they changed a supervisory behavior following the training:

2. "We had a young worker who frequently lifted heavy items by hand to load them in the truck. After discussing this risk with him he now uses a cherry picker."

Nine out of ten participants said they would recommend the training to others. In addition, we also received positive feedback on the training.

3. "Really good information; things I'll be able to use when working with youth on our farm. We are very aware of what a dangerous line of work we are in!"
4. "I have completed the training and thought the training information was presented well and would like my supervisors to also participate. I also like that there is a Certificate of Training Completion available once the training is complete."

4. Discussion

A theoretically based and TWH approach were used to develop an online training for supervisors (e.g., employers, educators, parents) of young agricultural workers. Adolescents and young adults (<25 years) working in agriculture are at greater risk of injury than youth working in other industries [1–3]. Supervisors play an important role in protecting these young workers who may lack workplace experience and who's bodies and brains are still developing [4,21–23]. The training incorporated materials from existing trainings focused on working youth and utilized a TWH approach to address an expanded view of occupational safety that not only addresses injury prevention, but also focuses on health promotion and worker well-being.

A pre-post/post study design was used to evaluate the training among supervisors. One-hundred-eighty-two participants completed all parts of the efficacy trial. Participants included agricultural educators, farmers and producers, supervisors, and safety and health

professionals. The overall reaction to the training was positive. Positive changes in knowledge, beliefs, and supervisors' communication behaviors were observed.

4.1. Significant or Key Findings

In this efficacy trial, training intervention produced significant and sustained changes in beliefs and supervisors' communication behaviors that are likely to impact the occupational health and safety of young, vulnerable, agricultural workers. Although knowledge increased at immediate post-test, it was not sustained at 3-month follow-up. At pre-test, knowledge was high, which may reflect the years of supervisory experience of our participants. These findings indicate that immediately after completing the training, supervisors had a greater understanding of the risks to young workers. At 3-month follow-up they were more likely to engage in behaviors to protect the safety and health of young workers than they were prior to taking the training. Positive changes in when, how, and under what circumstances supervisors talk about safety and health with their young workers occurred. Establishing patterns of protective behaviors in the workplace (including family farms) can have lifelong impact, particularly among young workers. While additional research is needed, these findings indicate that an online training targeting supervisors is a promising approach to changing safety and health behaviors in agricultural settings.

4.2. Dissemination

Dissemination activities included promoting the training through multiple channels to a broad audience. Materials were disseminated through the Agricultural, Forestry, and Fishing Centers of Excellence funded by the National Institute for Occupational Safety and Health (NIOSH AgFF) as well as through programs addressing agricultural safety and health, employers, commodity groups, extension, and agricultural educators. They are listed as a resource as part of the Cultivate Safety materials (https://cultivatesafety.org, accessed on 31 July 2021). They are also promoted through the Great Plains Center for Agricultural Health as part of other online modules addressing agricultural safety health and integrated into the curriculum of Agricultural Safety and Health courses at the University of Iowa. These materials can be used by anyone who assigns tasks in the workplace, provides training, develops policies to address safety, provides supervision, or has regular and frequent opportunities to communicate with workers. Although designed for employers, the training may also be relevant to parents who have children working on a family farm as well as high school agricultural teachers, 4-H leaders, and FFA advisers.

In addition to the online training, Supplementary Materials were developed including a classroom presentation, ten videos, and two short "toolbox-talk" activities that emphasize different aspects of the training. All training and materials are available in English and Spanish. We took care to ensure that materials developed during the project are housed in Translation Supporting Structures [33]. Specifically, the use of the Healthier Workforce Center of the Midwest (https://hwc.public-health.uiowa.edu/protecting-young-ag-workers/, accessed on 31 July 2021) and the Institute for Public Health Practice (https://www.training-source.org/category-pilms/agricultural-health, accessed on 31 July 2021) websites to house the intervention and other materials developed will ensure that the evidence-based intervention remains freely accessible to key audiences.

4.3. Research Outcomes/Impact

The development of material involved the integration of health promotion, health protection, TWH, and evidence-based communication approaches to provide supervisors the tools to increase the likelihood of impacting worker behavior. Behaviors emphasized in the training (e.g., teach-back, role modeling, asking open-ended questions, and enacting workplace policies) are transferable to many safety and health risks. These behaviors are not limited to specific agricultural operations, but rather fit all workplaces.

The efficacy trial demonstrated changes in knowledge, beliefs, and supervisors' communication behaviors. These short-term and moderate-term (3 month) impacts are essential

to longer-term changes in morbidity and mortality [34,35]. We successfully altered supervisors' behaviors through the implementation of communication science [31]. In the long-term, these behaviors will lead to organizational changes that will impact the safety and health of vulnerable agricultural workers. Moreover, altering the safety and health risks of adolescents and young adults establish practices that become integrated into the workplace culture and assist in the development of habits to promote safety, health, and well-being.

Study participants included those with many years of experience supervising young workers in agriculture. Interestingly, changes in beliefs and behaviors were observed among these more experienced supervisors. Although designed primarily for employers, the most eager study participants in the efficacy trial were high school agricultural education teachers. This is a population that is ripe for intervention and dissemination as intermediaries. They have access to a large number of youth and can build expectations about workplace practices and build confidence in youth to talk about safety and health. Future research should target this influential population. Promoting safety and health can lead to changes in the workplace that will not only reduce injuries, but also promote health and well-being on and off the farm.

5. Conclusions

This project was unique in its comprehensive approach to addressing the combination of both preventing workplace injuries (health protection) and promoting healthy lifestyle behaviors, utilizing a Total Worker Health approach. Moreover, the addition of workplace policies expanded the intervention to address multiple levels of influence in the Social Ecological Model: supervisors and workplaces. The Extended Parallel Process Model was used to address elements in the intervention necessary to change supervisors' behaviors. An efficacy trial demonstrated training effectiveness, specifically positive increases in knowledge, beliefs, and supervisors' communication behaviors.

Supplementary Materials: The following are available online at https://hwc.public-health.uiowa.edu/protecting-young-ag-workers/. Online training: English/Español. Classroom training: English/Español. YouTube videos: English/Español. Let's Talk activities: English/Español.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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Conflicts of Interest: cTRAIN was developed by the Northwest Education Training and Assessment LLC (NwETA) owners Kent Anger and Diane Rohlman. Rohman has a significant financial interest in NwETA, a company that may have a commercial interest in the results of this research and technology. This potential conflict of interest was reviewed, and a management plan approved by the University of Iowa Conflict of Interest Research Committee was implemented.

References

1. U.S. Department of Labor. *Child Labor Bulletin 102: Child Labor Requirements in Agricultural Occupations under the Fair Labor Standards Act*; U.S. Department of Labor: Washington, DC, USA, 2007.
2. USDA. Demographic Characteristics of Hired Farmworkers and All Wage and Salary Workers. 2018. Available online: https://www.ers.usda.gov/topics/farm-economy/farm-labor/ (accessed on 28 July 2021).
3. NIOSH. *Analysis of the Bureau of Labor Statistics Census of Fatal Occupational Injuries Microdata*; U.S. Department of Labor Statistics; U.S. Department of Labor: Washington, DC, USA, 2019; unpublished.
4. Lee, B.C.; Bendixsen, C.; Liebman, A.K.; Gallagher, S.S. Using the socio-ecological model to frame agricultural safety and health interventions. *J. Agromedicine* **2017**, *22*, 298–303. [CrossRef]
5. Estes, C.R.; Jackson, L.L.; Castillo, D.N. Occupational injuries and deaths among younger workers—United States, 1998–2007. *Morb. Mortatility Wkly. Rep.* **2010**, *59*, 449–455.
6. Gorucu, S.; Murphy, D.; Foster, D.; Hanagriff, R.; Ewing, J. Technology Use Among Youth While Operating Farm Equipment. *J. Agromedicine* **2018**, *23*, 305–314. [CrossRef] [PubMed]
7. Teixeira, L.R.; Fischer, F.M.; de Andrade, M.M.; Louzada, F.M.; Nagai, R. Sleep patterns of day-working, evening high-schooled adolescents of São Paulo, Brazil. *Chronobiol. Int.* **2004**, *21*, 239–252. [CrossRef] [PubMed]
8. Teixeira, L.R.; Fischer, F.M.; Lowden, A. Sleep deprivation of working adolescents—A hidden work hazard. *Scand. J. Work Environ. Health* **2006**, *32*, 328–330. [CrossRef] [PubMed]
9. Davis, L.; Castillo, D.; Wegman, D. Child and adolescent workers. In *Occupational Health: Recognizing and Preventing Work-Related Disease*; Little, Brown and Company: Boston, MA, USA, 2000; pp. 689–699.
10. Salazar, M.K. *AAOHN Core Curriculum for Occupational Health Nursing*; WB Saunders Company: Washington, DC, USA, 1997.
11. Shipp, E.M.; Cooper, S.P.; del Junco, D.J.; Cooper, C.J.; Whitworth, R.E. Acute occupational injury among adolescent farmworkers from South Texas. *Inj. Prev. J. Int. Soc. Child Adolesc. Inj. Prev.* **2013**, *19*, 264–270. [CrossRef] [PubMed]
12. Postel, M.W.; Jaung, M.S.; Chen, G.; Yu, S.; Stallones, L.; Xiang, H. Farm work-related injury among middle school students in rural China. *J. Agric. Saf. Health* **2009**, *15*, 129–142. [CrossRef] [PubMed]
13. Cooper, S.R.; Cooper, S.P.; Felknor, S.S.; Santana, V.S.; Fischer, F.M.; Shipp, E.M.; Vela Acosta, M.S. Nontraditional work factors in farmworker adolescent populations: Implications for health research and interventions. *Public Health Rep.* **2005**, *120*, 622–629. [CrossRef]
14. Spear, L.P. Alcohol's effects on adolescents. *Alcohol. Res. Health* **2002**, *26*, 287–291.
15. Anger, W.K.; Elliot, D.L.; Bodner, T.; Olson, R.; Rohlman, D.S.; Truxillo, D.M.; Kuehl, K.S.; Hammer, L.B.; Montgomery, D. Effectiveness of total worker health interventions. *J. Occup. Health Psychol.* **2015**, *20*, 226–247. [CrossRef]
16. DeJoy, D.M.; Southern, D.J. An integrative perspective on work-site health promotion. *J. Occup. Med.* **1993**, *35*, 1221–1230. [PubMed]
17. Barbeau, E.M.; Goetzel, R.Z.; Lakdawalla, D.; Reville, R.T.; Seabury, S.A.; Sorensen, G. *Research Compendium: The NIOSH Total Worker Health Program: Seminal Research Papers 2012*; Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health: Washington, DC, USA, 2012.
18. Sauter, S.L. Integrative approaches to safeguarding the health and safety of workers. *Ind. Health* **2013**, *51*, 559–561. [CrossRef]
19. Sorensen, G.; McLellan, D.; Dennerlein, J.T.; Pronk, N.P.; Allen, J.D.; Boden, L.I.; Okechukwu, C.A.; Hashimoto, D.; Stoddard, A.; Wagner, G.R. Integration of health protection and health promotion: Rationale, indicators, and metrics. *J. Occup. Environ. Med./Am. Coll. Occup. Environ. Med.* **2013**, *55*, S12. [CrossRef] [PubMed]
20. Schill, A.L.; Chosewood, L.C. The NIOSH total worker health™ program: An overview. *J. Occup. Environ. Med.* **2013**, *55*, S8–S11. [CrossRef]
21. NIOSH. Hiearchy of Controls. Available online: https://www.cdc.gov/niosh/topics/hierarchy/default.html (accessed on 28 July 2021).
22. NIOSH. Safe Skilled Ready Workforce Program. Available online: https://stacks.cdc.gov/view/cdc/80632 (accessed on 28 July 2021).
23. NIOSH. Talking Safety. Available online: https://www.cdc.gov/niosh/talkingsafety/default.html (accessed on 28 July 2021).
24. Rohlman, D.S.; Campo, S.; TePoel, M. Protecting Young Agricultural Workers: The Development of an Online Supervisor Training. *J. Agromedicine* **2021**. [CrossRef] [PubMed]
25. Bandura, A.; McClelland, D.C. *Social Learning Theory*; Prentice Hall: Englewood Cliffs, NJ, USA, 1977; Volume 1.
26. Witte, K. Putting the fear back into fear appeals: The extended parallel process model. *Commun. Monogr.* **1992**, *59*, 329–349. [CrossRef]
27. Witte, K. Fear control and danger control: A test of the extended parallel process model (EPPM). *Commun. Monogr.* **1994**, *61*, 113–134. [CrossRef]

28. Smith, S.W.; Rosenman, K.D.; Kotowski, M.R.; Glazer, E.; McFeters, C.; Keesecker, N.M.; Law, A. Using the EPPM to create and evaluate the effectiveness of brochures to increase the use of hearing protection in farmers and landscape workers. *J. Appl. Commun. Res.* **2008**, *36*, 200–218. [CrossRef]
29. Cismaru, M. Using the extended parallel process model to understand texting while driving and guide communication campaigns against it. *Soc. Mark. Q.* **2014**, *20*, 66–82. [CrossRef]
30. Gore, T.D.; Bracken, C.C. Testing the theoretical design of a health risk message: Reexamining the major tenets of the extended parallel process model. *Health Educ. Behav.* **2005**, *32*, 27–41. [CrossRef]
31. NIOSH. Communication and Information Dissemination Program. Available online: https://www.cdc.gov/niosh/programs/cid/default.html (accessed on 22 September 2021).
32. Coleman, C.; Hudson, S.; Pederson, B. Prioritized health literacy and clear communication practices for health care professionals. *HLRP: Health Lit. Res. Pract.* **2017**, *1*, e91–e99. [CrossRef] [PubMed]
33. Wilson, K.; Brady, T.; Lesesne, C. on behalf of the, NCCDPHP Work Group on Translation An organizing framework for translation in public health: The Knowledge to Action Framework. *Prev. Chronic Dis.* **2011**, *8*, A46. [PubMed]
34. Robson, L.S.; Stephenson, C.M.; Schulte, P.A.; Amick III, B.C.; Irvin, E.L.; Eggerth, D.E.; Chan, S.; Bielecky, A.R.; Wang, A.M.; Heidotting, T.L. A systematic review of the effectiveness of occupational health and safety training. *Scand. J. Work Environ. Health* **2012**, *38*, 193–208. [CrossRef] [PubMed]
35. Waehrer, G.M.; Miller, T.R. Does safety training reduce work injury in the United States? *Ergon. Open J.* **2009**, *2*, 26–39. [CrossRef]

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Intermediary Perspectives on Total Worker Health in Small Businesses

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Abstract: The future of work will include not only more small business employment, but also a need for greater consideration of more holistic approaches to addressing worker well-being. Previous research has suggested smaller firms need external assistance to add new or improve existing workplace health and safety activities. A Total Worker Health® (TWH) approach is potentially appealing to small employers as it is intended to identify and support comprehensive practices and policies that take into account the work environment (both physical and organizational) while also addressing the personal health risks of individuals, thus being more effective in preventing disease and promoting health and safety than each approach taken separately. NIOSH researchers applied the NIOSH Small Business Intervention Diffusion Model to conduct parallel community-based TWH activities in two geographically distinct communities in a large metropolitan area. Data were collected from intermediary organizations that work with or serve small businesses about their perceptions of the TWH approach as a potential service for them to offer small firms. Intermediary organizations engaged in implementation of TWH approaches with small businesses in the respective geographic areas for approximately one year. Results indicated intermediary organizations find value in providing TWH assistance to small employers, but several challenges for intermediaries implementing TWH among small employers remain.

Keywords: small business; total worker health; safety and health

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1. Introduction

The need to address both occupational and personal health in a more holistic manner has been called for to shape the future of work [1]. Studies have shown that workers with underlying health conditions may be at greater risk for certain occupational injuries and illnesses [2,3]. The consideration of both personal and occupational health and safety will continue to shape the future of work.

A significant challenge to addressing occupational safety and health (OSH) in general is that a large proportion of employers lack necessary resources to effectively manage OSH, as well as promote worker health and well-being. Most businesses are small—90% of firms have fewer than 20 employees [4], and small businesses are more likely to have limited resources to address health and safety [5]. As the business and workforce landscape evolves, average business size in terms of number of employees, is expected to continue on a downward trend [6]. Given the greater alignment of business and public health goals related to workforce health, and the limited resources to address workforce health management in the ever-increasing number of small businesses, the need for novel ways to deliver workplace safety and health assistance to small employers is as critical as ever.

The aim of this paper is to describe the application of the *NIOSH Small Business Intervention Diffusion Model* to better understand the experience of intermediary organizations in offering [5] and delivering assistance to small employers with implementing a Total Worker Health® (TWH) approach, and thus help employers to address occupational and personal health, safety, and well-being more holistically. TWH is defined as "policies, programs,

and practices that integrate protection from work-related safety and health hazards with promotion of injury and illness prevention efforts to advance worker well-being" [7].

Business size has been shown to be one of the best predictors of a small business's involvement with workplace health promotion and safety activities such as TWH [8,9]. For businesses to survive, they need to sufficiently manage OSH [5,10], Promotion of occupational safety and health performance through programs such as TWH are critical to early business success. However, small businesses generally deliver *fewer* workplace health promotion and occupational safety and health activities than larger businesses [8,11,12]. In addition, small businesses endure a higher burden of occupational injuries and illnesses [13] and tend to need more external assistance with integrated safety and employee health programs such as TWH [14]. Furthermore, lack of resources, isolation, and inaccurate perceptions of illness and injury rates also contribute to small businesses' lack of motivation to engage in prevention [9,15–17]. In 2012, only 34% percent of small businesses (defined as 50–100 employees in this example) offered even a minimal wellness program [18].

In spite of the limited ability to provide prevention-focused health and safety programs, the majority of small business decision-makers (93%) say the physical and mental health of their employees is important to their business' bottom line [19]. Nearly half of small-businesses indicate that health and wellness programs are critical for recruiting and retaining the best employees, and nearly two-thirds believe such programs are worth the investment. The top three workplace health promotion (WHP) implementation motivators were identified as: (1) lower health care costs in the long term; (2) improved morale; and (3) increased productivity on the job [19]. Despite the value seen by employers, execution of such programs has been limited.

The use of intermediaries, or organizations that provide goods or services to small businesses, has been demonstrated to be an effective way of reaching small employers with health and safety assistance, and doing so through a trusted or at least a potentially acceptable source that a small businesses recipient might listen to [16,20–24]. Examples of intermediary organizations include, but are not limited to insurers, health providers, government agencies, suppliers, trade associations, and chambers of commerce. Such an approach requires that the intermediaries can be effectively engaged and acquainted with the public health source and the information to be communicated. For this study, the TWH concept and suggested programming were introduced to intermediary organizations and small businesses, with recognition of the need for multiple levels of intervention to support employee health promotion efforts, including support from the community [25–27] and working with intermediary organizations [9,21] in a small geographic area [28]. One assumption underlying this study was that development of a strong business case for TWH that included not only financial costs and benefits, but also personal effort required, time commitment, compatibility with existing systems, and expected outcomes, would be essential for participants to remain open to the concept and for the research team to potentially gain insight into successful future adoption [29,30].

The aims of the study reported here were (1) to understand perceptions of TWH among intermediary organizations that serve small businesses; and (2) to explore methods for encouraging promotion of TWH approaches by intermediaries to small businesses. In summary, this study attempted to address the question: How can the concept of Total Worker Health (TWH) be effectively introduced and delivered to intermediary organizations and small businesses using the NIOSH Small Business Diffusion Model? This report focuses on intermediaries' experiences engaging in TWH-related outreach to small business employers in their respective communities. The goal is to shape the future of work by sharing key takeaways that may inform future TWH outreach and assistance efforts.

2. Materials and Methods

2.1. Procedure

The *Intermediary–Small Business Diffusion Model* was used as the basis for structuring and designing this study (Figure 1). The model was previously developed by the NIOSH

Small Business Assistance Program, and its utility has since been demonstrated [22–24,31]. The model consists of two phases, an initiator–intermediary phase and an intermediary–small business phase, which provide a framework for identifying who small businesses use for information, how to reach out to those intermediaries, and how to work with those intermediaries to then reach out to and engage small businesses. This model is ideal for learning about both small businesses and intermediaries, as phases may overlap at multiple points. While the overall project applied both phases of the model, the results reported in this paper are focused primarily on the first, initiator-intermediary phase.

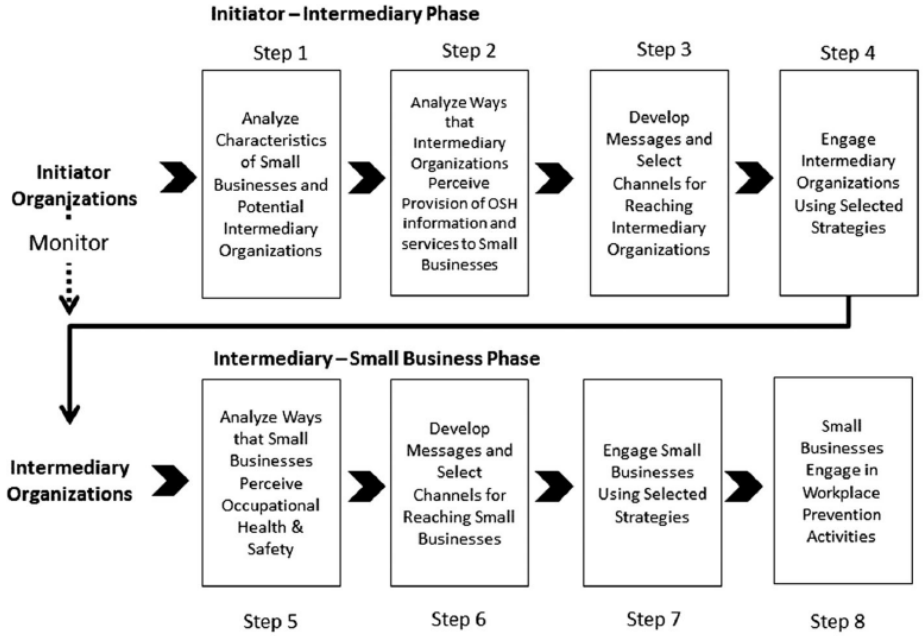


Figure 1. The intermediary–small business diffusion model.

This part of the study included: (1) identifying and recruiting intermediaries, (2) deciding the best approach through discussions with the intermediaries, (3) intermediaries engaging with small businesses via consultations and offering TWH-related services, (which included a participatory research approach to having the intermediaries design and execute a pre- and post-interview data collection effort), and (4) asking intermediaries to reflect on the experience during a final debriefing focus group.

2.2. Identifying and Recruiting Intermediaries

This study targeted two communities in two geographically distinct, large communities in the same greater metropolitan area. These two communities were selected for convenience, as well as to explore perspectives of intermediaries in different types of communities (urban vs. suburban). Two sets of intermediaries were identified and recruited. The research team approached several intermediaries that were known to the research team through their memberships in local chambers of commerce. These intermediaries were considered likely to have some familiarity and experience in assisting employers with elements of a Total Worker Health approach, and included: occupational and business health services organizations, safety consultants, local health departments, and workers compensation insurers (see Table 1). Health departments were expected to be ideal partners because of their interest in new channels to deliver health objectives, experience in data collection, and interest in health outcome changes. Business health services were expected to be ideal partners because they already offered employee health services to businesses, were interested in market research, and understood the importance of both prevention and return-to-work activities. Safety consultants were expected to be ideal partners because of

their knowledge related to workplace safety and regulations and their ability to discuss options to decrease risk of injury and illness.

Table 1. Intermediaries for two communities.

Community A	Community B
Health Department A	Health Department B
Healthcare Provider A (Hospital Wellness Services)	Healthcare Provider B (Hospital Healthcare/Business Health Services; includes ergonomist)
Retired Workers Compensation Safety Consultant	Workers Compensation Provider
	Safety Consultant

2.3. Intermediary Discussions: Initial Perspectives on TWH

Data were collected during introductory meetings/discussions, which were key-informant interviews regarding intermediary perceptions about TWH. Meetings occurred 1–2 times for approximately 1 h with each participating intermediary. At the beginning of each meeting, the research team presented an overview of the TWH approach, which included the NIOSH definition and examples of TWH interventions [7]. The following responses were noted by a research assistant during the course of these introductory discussions with intermediary organization representatives (See Table 2). These questions and responses are included here to provide context for the experiences of the intermediary participants.

Table 2. Questions and representative responses with intermediary organization representatives.

Question	Response
What is your reaction to TWH (as described with the NIOSH definition and examples of TWH interventions [7])?	Healthcare Provider B stated they thought about TWH in terms of preventive health maintenance and post-injury care. Health Departments (A, B) reported limited focus on OSH. Instead, their engagement with employers was mainly focused on workplace health promotion or wellness, with emphasis on physical activity and smoking cessation activities.
How compatible is the "TWH for small businesses idea" with the past experiences, existing range of program products, and strategic directions of this organization?	Healthcare Provider B stated they felt TWH was fairly compatible because they already had some activities related to wellness and safety, which were similar to the examples of TWH interventions described by the research team (e.g., ergonomics consultations with employers). Health Department A felt they did not have any programs currently related to OSH. Instead, their work–life programs tended to focus on wellness.
How difficult would it be for your organization to try delivering TWH ideas and services to small businesses?	Health Department A noted a barrier for their organzation, specifically, people are unlikely to perform a task not in their job responsibility. Healthcare Provider B noted low number of employees per business, and therefore business may not be able to afford services.
Compared to other business improvement ideas that your organization offers to small businesses, how difficult is the TWH idea to understand for people in your organization?	Healthcare Provider B speculated that some might think of "at work" vs. "outside of work" while others might think of preventive health maintenance versus post-injury care.
Would a subsidy make a difference in the willingness of your organization to offer TWH information and/or services to small businesses? If so, how would different subsidy levels make a difference?	The overall opinion was that money makes a difference in most cases: Healthcare Provider B felt offering each business some TWH activities about 4 times per year seemed doable for roughly USD 20,000. In regard to worker safety and health and tax credits or incentives, Health Department A noted that when small businesses have an opportunity to receive a financial reward, the option for financial incentives becomes the benefit most preferred by small businesses employers. Money was not a factor with the Workers' Compensation Provider in Community B, because they were simply not interested in wellness. [This group eventually withdrew from participating as a potential intermediary.]

It should be noted that many of the wellness activities, especially through the health departments, would have been completed regardless of study participation, however additional funding was needed to provide the financial support for taking on and providing OSH assistance to the participating small businesses.

2.4. Intermediary Discussions: Formulating the Community-Based Approach

Each set of community partners, or intermediaries, selected slightly different approaches for identifying small businesses as participants (see Table 3). Intermediaries were instructed that potential participating businesses were eligible if they had at least five but fewer than 50 employees [32]. Community A (an urban community) intermediaries selected a geographic approach which focused on 4 neighborhoods of previous interest, whereas Community B (a suburban community) intermediaries selected a sector-based approach (i.e., construction, childcare centers, manufacturing, municipalities). Community A included a focus on bringing businesses in the community together to pool funds for wellness and safety activities, while Community B tried collective activities in one sector (childcare) and engaged employers individually in the other sectors.

Table 3. Eligibility and outreach strategies for two communities.

	Community A	**Community B**
Targeted businesses	Located within 4 neighborhoods	Sectors: manufacturing, construction, childcare, municipalities
Business Size	5 < eligible < 50 employees	
Outreach	Phone calls or walking the neighborhood and dropping in to distribute information	Phone calls

2.5. Intermediaries Engaging with Small Businesses Using TWH

Initial outreach efforts to small employers were conducted by the health departments via phone calls and interview data collection. Identifying local businesses already familiar to the participating intermediaries was helpful and contributed to the successful recruitment of 50 small businesses across the two communities from April 2014 to February 2015. Baseline interviews conducted by health department representatives with small business owner/managers in each community gathered initial perceptions about the TWH concept and determined what the business may be doing or may be interested in doing for employee personal health and occupational safety and health. While engagement with small employers was a part of the overall study, and preliminary results reported previously [33,34] indicated varying levels of successful engagement, the research question addressed within this paper is focused on the experience of intermediaries involved in offering TWH services to small employers.

The research team instructed the intermediaries to develop their own approach to offering TWH assistance to employers, with the general requirement that they offer services that collectively address worker safety, health, and well-being. One of the services that the intermediaries agreed to provide to the small businesses was a team consisting of a business health service provider and safety consultant, who would partner with the business to: (1) develop the mission and vision for the wellness and safety program, (2) develop goals and objectives for a customized wellness and safety plan, (3) implement the wellness and safety plan, (4) provide aggregate data report for screening (>20 participants), and (5) provide support in applying for safety and wellness grants.

While it was agreed that each employer would likely require a flexible, and customized approach, the intermediaries offered employers examples of services that could be provided during the course of the project, including: access to consultant expertise for wellness and safety for up to 3 onsite visits, as well as communication via phone or email; wellness/safety

assessment; wellness/safety strategic plan; creative suggestions for enhancing wellness and safety programs and culture; participation in Employee Wellness Days (e.g., blood pressure screenings, health risk assessments, educational days about specific health topics). These service offerings were based on what the intermediaries suggested businesses are typically interested in, however changes to the service plan could still occur after individual business consultations. During these business consultations, consultants met with businesses and provided resources as requested.

Exit interview questions were collected by health department representatives in each community which were similar to those in the baseline interviews but also sought to elicit descriptions of changes in perceptions regarding TWH. Thus, all intermediary participants across the two communities were engaged with some TWH outreach and service delivery with small business employers during the course of the overall project.

2.6. Focus Group Interview Analysis

The final intermediary focus group interview was recorded and transcribed. The transcribed interview responses were analyzed by an inductive approach with thematic coding and a subsequent iterative process for further clarification of themes [35,36]. During familiarization, or phase 1, the research team independently reviewed the transcript and then together reached consensus on important themes and ideas. The team developed a codebook to guide data analysis. In phase 2 (generating initial codes), the research team systematically coded interesting features, direct quotations, and patterns across the entire interview, reviewing differences in coding until consensus was reached. During phase 3 (searching for themes), the data were reviewed, gathered into relevant groups, and collated into potential themes. Finally, the team conducted ongoing analysis to refine each theme and further condense the themes into a cohesive narrative. Text included in the results that appear in quotation marks are portions of the overall focus group transcript which are included to further demonstrate the participants' experiences.

3. Results

The final intermediary focus group was composed of 11 attendees who work at health departments, hospitals, and other providers of safety or wellness/employee health services. The focus group began with asking about everyone's overall thoughts on the concept of TWH, and then the discussion flowed from there to include participants' perspectives on what worked well in implementing TWH, what did not work well, changes they have implemented based on their experience with the project, and ideas for how implement TWH approaches on a larger scale with small employers.

Overall, the intermediaries confirmed that small business employers care about their employees and are open and receptive to the idea of TWH and related new programming. They noted that wellness is a harder sell than workplace safety, and thus recommend that wellness be framed as a business proposition and emphasize the benefit to the company's bottom line. Intermediaries reported that most small businesses already have safety programming which is often based on regulations in place, but wellness will have to be the add-on.

The intermediaries overwhelmingly confirmed the need for TWH programming that is flexible and tailored to the individual businesses. Intermediaries corroborated small business interviewees regarding the lack of resources or organizational structures to sustain TWH. Surprisingly, intermediaries reported that money was not a sufficient incentive to engage employers in health and safety programming. Instead, programs and initiatives that focused on bringing different small businesses together to pool resources and share events were more successful. Recognition and personal relationships were the primary motivators for small businesses when considering health and safety programming. Intermediaries suggested that the businesses needed to own the process for programs to be successful. They also mentioned that identifying one or two employees to be responsible points of contact and/or project coordinators was a factor for success.

The intermediaries from Community B that participated in the final focus group highlighted the childcare sector as the leader in TWH programming. They described specific TWH resources tailosector as "passionate" and very interested in TWH programming and described these experiences as the most successful.

3.1. General Reflections on the TWH Concept

Healthcare Provider A felt that that TWH made "a lot of sense", and in their experiences, small businesses already had policies and communications prepared for safety, and they simply needed to broaden those messages to include wellness. They also mentioned a trend in the marketplace to include more on well-being, and how TWH fit into that as well. Safety Consultant B discussed the importance to trying to fit wellness in with safety and not the reverse, as many business, such as those in manufacturing, have a safety piece in place. One representative of Health Department A also mentioned the advantage of being able to get through the initial "door" by talking about safety and then say "Hey, by the way, let's talk about wellness".

A second representative of Health Department A described the TWH concept as innovative, as it had them thinking about safety and how it relates to residents in the community, such as how physical activity can be addressed from the safety perspective. Safety Consultant A also brought up that many small business employers are motivated by their own self-interest, and the need to stay open, paying employees. They also reported needing more from a risk management perspective, and that participating employers appeared "grateful for the assistance that they got with the recognition, evaluation, and control of hazards". Safety Consultant A continued with describing TWH and this experience as entry point to the home, because "we're interacting with people that spent a third of their lives, if they're lucky, at work and why not that Total Worker Health® and parts thereof be translated back home and underscored in a real public health perspective"?

3.2. Changes in Intermediaries Based on Experience with TWH Assistance for Small Employers

Some of the intermediaries shared that they changed how they talk to employers. Healthcare Provider A described how they were already heading down the "path of looking at people holistically and companies holistically" and that talking to people about their worksite culture of health and wellness provided insight into what drives the kind of support they have, what kind of communication they have, and what works from a communication perspective. They concluded by explaining that they had been previously asking about worksite wellness, but not safety; and that by learning about both, they had a "more rounded view of their worksite culture". They also mentioned that they looks for opportunities now to include both safety and wellness, such as with respirator training and including discussion about tobacco cessation.

Safety Consultant B felt that with TWH, from the dollar and cents perspective, "we ought to be doing this". They often work with businesses to address industrial hygiene/safety concerns, however, afterwards they ask the employer, "What support are you also offering your employees as far as wellness?" Even though this wellness piece may not be something offered, they want to draw attention to it since it keeps people healthier on the job, with less turnover, and fewer days away from work.

A couple of the intermediaries shared how the programming the offered to employers changed after their participation in the TWH activities. Health Department B described how they created a worksite wellness program for childcare providers that is now available on their state website. They went on to describe how this program has been shared by partners statewide.

Safety Consultant B described a situation where they asked workers what they hated most about their job, and were told about a tool that was difficult to use, "It was a pound a rod in the ground that deep and then there was a little teeny, wrench that you had to kind of twist at ankle height to get it out of the soil. Additionally, the people that were doing the job were, you know, it was people in their second-last career, you know, they're

overweight people with knees that don't work but they had to do this". Additionally, they asked the workers why they used the tool and was told that it came with the kit. They went on to describe how they found a fabricator to create a new tool so that the workers could stand up doing the task, making 300 of these tools per month, and back injuries have been reduced over this time with the new tool.

3.3. What Worked Well and What Didn't Work Well to Assist Small Businesses with TWH

Many of the intermediaries recognized that the small businesses had limited resources, and that communication was key to understanding the needs and limitations. One Health Department A representative described the need to help them understand the value and benefits of TWH. "You can meet the regulations that you need to while also sending your employees home at the end of the day healthier or better taken care of. I mean, having that communication was just- I cannot describe to you how important that was". Safety Consultant A agreed, and went on to describe what they had experienced.

"They don't have an organization structure that they can put this stuff into, they don't have time, they don't have money. What I found to be most attractive to the employers that we interacted with was almost a communal sense that really was palpable in [the neighborhood]. Where we were able to pull together different employers kind of through a loose-knit . . . business association. I think they're generally aware of the demographics of their workers, they understand in some instances it's an aging workforce. They're concerned about turnover, but how do we pull these things together? In many instances they don't even provide healthcare coverage. You really have to help them understand concepts like presenteeism, absenteeism, to help them get a sense for what's going on. I didn't get a sense that any of the employers needed an explanation from a return on investment perspective. They just needed to understand that if we can all come together, we can find the benefit".

3.3.1. The Value of Small Employer Groups

Another interesting aspect of the study that seemed to be positive was the formation of small groups of employers that participated in group discussions with the intermediaries. The employers could see the commonalities and bounce ideas off each other, and there was a positive peer pressure to participate. These employer groups also led to efficiency for some of the health services, as described by Hospital B: " . . . especially on the healthcare side we're a little strapped for resources also, so, you know, if we can do things in large groups and be more efficient about things, that makes it easier for me". Many of the intermediaries also noted that in the groups, the employers "learned and understood a lot more about health and safety because they started talking each other's language. Additionally, before it was us trying to educate them on one-on-one when we first did the interviews about "This is what health is. This is what safety is". However, when they heard their peers talking back and forth, I feel like they got a better understanding than us just talking to them".

3.3.2. Consistency of Engagement of Intermediaries with Small Employers

Intermediary opinions and experiences differed when it came to the consistency of engagement with the employers. For Health Department B, because they were already working with childcare centers, there was no handoff to another intermediary group after the recruitment period, and instead it was a smooth transition to TWH activities—this was seen as a factor that led to successes that were not necessarily seen in the other targeted industries (i.e., construction, manufacturing, municipalities).

Other intermediaries mentioned the lack of ownership or not having a single person be the key driver, resulted in difficulties. One representative of Health Department A explained, "Additionally, part of that comes with the fact that small businesses, you know, make connections with people, they are not large, corporate entities and they remember you—that you had this conversation with them and you built this relationship and so I

had cultivated relationships and then I had to leave and then [another Health Department A employee] is trying to call and they're like "Who's [name of Health Department A employee 2]? Where's [name of health department employee 1]"?

There were intermediaries that left jobs and came into new positions during the study which led to additional difficulties. Safety Consultant A described, "I know NIOSH is the umbrella, but I never felt like it was owned and it felt like we were in silos oftentimes where the communication was just- it was tough sometimes to try to figure it out [how] to get you guys and me and all you guys, all moving in one direction. . . . money is not a motivator [for small employers]. I think what motivated people was our listening- it's person-to-person, you had the most success when you interact and they know who you are and that they can identify that's something that you're bringing".

3.3.3. Flexibility to Meet Employers' Needs

Another key point that the intermediaries brought up was the need to have flexibility within the TWH program offerings to meet the employers' needs. Many of the employer groups based in a neighborhood wanted to do things together, like lunch-and-learns, which seemed to give activities more "traction". The intermediaries that worked with the childcare centers talked about how they first surveyed employees, and then held a health fair that included vaccinations and flu shots for all the childcare centers. Another intermediary mentioned that the pre-prepared model of activities they initially shared with the neighborhood group did not resonate, but once they allowed employers the flexibility to make changes that really made a difference.

3.4. Key Challenges to Implementation

Representatives from both health departments agreed that money was not a motivator for these businesses to try out TWH programming. They expressed surprise that the incentives to participate did not bring much success initially. Instead, they found that there needed to be an "energy around something" to motivate the businesses. A participant from Health Department A shared, "I think what worked more is when they were able to get together and they could bounce ideas off of one another. Additionally, then they started understanding together and then they started building once they understood together. That seemed to be the driver". Additionally, Health Department B mentioned there were sector specific challenges. The example they provided expressed that the construction sector was particularly difficult to reach. They explained that, "You had to catch them when it was raining or when it was winter so that you could actually talk to them because as soon as it got sunny, they aren't going to be in their office . . . ".

3.5. Organizations Best Suited for TWH Assistance for Small Employers

The intermediaries also shared their thoughts on what kinds of organizations might be best suited to assist with providing TWH to small businesses. One Health Department B representative shared that for some of the intermediaries, like the healthcare providers, "they're in the business of business health and so we were partnering with them . . . trying to work under that umbrella, where they're providing a service that is not taking away from their business, either".

3.5.1. Need to Take Advantage of Existing Networks, Not Create New Ones

Most representatives recognized the need to take advantage of existing networks, and not necessarily create new ones. Chambers of commerce were discussed as possibly being a helpful way to bring businesses together, however, it was also pointed out that the disadvantage with that organization is chambers charge a membership fee. Healthcare Provider A mentioned the advantage of neighborhood associations and good connections made through that option. Safety Consultant A pointed out that it was important to listen for and identify what resonates with the small businesses, "Am I hearing something from the women's perspective? Is this a minority perspective? Where are the touchpoints for

these people? Are they disabled veterans? These are all small business touchpoints that people will have in common and there's not a lot of them but if you can have the good fortune to interact with them and have the ears to pick up on those kinds of issues or needs, you could put them together, you could make a bigger thing happen beyond just those handful of employers".

3.5.2. Small Versus Large Employers

The size and definition of small businesses were also discussed as a factor within the study and thinking about the future. Some, like Safety Consultant A, felt that increasing the number of employees in the small business definition, might have been better. Healthcare Provider A agreed, especially considering that in the near future, they would only be working with businesses with 100 or more employees. However, a representative of Health Department B mentioned that from their experiences, "small businesses are more like community than actual, larger businesses".

3.6. Key Drivers to Make TWH Work for Small Businesses

The participating intermediaries had a few thoughts and ideas for what was needed to make TWH work for small businesses, including having more resources and intermediaries interested and available, clear messaging and examples of best practices, and the ability to reach new businesses.

Healthcare Provider A mentioned that they felt like more partners were needed that could provide free resources in order for TWH to be sustainable when there is not a large budget available for activities.

Health Department A mentioned that TWH was hard to "pin down" because "it's everything", so having key programs that worked in particular industries with data backing it up would help those starting activities at businesses in the future. Safety Consultant A agreed and mentioned that demonstrating success with outcomes and numbers was important. Promotion and messaging were mentioned by another representative of Health Department A as important, "We started to figure out a quicker way to say exactly what we were trying to do but I think in the beginning it was like two to three sentences and then we kind of got it down to a phrase and so I think messaging was important".

A representative from Health Department A and a safety consultant from Community B both speculated that if possible, it would make sense to promote the idea of TWH early, to a business just starting out. They wondered how that might be introduced to a brand-new business in order to introduce and implement programming from the beginning.

4. Discussion

Given the rapidly evolving work environment where both occupational safety and health and personal health are considerations (which has been possibly amplified by the COVID-19 pandemic), and the continued shift toward more workers being employed by smaller firms [6,37], the need to understand effective methods for implementing TWH in small businesses is increasingly critical. The results of our community-based, participatory experience with several intermediary organizations suggest there is great potential for improving the dissemination and implementation of TWH approaches among the small business workforce.

There has also been increasing attention to understanding and overcoming OSH challenges among small business employers. Much of the most recent international small business OSH conference, the Understanding Small Enterprises Conference, included discussion of the changing nature and future of work [38]. Small business OSH issues continue to present myriad challenges, but several promising lines of research continue to drive knowledge about how to effectively improve OSH best practices in small businesses [39].

There have been several important efforts to address TWH among small employers. For example, Newman and colleagues have demonstrated an approach to reaching small employers with TWH-related assistance via a coordinating organization, Health

Links ™ [40]. This effort was launched with strong support from an insurance partner and a NIOSH Center of Excellence for TWH and has developed into a combination of a membership organization, credentialing or certification function, robust outreach and training delivery system, and networking opportunity for small employers based around TWH. Strong collaborative relationships are a key driver of its success and the results presented here suggest there is opportunity to involve many diverse intermediaries toward forming more customized and collective efforts around TWH among small businesses. Rohlman and colleagues have also demonstrated success in engaging small employers in both rural and urban environments [41]. In one example, the St. Louis Area Business Health Coalition has been serving as an intermediary organization delivering TWH to the St. Louis, MO business community [42]). As suggested by the health department representatives in this study, there may be opportunities to engage collectives of larger, more well-resourced employers and consider approaches to providing free and easily accessible assistance to smaller employers with interest to explore TWH approaches.

Identifying appropriate intermediaries for TWH efforts is also a consideration that needs to be well-thought out. As seen in this study, the health departments were great partners because they had: interest in finding new ways to reach out and deliver health messaging, experience in data collection, and interest in health outcome changes. Additionally, the business health service providers were good partners because: they already offer employee health services to businesses, they were not concerned with new clients but more interested in the market research aspect, and they understood the importance of both prevention and return to work activities. Additionally, of course, the safety consultants were ideal partners because of their expertise in workplace safety and regulations, and they could discuss options to decrease risk of injury at various businesses.

Key Learnings

Several points can be taken away from the experience of intermediaries in delivering TWH assistance to small employers.

First, we may be overly reliant on our assumption that there is a need for significant financial support to enable greater engagement among intermediaries and small employers around TWH assistance and activities. At initial interview, most intermediaries expressed the assumption that financial resources would be among the most critical components to enable the planned TWH assistance activities with small employers. In the final intermediary focus group, there seemed to be agreement that motivation among employers, as well as social norms regarding responsibility for supporting health- and well-being-enhancing activities (versus pay), were key determinants to successful implementation of their planned activities for TWH assistance for small employers.

The intermediary participants in the baseline interviews and focus groups were aware of several prominent themes in their interactions with the small employer participants, which are reflected in the following summary of preliminary findings [33].

Overall, participating small employers have the motivation and willingness to incorporate safety and wellness into their workplace and recognize that they have not to date done enough. Participating employers have completed the requirements to meet OSH standards. They also have held small, informal activities to boost morale and support wellness. Despite their appreciation of safety and wellness as beneficial to their company's success, many employers felt it was unlikely they would continue to offer wellness programming beyond their participation in the study primarily because of lack of budget, time, and easily accessible resources. After money, the other most salient challenges for employers trying to engage in new TWH program elements are time, employee interest, and a mindset that health and safety should be driven by employees' individual responsibility with the site offering support and resources as feasible. At the start of the study, respondents almost universally discussed safety and wellness as separate issues. When asked about integrating, some believed it made sense to integrate wellness and safety as part of the same overarching program. However, about half of the respondents felt that safety should

be kept separate. Because of the broad diversity of employees, size of company, type of work, and environmental context, a "one-size-fits-all" integrated TWH program would likely not work across participating sites. Although cost, time, and employee interest were overarching challenges, respondents described assets and challenges unique to their workplace that would be crucial to consider in designing a successful program.

Based on the perspectives of the participating intermediaries, it is evident that a cultural shift will be necessary to implement TWH programming. As the intermediaries observed in their interactions with small employers, respondents expressed interest and willingness to support employee health/wellness and safety, but there was not the sense that they saw wellness as a fundamental part of their workplace. This may further support the suggestion that a multi-layered approach to supporting small employers in addressing worker safety, health and well-being is needed from intermediary organizations. Not only do many employers not see themselves as fundamentally responsible for personal health and well-being of individuals they employ, they also lack adequate resources to adopt and manage new approaches and activities.

It has been suggested that key drivers of small firm culture include the owner/manager, as well as the community with which the firm identifies [5]. The results presented here compare and contrast a geographically defined and a sector defined community approach to engaging small employers in TWH activities. There may be positive and negative aspects of both approaches, and the experience of the intermediaries described here suggests this is perhaps a key element of a customized approach to disseminating and implementing TWH approaches among small employers.

Perhaps the most challenging step in initiating the TWH diffusion demonstration described here is identifying and engaging with potential champions and supportive opinion leaders within intermediary organizations. The work described here has followed an ongoing OSH research and outreach effort which has included active participation by the research team in various business networks, associations, and other organizations that either do, or have potential to offer, OSH assistance to small employers. Potential intermediaries must have top level support, individual interest that adds to their motivation, and a desire to work with small businesses, whether driven by goals related to finding new clients, adding members, reaching more service recipients, or other organizational objectives. Each of the intermediaries approached for this project were known to have some ongoing workplace health and/or safety role, but not all were necessarily receptive to the concept of TWH. These challenges highlight some weaknesses of the intermediary model, including turnover of champions within intermediary organizations, shifting priorities, and inconsistent funding support.

As suggested by the Small Business diffusion model [22,23], it is key for the initiator of TWH diffusion efforts to monitor activities of intermediaries, and take an active and participatory role in the community of interest. There is a delicate balance between sharing knowledge with intermediary partners and allowing them to act upon the knowledge in a way that will be sustainable after the initial demonstration of the initiator-intermediary-small business relationship. There is also an important social exchange occurring in each instance of communication between the initiator (here, the research team) and intermediary participants when sharing TWH knowledge. That is, the intermediaries must perceive value in the exchange, and thus act upon the knowledge, in a way that is compatible with their organizational practices, policies, culture, etc. The research team in this project aimed to share the concept of TWH as well as the importance of assisting small employers clearly with the intermediary partners, and then observe and capture a record of their experience in engaging small employers around the concept of TWH. For example, a safety consultant partner was lost due to lack of top-level support for providing workplace health promotion assistance. The intermediary organizations developed their own approach to engaging small employers, and they also observed what worked and what did not in delivering TWH services to small businesses.

Based on both our results presented here and previous work in reaching small employers with TWH approaches, flexibility is key. TWH looks different in each organization and likely varies in program elements included, leadership of TWH activities, and evaluation of outcomes (both perceived and measured).

The way TWH is described by intermediaries may not align directly with the prescribed definition (NIOSH, 2017), and part of the adoption of TWH among intermediaries and small employers may veer between more academically precise and business/organizational terminology. For example, organizations engaged in this project frequently used the terms "workplace safety and wellness" instead of "health promotion and occupational safety and health". Although the definition of TWH was clearly shared and understood among the intermediaries, much of the practical discussion among intermediaries and small employers included reference to 'wellness', which is clearly not synonymous with TWH (NIOSH, 2021).

Incentives may be needed to motivate intermediaries to assist small businesses. While monetary support seemed be less of a concern in interactions between intermediaries and small employers, the intermediaries involved in this project all received some level of financial support to engage in this project, and in some instances these scarce public health/OSH research financial resources were noted as a limiting factor among the intermediaries. Some financial assistance for small employers to add new TWH-related elements to their safety and health management systems has been shown to be effective in increasing uptake of TWH interventions (e.g., grants from workers' compensation insurers [43]; Health Links business grants [40]). While preliminary results suggested a $50 participation incentive may be insufficient to entice employers to engage in opening discussions of TWH [33], exit focus group results suggest financial incentives were not a strong motivator for employers to engage with intermediaries on TWH. Clearly there is ongoing need for use of scarce health and well-being resources to be creatively and efficiently applied to assist small employers, which will likely be in greater demand as future workplaces will need to address worker well-being to remain competitive and survive.

Evaluation and feedback are critical in launching a new collaborative effort such as those described here, and are also a part of the social exchange between the initiator and intermediaries which has been noted as adding value for intermediaries [23]. In this project, it is difficult to assess any quantifiable effect ongoing feedback from the research team had on intermediaries' increased adoption of TWH, however, several instances of intermediaries disseminating results of their experiences with engaging small employers in TWH to their own peer networks (e.g., presentations by intermediary participants to national and state professional conferences) suggest there was substantial value perceived by those participating intermediaries.

5. Conclusions

This study explored how the concept of Total Worker Health can be effectively introduced to community organizations, so that they may in turn deliver TWH assistance services to small businesses.

It has been known that limited resources are a central barrier to implementing safety and health interventions. This study adds to the limited, but growing literature that suggests a need for financial and programmatic support for intermediary organizations able to assist small employers with implementation of TWH approaches to managing worker well-being.

Interestingly, the COVID-19 pandemic has synergized many business and public health interests, as evidenced by employers' efforts to follow public health recommendations to limit the spread of SARS-CoV-2, encourage employee vaccinations, and in some cases, bolster trust in public health [44]. Although this study pre-dates the COVID-19 pandemic, the findings from discussions with intermediaries seem more relevant than ever as employers struggle with meeting greater demand for OSH management while also

facing business survival challenges as the nature of work continues to evolve, perhaps in even more rapid and unanticipated ways.

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References

1. Felknor, S.A.; Streit, J.M.; Chosewood, L.C.; McDaniel, M.; Schulte, P.A.; Delclos, G.L. How will the future of work shape the OSH professional of the future? A workshop summary. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7154. [CrossRef]
2. Craig, B.N.; Congleton, J.J.; Kerk, C.J.; Amendola, A.A.; Gaines, W.G. Personal and non-occupational risk factors and occupational injury/illness. *Am. J. Ind. Med.* **2006**, *49*, 249–260. [CrossRef]
3. Luckhaupt, S.E.; Cohen, M.A.; Li, J.; Calvert, G.M. Prevalence of obesity among US workers and associations with occupational factors. *Am. J. Prev. Med.* **2014**, *46*, 237–248. [CrossRef] [PubMed]
4. U.S. Census Bureau. 2018 SUSB Annual Datasets by Establishment Industry. 2018. Available online: https://www.census.gov/data/datasets/2018/econ/susb/2018-susb.html/ (accessed on 1 July 2021).
5. Cunningham, T.R.; Sinclair, R.; Schulte, P. Better understanding the small business construct to advance research on delivering workplace health and safety. *Small Enterp. Res.* **2014**, *21*, 148–160. [CrossRef]
6. Choi, E.J.; Spletzer, J.R. The declining average size of establishments: Evidence and explanations. *Mon. Lab. Rev.* **2012**, *135*, 50.
7. NIOSH; Lee, M.P.; Hudson, H.; Richards, R.; Chang, C.C.; Chosewood, L.C.; Schill, A.L.; on behalf of the NIOSH Office for Total Worker Health. *Fundamentals of Total Worker Health Approaches: Essential Elements for Advancing Worker Safety, Health, and Well-Being*; U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health: Cincinnati, OH, USA, 2016; DHHS (NIOSH) Publication No. 2017-112.
8. Linnan, L.; Bowling, M.; Childress, J.; Lindsay, G.; Blakey, C.; Pronk, S.; Wieker, S.; Royall, P. Results of the 2004 national worksite health promotion survey. *Am. J. Public Health* **2008**, *98*, 1503–1509. [CrossRef]
9. Sinclair, R.C.; Cunningham, T.R. Safety activities in small businesses. *Saf. Sci.* **2014**, *64*, 32–38. [CrossRef]
10. Holizki, T.; Nelson, L.; McDonald, R. Injury rate as an indicator of business success. *Ind. Health* **2006**, *44*, 166–168. [CrossRef] [PubMed]
11. Sims, R. Hazard Abatement as a Function of Firm Size: The Effects of Internal Firm Characteristics and External Incentives. Ph.D. Thesis, Pardee Rand Graduate School, Santa Monica, CA, USA, 2008.
12. Tenney, L.; Fan, W.; Dally, M.; Scott, J.; Haan, M.; Rivera, K.; Newman, M.; Newman, L.S. Health Links™ assessment of Total Worker Health®practices as indicators of organizational behavior in small business. *J. Occup. Environ. Med.* **2019**, *61*, 623. [CrossRef]
13. Mendeloff, J.M.; Nelson, C.; Ko, K.; Haviland, A. *Small Businesses and Workplace Fatality Risk: An Exploratory Analysis*; Rand Corporation: Santa Monica, CA, USA, 2006; Volume 371.
14. Newman, L.S.; Tenney, L. Total Worker Health®Approaches in Small-To Medium-Sized Enterprises. In *Total Worker Health*; Hudson, H.L., Nigam, J.A., Sauter, S.L., Chosewood, L.C., Schill, A.L., Howard, J., Eds.; American Psychological Association: Washington, DC, USA, 2019.
15. De Kok, J.M. Precautionary Actions within Small and Medium-Sized Enterprises. *J. Small Bus. Manag.* **2005**, *43*, 498–516. [CrossRef]

16. Hasle, P.; Limborg, H.J. A review of the literature on preventive occupational health and safety activities in small enterprises. *Ind. Health* **2006**, *44*, 6–12. [CrossRef]
17. Lentz, T.; Wenzl, T. Surveillance: Small businesses with high fatality rates: Assessment of hazards and their prevention. *J. Occup. Environ. Hyg.* **2006**, *3*, D8–D14. [CrossRef] [PubMed]
18. Mattke, S.; Liu, H.; Caloyeras, J.; Huang, C.Y.; Van Busum, K.R.; Khodyakov, D.; Shier, V. Workplace wellness programs study. *Rand Health Q.* **2013**, *3*, 7.
19. National Small Business Association. Workplace wellness programs in small business: Impacting the bottom line. *Retrieved August* **2012**, *21*, 2014.
20. Okun, A.H.; Watkins, J.P.; Schulte, P.A. Trade associations and labor organizations as intermediaries for disseminating workplace safety and health information. *Am. J. Ind. Med.* **2017**, *60*, 766–775. [CrossRef]
21. Hasle, P.; Kvorning, L.V.; Rasmussen, C.D.; Smith, L.H.; Flyvholm, M.-A. A model for design of tailored working environment intervention programmes for small enterprises. *Saf. Health Work* **2012**, *3*, 181–191. [CrossRef]
22. Sinclair, R.C.; Cunningham, T.R.; Schulte, P.A. A model for occupational safety and health intervention diffusion to small businesses. *Am. J. Ind. Med.* **2013**, *56*, 1442–1451. [CrossRef]
23. Cunningham, T.R.; Sinclair, R. Application of a model for delivering occupational safety and health to smaller businesses: Case studies from the US. *Saf. Sci.* **2015**, *71*, 213–225. [CrossRef] [PubMed]
24. Bruening, R.A.; Strazza, K.; Nocera, M.; Peek-Asa, C.; Casteel, C. How to engage small retail businesses in workplace violence prevention: Perspectives from small businesses and influential organizations. *Am. J. Ind. Med.* **2015**, *58*, 668–678. [CrossRef] [PubMed]
25. Faghri, P.D.; Kotejoshyer, R.; Cherniack, M.; Reeves, D.; Punnett, L. Assessment of a worksite health promotion readiness checklist. *J. Occup. Environ. Med.* **2010**, *52*, 893–899. [CrossRef] [PubMed]
26. Baker, E.; Israel, B.A.; Schurman, S. The integrated model: Implications for worksite health promotion and occupational health and safety practice. *Health Educ. Q.* **1996**, *23*, 175–190. [CrossRef]
27. DeJoy, D.M.; Southern, D.J. An Integrative Perspective on Work-Site Health Promotion. *J. Occup. Med.* **1993**, *35*, 1221–1230. [PubMed]
28. O'Donnell, M.P. A billion and change in federal grants for health promotion. *Am. J. Health Promot. AJHP* **2012**, *26*, iv–ix. [PubMed]
29. Rogers, E. *Diffusion of Innovations*, 5th ed.; Free Press: Tampa, FL, USA, 2003; Volume 2, pp. 14–45.
30. Maddux, J.E. Expectancies and the Social–Cognitive Perspective: Basic Principles, Processes, and Variables. In *How Expectancies Shape Experience*; Kirsch, I., Ed.; American Psychological Association: Washington, DC, USA, 1999; pp. 17–39.
31. Bruening, R.A.; Strazza, K.; Nocera, M.; Peek-Asa, C.; Casteel, C. Understanding small business engagement in workplace violence prevention programs. *Am. J. Health Promot.* **2015**, *30*, e83–e91. [CrossRef]
32. NIOSH Small Business Assistance Program. Available online: https://www.cdc.gov/niosh/programs/sba/default.html (accessed on 14 February 2021).
33. Jacklitsch, B.L.; Cunningham, T.R. Total Worker Health in Childcare Centers: Preliminary Results from a Community-based Model. In Proceedings of the Understanding Small Enterprises Conference, Denver, CO, USA, 25–27 October 2017.
34. Cunningham, T.R.; Jacklitsch, B.L. Using intermediaries to implement Total Worker Health interventions in challenging industries. In Proceedings of the 2nd International Symposium to Advance Total Worker Health, Washington, DC, USA, 8–11 May 2018.
35. Braun, V.; Clarke, V. Using thematic analysis in psychology. *Qual. Res. Psychol.* **2006**, *3*, 77–101. [CrossRef]
36. Gale, N.K.; Heath, G.; Cameron, E.; Rashid, S.; Redwood, S. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Med. Res. Methodol.* **2013**, *13*, 117. [CrossRef]
37. Headd, B. *An Analysis of Small Business and Jobs*; Office of Advocacy, US Small Business Administration: Washington, DC, USA, 2010.
38. Brown, C.E.; Cunningham, T.R.; Newman, L.S.; Schulte, P.A. Conference Summary Understanding Small Enterprises Conference, 25–27 October 2017. *Ann. Work Expo. Health* **2018**, *62* (Suppl. 1), S1–S11. [CrossRef]
39. Cunningham, T.R.; Schulte, P.A.; Jacklitsch, B.L.; Burnett, G.; Newman, L.S.; Brown, C.; Haan, M. *Understanding Small Enterprises, Proceedings of the 2017 Conference, USE 2017, Denver, CO, USA, 25–27 October 2017*; National Institute for Occupational Safety and Health: Cincinnati, OH, USA, 2018.
40. Colorado School of Public Health Center for Health Work & Environment Health Links™. Available online: https://coloradosph.cuanschutz.edu/research-and-practice/centers-programs/chwe/practice/health-links (accessed on 29 July 2021).
41. Rohlman, D.S.; Campo, S.; Hall, J.; Robinson, E.L.; Kelly, K.M. What could Total Worker Health® look like in small enterprises? *Ann. Work. Expo. Health* **2018**, *62* (Suppl. 1), S34–S41. [CrossRef]
42. St. Louis Area Business Health Coalition. *Total Worker Health Employer Guide: Missing Pieces to the Employee Well-Being Puzzle*; Schulte, L., Ed.; St. Louis Area Business Health Coalition: St. Louis, MO, USA, 2017; Available online: site-ym.com (accessed on 16 April 2021).
43. Meyers, A.R.; Al-Tarawneh, I.S.; Bushnell, P.T.; Wurzelbacher, S.J.; Lampl, M.P.; Tseng, C.-Y.; Turner, D.M.; Morrison, C.A. Degree of Integration Between Occupational Safety and Health Programs and Wellness Programs: First-year Results from an Insurer-Sponsored Wellness Grant for Smaller Employers. *J. Occup. Environ. Med.* **2019**, *61*, 704–717. [CrossRef]
44. Health Action Alliance. Seven Ways Businesses Can Align with Public Health for Bold Action and Innovation. Prepared by The Institute for Health and Productivity Studies at the Johns Hopkins Bloomberg School of Public Health and the de Beaumont Foundation. Available online: https://debeaumont.org/businesspublichealth/ (accessed on 3 August 2021).

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Review

Industry Context as an Essential Tool for the Future of Healthy and Safe Work: Illustrative Examples for Occupational Health Psychology from the Hospitality Industry

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Abstract: Contextual nuance holds value for occupational health and safety, particularly as workplace challenges and solutions become more complex. However, disciplines that inform occupational safety and health vary in the degree to which they target breadth and depth of understanding. The future of work presents challenges related to work, the workplace, and the workforce, and an appreciation of the context of industry will ready researchers and practitioners with the most informed solutions. Broadly developed solutions for future of work challenges may flounder without an appreciation for the context of industry, as evidenced by two examples provided in this review. As occupational safety and health disciplines answer the call provided by the future of work, this review provides an account for the value of industry context and recommendations for achieving both breadth and depth of scientific inquiry and practical reach.

Keywords: industry; context; occupational safety and health; occupational health psychology

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1. Introduction

There is increasing recognition that the changing nature of work warrants adaptations in traditional approaches of occupational safety and health (OSH) research and practice in order to protect and promote workplace health, safety, and well-being amidst a backdrop of a changing future of work [1]. Future of work trends have tended to be discussed as applying broadly across work, industry, and temporal contexts. This is particularly the case in the occupational health psychology (OHP) literature. Historical accounts of the development of occupational health psychology note a focus on broad topics that apply to the majority of jobs, including supervision and workplace policies and procedures [2]. This focus on breadth within the OHP literature differentiates it from the general OSH literature, which more frequently considers the context experienced by a subset of workers, such as workers within a single sector of the national economy [3]. In this paper, we explore applications of industry context to promote both breadth and depth in OSH disciplines as they address future of work challenges. We describe future of work challenges and solutions that require an appreciation of context within an illustrative group, the hospitality industry, and in doing so hope to motivate OHP researchers and practitioners to incorporate a focus on the nuance provided by industry more often.

The current paper aims to offer an increased appreciation for context as a meaningful component of OSH/OHP research and practice that may shape both (a) what the future of work looks like and (b) the available solutions to its concomitant psychosocial workplace effects. From a conceptual standpoint, Johns [4] defines context as "situational or environmental stimuli that impinge upon focal actors and are often located at a different level of analysis from those actors". In that vein, elements of omnibus context (the reporters'

questions of what, where, when, why) have downstream consequences on work, work environment, work design, and organizations [5,6]. Johns [4] points out that elements of context that may have particular impact are those that serve as background variables, for example occupation or demographic makeup. We suggest that industry membership is also one of these variables. Industries/sectors have different work demands and work environments, different organizational structures, different workforce characteristics, different values and priorities, and different regulatory and labor context and standards. As the World Health Organization points out, there is no 'one size fits all' approach to occupational safety and health [7]. As such, it is difficult to imagine that solutions to occupational health and safety issues would work well for all industries, even if industries share some cross-cutting psychosocial issues.

Within this paper, we will describe the benefits of accounting for industry context, examine current trends in the incorporation of industry context in the OHP literature, and, using the hospitality industry as an example, describe challenges or solutions to future of work issues that would be better understood or implemented with industry in mind. In doing so, we suggest that a greater consideration of the context provided by industry membership will be beneficial within the OHP literature in order to better align its approach with other OSH-informing disciplines and to ready OHP researchers and practitioners for the complex challenges and nuanced solutions that the future of work will bring.

2. Industry as Under-Addressed Context in OHP Research

An industry refers to a distinct grouping of productive or profit-making enterprises, narrower than a sector and broader than occupational classifications. Examples include the healthcare industry, the construction industry, and the retail industry. Agencies, such as NIOSH, recognize the value of accounting for industry in the surveillance and intervention of occupational safety and health [3], offering resources that correspond to common industry classification systems including the Census Industry and Occupational Classification System, the North American Industry Classification System (NAICS), and the Standard Occupational Classification (SOC). Although it is a widely understood term, there is no universal operationalization of the variable of "industry". For example, NIOSH organizes resources and agendas by sectors that are aggregates of NAICS industry classifications and sector groups. This variability in classification and grouping schemes is generally not of concern given that useful cross-walking tools allow for comparison, such as the NIOSH Industry and Occupational Classification Coding System (NOICCS), so long as industry data are collected and coded in research and practice.

The industry-specific context can influence OSH research and practice in several ways. First, industry shapes the setting in which work typically occurs, tasks that are typically performed, the physical or psychosocial hazards that employees encounter, and the types of intervention methods that are possible or easily integrated into existing work processes. Some industry-related contextual factors may limit what is possible; for instance, the implementation of a sit-stand workstation intervention would not be possible in industries such as transportation [8]. This emphasizes the important point that an intervention developed for one industry may not match the context of another and without literature informing the context of each industry, we may not know how to adapt an intervention to promote safety or health across contexts.

Second, industry membership can provide clues to shared values, widely held assumptions, or norms among groups of employees. These powerful forces could influence both the experience of a work stressor or the welcomed or unwelcomed interventions to address that stressor. For example, the idiom "the customer is always right" may act as a threshold for perceptions of customer mistreatment in the hospitality industry and constrain policy and practice options for addressing this psychosocial stressor. What could be considered a major stressor in another industry might be interpreted as "just part of the job" for a hospitality employee. In an exploratory study using fMRI technology, no

differences in stress were observed in survey data from hospitality employees and employees of other industries. However, fMRI activation revealed patterns of habituation to stress from customer mistreatment [9]. In other words, more frequent or severe instances of customer mistreatment would be needed to warrant a higher stress score than participants from other industries. Here, the nuance of industry membership sheds incredible light on the processes of work stress that would otherwise be ignored. Based on these findings, an industry-informed researcher would know to expect higher thresholds for self-reported stress when collecting survey data on customer-related stressors in the hospitality industry and/or account for potential industry-related differences among survey data in a general working population sample.

In another example, despite the prevalence of mental health-focused programming in their workplaces, first responders have been known to access employee assistance programs or other resources at lower rates. This has been attributed to a shared value of "mental toughness" resulting in stigma for those who seek mental health treatment [10]. Accounting for these shared ideas could illuminate attitudinal or behavioral trends occurring within groups of employees. An intervening OSH professional might anticipate these industry-related shared perceptions and might first implement pre-intervention programming targeting social stigma to increase readiness for a treatment-based intervention in the public safety sector [11]. These examples illustrate how shared industry-related norms can influence both the experience of stressors and the success of efforts to address those stressors.

Finally, membership in an industry is known to intersect with other topics of contemporary relevance. The OHP literature is advancing to include topics of broader societal importance into our study of work, such as poverty, health equity, and overlooked working populations [12]. A consideration of industry would further these aims given that there are marked trends regarding wages and benefits by industry [13] and that demographic and socioeconomic trends within occupational safety and health risk often vary together by industry [14]. Factors that shape likelihood to participate in an OHP intervention, such as individual factors, structural conditions, or sociocultural context, can also vary by industry [14]. In other words, industry reflects a point of intersection of multiple individual and group identities including both occupational and cultural factors with meaningful implications for health and safety equity, occupational risk factors, and employee intentions related to safety and health. A more purposeful inclusion of industry context into our research could help OHP understand shared experiences of contemporary constructs within groups of employees, such as within an industry. As these contemporary topics become more important in the future of work [1], we assert that now is the ideal time to address an absence of industry context to better equip OHP researchers and practitioners to respond to the complexities of the changing nature of work and extend the positive implications of OHP to often overlooked or disadvantaged groups.

Surprisingly, despite the presence of industry context within national classification and surveillance systems, the current state of the OHP literature tends not to incorporate a strategic focus on the contextual variable of industry. Our research typically relies on methodologies that collect information from participants, generally working adults in OHP research [15]. Although a methods section will often contain a description of contextual factors associated with data collection, such as the industry to which participants belonged, industry is rarely studied as a central element of the research. A study sample containing one or a few industries can often be viewed as a narrow or atypical sample of convenience in field-based survey research (e.g., refer to Landers & Behrend [16] for helpful recommendations on considering the potential implications associated with single industry samples, such as possible range restriction).

The absence of industry context can be observed in both conceptual/theoretical work and empirical studies within OHP. We reviewed four conceptual models or frameworks on determinants and outcomes of work safety, health, and well-being [7,17–19]. Central constructs in each model largely focused on the individual level (e.g., personal resources as

determinants; stress and physical health as outcomes) and organizational level (e.g., work environment and work practices as determinants; reduced absenteeism and turnover as outcomes). Only the World Health Organization Healthy Workplace Framework named factors existing outside of the organization, such as enterprise involvement with the community. This category of variables focuses on the efforts made by an organization to follow regulatory mandates in ways that cause no harm to the broader community or assist the community in addressing social issues [7]. The WHO Healthy Workplace Framework also explicitly states that their conceptual model is not a one-size fits all solution and that the realization of a healthy workplace will look different from industry to industry [7]. Given this important point, there is an opportunity to increase the presence of industry-relevant constructs in theoretical frameworks that identify the determinants and outcomes of employee safety, health, or well-being in OHP.

Given that our field prioritizes the building of theory [20] it stands to reason that an absence of industry context in theory would translate to a large proportion of industry-agnostic empirical studies in the OHP literature. To confirm this, we borrowed from content analysis methods of previous attempts to characterize the features of the OHP literature [15]. Specifically, we reviewed work-related articles published in the *Journal of Occupational Health Psychology* and *Stress & Health* from the previous five years (372 articles) and found that 74.5% of articles made no mention of industry, 10% incorporated industry into methodology (meaning that they considered how industry could influence the effectiveness of study design or measures, potentially adapting methods accordingly), 10% incorporated industry into the discussion section, and 4% focused their study on phenomena within a specific industry. Only two articles (0.5%) incorporated the features of an industry into their research question. For example, one study [21] examined the industry-related context of training in nursing and how it might influence an occupational health intervention. In another example, a study on posttraumatic stress among police officers incorporated contextual variables related to the public safety industry into research questions, such as the industry tenure and number of case reports [22]. Based on this cursory characterization of recent OHP literature, industry context is indeed underrepresented in the current state of the OHP literature.

We argue that it is imperative to account for industry context as OSH literature evolves to address future of work challenges. The below sections demonstrate how industry context is particularly relevant for occupational health, safety, and well-being in the future of work. First, we describe the OSH challenges associated with the changes in the workplace, the workforce, and work itself. We then provide examples, drawing specifically from the hospitality industry, of when a future of work challenge necessitates an industry-informed solution as opposed to a solution developed in a broad manner to apply to the general workforce.

3. Future of Work Challenges and Solutions in Context

There is general agreement that we are entering a future of work and workplaces that is fundamentally different from work and workplaces of the past several decades [23]. Although these changes are in many regards connected to the rapid rise in technological capabilities, there are also larger questions about the nature, design, and management of work as well as questions about government policy (e.g., policy regarding artificial intelligence (AI), labor market policies) and work-relevant societal issues such as climate change [1,24,25]. Within the field of occupational health, there is a sense that efforts should be made to both (a) try to predict trends in order to better adapt to them and (b) try to intervene, direct, or utilize trends in order to promote safer and healthier work [24–26].

Tamers and colleagues [1] provided a useful roadmap of future of work topics with relevance to occupational safety and health. They organized subtopics in terms of relevance to the future workplace, future work, and future workforce. Workplace issues concern the design of organizational policies and practices (e.g., sick leave), as well as organizational structure. For example, one major concern is the rise of precarious work, driven by

increasing job insecurity and the growing use of "arms-length" employment contracts such as temporary, contingent, contract, agency, seasonal, and gig work [27–29]. These precarious work experiences are associated with poorer health and health inequalities as well as accidents [30–32]. Other workplace issues involve the impact of automation on job displacement, design, and quality [12]. Work issues concern changes in work itself, which captures for example, the greater use of AI and other emerging technologies (e.g., 3D printing, exoskeletons) [24]. Finally, workforce issues related to the future of work capture topics such as productive aging, worker financial security, and worker skills.

Although organized in separate "buckets," Tamers and colleagues [1] emphasize that these issues are interconnected and impact each other. For example, worker re-skilling has been discussed as a potential solution to occupational polarization and job displacement due to AI. At the same time, AI and other emerging technologies have been discussed as both threats and opportunities for organizational design and workforce resilience, depending on how they are used. On the upside, AI can enhance the capabilities for real-time workplace monitoring and adjustment for health exposures and accident risks, as well as free workers from tasks that are monotonous or boring [25,32]. On the downside, AI may replace work or jobs, threaten occupational identities, result in further polarization of work quality, and create distrust through surveillance and opaque decision-making [33,34].

This idea that the future of workplace, work, and workforce decisions can have good or bad implications for occupational health and safety also necessitates and points to the value of a context-specific approach to the future of work. Indeed, Tamers and colleagues [1] note this by pointing out that contextual factors such as disasters, politics, and globalization form the backdrop of the future of work and are expected to have pervasive impacts on future workplace, work, and workforce issues. The COVID-19 pandemic and its ensuing work-related changes and challenges, as well as recent AI legislation by the European Union, provide salient examples of how the macro-context is acting to shape the future of work [35–37].

To address OSH challenges, particularly those related to the complexities of the future of work, will require a balance of breadth and depth in solutions. An example can be found in the intervention-focused research priorities described in the National Occupational Research Agenda (NORA). Although there is a need to study cross-cutting issues such as work design, the various constraints, opportunities, and needs from each industry will shape the available solutions and the best manner to implement those solutions. Workplace health promotion has documented the need to adapt interventions for a variety of contextual variables, including business size [38] or the proportion of demographic variables (i.e., gender) or job-related variables (i.e., blue collar vs. white collar) that have been shows to correlate with intervention participation [39]. Industry membership shapes experiences of these variables, resulting in barriers to or facilitators for intervention participation [14], and therefore interventions will likely benefit from a proactive consideration of industry context.

In as much as industry is relevant to explain current occupational health and safety issues, it is also a critical lens to apply to future of work issues. For instance, it is likely that disruption due to automation will not be felt equally across industries, and emerging technologies are likely to be implemented and received in different ways depending on industry context. Likewise, solutions to work design issues (e.g., burnout and stress prevention) are likely to be very different when one is dealing with an industry with a large proportion of contingent or agency workers versus an industry where most employment tends to be permanent, full-time. Industries also likely have different opportunities and constraints that may shape how they implement emerging solutions to occupational health and safety challenges. For example, while exoskeletons may be more accepted by the public and workers in nursing or construction, they are unlikely to be accepted in certain core roles in hospitality and entertainment, such as guest-facing roles. As research on AI has demonstrated, occupational identity is critical to how workers react and whether they utilize these systems [40,41]. Even similar OSH solutions may need to look different across

different industries. For instance, supply delivery robots may need to operate differently in the hospitality sector where new guests and seasonal staff will interact with the robots than in the healthcare sector where the staff is relatively constant, and robots may not need to interact with the public. The expectations for what these robots look like and how they function is also likely to be quite different across industries. In the following sections, we introduce the hospitality context as one example of how an industry context can better help understand, predict, and intervene in the future of occupational health and safety.

4. The Hospitality Industry

The U.S. leisure and hospitality supersector is classified under the service-providing industries supersector, according to the North American Industry Classification System (NAICS) [42]. The Leisure and Hospitality supersector consists of (1) arts, entertainment, and recreation; and (2) accommodation and food services sub-sectors. One of the largest workforce sectors in the U.S. pre-COVID-19, the hospitality industry employed 16.9 million workers in February 2020 [42]. In the post-pandemic workforce environment, the hospitality industry has made steady progress back to what would be considered almost "normal", reaching employment of 15.2 million workers as of July 2021 [42].

The hospitality industry is consumer-centric, and thus, service quality is a point of brand differentiation and competitive advantage. In the hospitality context, services are consumer-facing (visible), and yet also invisible due to the structures and processes unseen which support service interactions. This hospitality industry ecosystem is one with multiple stakeholders at various levels. Often characterized by "front of house" and "back of house" employees, the former are customer-facing, whereas the latter work in human resources, marketing, sales, and other supportive roles. In addition to the distinction between customer-facing and supporting employees, there is also a stratification of those in management. Typically, line-level employees serve customers, while supervisors, managers, and directors in hospitality organizations occupy the managerial strata and support line level workers. Yet, the ultimate stakeholder is the customer, and successful and well-known hospitality organizations, such as the Ritz-Carlton for example, pride themselves on both external (employee–customer) and internal (employee–employee) service quality, illustrated in their brand motto: "We are Ladies and Gentlemen serving Ladies and Gentlemen" [43].

While the accommodation and foodservice sub-sectors are among the top employers in the U.S. historically, they also lead the U.S. workforce in employee turnover. Prior to the pandemic, the U.S. fast food industry reached turnover rates at nearly 130% [44]. Dubbed the "fast-food turnover crisis", many brands moved to systemize jobs and thus adopted customer self-service kiosks in the front of the house, and cooking robots in the back of the house as a business strategy to reduce the costs associated with high turnover [44]. Line-level restaurant jobs have been criticized as severely underpaid, intensifying high turnover trends in the industry. Exacerbated by COVID-19 furloughs and layoffs, resulting from mandated shutdowns and stay-at-home orders, the U.S. restaurant industry has struggled to recruit workers as a consequence of not paying workers a fair wage historically, and due to poor treatment during the layoff period [45]. Even though the hospitality industry recovered to report 40% of the total job gains in June 2021, restaurants still face a labor shortage [45] despite adding benefits and increasing wages of up to USD 15 per hour [46]. The U.S. hotel industry also faces similar labor shortages as a result of poor wages and lack of benefits, aggravated by COVID-19 concerns around health and safety, customer mistreatment, and excessive work hours due to co-worker absenteeism or labor shortages [47].

Pressures in the hospitality industry to "get back to normal" compound post-pandemic labor shortages. Those workers who have returned are often income insecure and minority workers who have few options to earn an income, and thus disproportionately suffer from post-pandemic socioeconomic and health disparities [48]. Hotel workers, including housekeepers, laundresses, front desk agents, waiters/waitresses and kitchen workers, are

subjected to a variety of physical, biological, chemical, and environmental hazards while on the job [49]. Time pressures to serve the customer, long and irregular hours, exposures to chemical and biological toxins, and work-home conflicts, are all hazards encountered by line-level hotel employees [48,50,51]. Workers in the restaurant and foodservice industry experience similar mental and physical strains on their health and safety, contributing to allostatic load [48]. Chronic and acute work stress experienced by hospitality workers, coupled with their special circumstances around income insecurity, are contributing factors to a variety of health issues and diseases, magnified by the effects of the COVID-19 pandemic [52].

Until recently, the hospitality industry has not placed a high priority on employee health and wellness, aside from those wellness initiatives which generate a rapid return on investment [51]. This is due, in part, to resource allocation associated with thin profit margins, in which a misinformed rationale has undermined justification for employee wellness on its own merits [53,54]. Collectively, the U.S. hospitality industry is facing increasing uncertainties about its labor force in a time of heightened awareness around fair wages and forecasted increasing consumer demand [47]. In the short-term, the hospitality industry may continue to offer higher living wages; however, a more holistic approach would be to offer healthcare, childcare, fertility assistance, tuition reimbursement, career training and development, housing, flexible work schedules, etc. Until the hospitality industry can make substantial progress on much-needed structural changes, the workforce will be hesitant to return. If the current trend continues, workers will continue to seek out employment in other service-related industries, such as in digital sales, shipping, healthcare, and senior living [55]. In the meantime, industry leaders have become increasingly reliant on automation, AI, and other technological solutions to meet the post-COVID-19 consumer demand [56]. With a foundational knowledge of the defining characteristics of the hospitality industry, we will now describe challenges or solutions related to the future of work, both outside of and within the context of the hospitality industry.

5. General Future of Work Challenges and Solutions in the Hospitality Context

As noted above, the central thesis of this paper is that as researchers and practitioners respond to the need to align research and interventions to the changing nature of work, they should consider the addition of a meaningful focus on contextual variables (such as industry) as a component of this evolution. We offer two illustrations to describe how future of work-related OSH interventions need to consider industry context. We describe two occupational safety and health challenges created or influenced by future of work trends and their solutions according to broadly-based OHP literature. Specifically, we discuss the challenge of technological job displacement (along with the associated solution of reskilling) and the challenge of increased work-family conflict (and the associated solution of work-family programming). We then describe features within our example industry, the hospitality industry, that would significantly hinder the effectiveness of each solution. Finally, we offer suggestions for a tailored solution that incorporates industry context.

5.1. Technological Job Displacement

Anecdotal reports have suggested that by 2025, 85 million jobs will be disrupted globally due to what is known as the "next wave of automation", largely induced by the pandemic [56] and further spurred by decreasing costs in automation technologies [57]. Yet, scholars in this area offer a different point of view, based on targeted "right" types of technological advancements in the workplace, which hold promise for potentially better social and economic outcomes [58]. The latter argues for new types of jobs or re-skilling due to a technological paradigm shift in the workplace [59]. Regardless, the "changing workplace" category of the future of work paradigm carries the likelihood of "significant downstream effects" including the polarization of skills levels and the threat to middle-skill jobs [1]. The occupational safety and health challenges associated with technological job displacement are clear, as long-term economic and career related outcomes have been noted

following job displacement [60]. Related to the economic impacts, job displacement could result in the disruption of benefits needed to maintain health, such as medical insurance, possibly explaining the link between job displacement and mortality [61]. A traditional, broadly-based solution to the future of work challenge of technological job displacement is the reskilling of workers whose medium-skilled jobs will disappear with the goal of making them competitive for a different, higher-skill job [62].

The trend of technological job displacement is present within the hospitality industry but associated with a few contextual nuances. For example, the U.S. hotel industry has not only adopted self-serve kiosks for check-ins, smart device integrations for payment and room key, and service robots for small deliveries, but the industry has also taken the additional step of structurally and architecturally designing hotels for an end-to-end technological experience [57].

In an industry highly dependent on the service experience, critics have called into question the capability of a fully implemented technological guest experience. Moreover, concerns have grown regarding worker displacement and the need for reskilling the hospitality workforce to either work with, or manage, service robots and technologies. Advocates for using more and greater technological resources in the hospitality industry include contactless options for payment and service for health and safety purposes, and increased efficiency and productivity in the wake of high turnover and low recruitment. However, researchers have posited that a hybrid approach to adopting robot technologies in the hospitality service environment has proven to be simultaneously advantageous for both customers and employees, underscoring the special considerations under multiple stakeholders in the industry [63]. For example, service robots and other AI technology could be deployed for highly automated tasks (i.e., vacuuming, delivering items to rooms, accepting payment), thus freeing hospitality employees to serve customers in ways that are more personally and occupationally fulfilling. As service quality is a tenet of the hospitality industry and a focal point of differentiation and competitive advantage, a shift to reskill workers to manage service robots and related technologies for repetitive tasks, will allow the hybrid approach to direct what resources remain after the pandemic, to focus on guest service quality.

These industry-specific trends do not align well with the more generalized, and somewhat anecdotal, prediction [59] of the disappearance of medium skill jobs and the use of reskilling interventions to target advancement to different, high-skill jobs [1]. Within the hospitality industry, tailored solutions exist, such as the hybridized reskilling approach, that better represent the predicted stability of the need for person-delivered service alongside advancing technologies. Several recommendations have been made in observance of reskilling employees to integrate advanced technology into medium-skill service roles and include the potential for hiring hardware and software specialists, training employees to manage teams of robots, and the reorganization of departments with a focus on services and marketing integrations for the use of robots [64]. Anecdotal industry reports advocate for the use of robots as a supplement to human workers, rather than a replacement [65]. Targeting the use of robots and other AI technologies for low-level repetitive tasks enable hospitality employees to work safely and more efficiently while focusing on their primary stakeholder, the guest, to deliver on the service promise. In other words, an industry-informed solution involves reskilling to work in the same job alongside technology, ideally using technology to take over dangerous or repetitive tasks, as opposed to the broadly-based solution that proposes reskilling with a completely different job in mind.

5.2. Work-Family Programming

Within discussions of the changing nature of work, trends in both the "workplace" and the "workforce" highlight the growing challenges of work-life balance. This is influenced by multiple future of work trends, as increasing rates of remote work blur the physical boundaries between work and home life and more equitable rates of labor force participation bring work-family challenges for dual-earner families [1]. Poor work-life

balance is indeed an occupational health and safety challenge, as it is associated with psychological and behavioral strain [66]. Work–family programming represents a systemic organizational solution to this future of work challenge, and typically includes paid leave benefits (i.e., parental leave), resources dedicated to the management of family demands (i.e., employer-sponsored childcare), education for supervisors regarding the best ways to support work-life balance for their subordinates, and flexible work arrangements such as self-scheduling [1].

The future of work challenge of work-family conflict is relevant to the hospitality industry, yet the drivers are distinct. Rather than increases in remote work, factors such as "irregular hours, emphasis on face time, frequent relocation," [67] low job security, and job tasks that require a high degree of coordination between shifts [68] contribute to work-family issues among hospitality employees. In fact, those in the service industries report worse work-life balance than employees who belong to other industries, even after controlling for work hours [69].

Similar to the generalized solutions mentioned above, successful programming to alleviate work-family conflict in the hospitality industry includes the presence of paid leave benefits, visible work-life balance behaviors from senior management, and the presence of resources such as childcare [70]. However, it is worth noting that these programs have historically focused on the retention of highly educated hospitality employees [70]. It seems that trends regarding benefits coverage in the hospitality trend may not have dramatically changed recently, as 2021 data reports that the average hospitality employee receives benefits that value USD3.10 per every hour worked [42], while the national average is USD 12.18 per hour worked [71]. These generalized solutions to work-family issues, when implemented alone, could ignore the needs of a larger proportion of the hospitality industry, specifically front-line service workers or contract workers in positions that do not typically receive comprehensive benefits. Thus, these examples illustrate a gap where effective broadly developed future of work solutions may not be applicable to all industry contexts, and where the context of implementation must be carefully considered.

In contrast, hospitality organizations have successfully implemented programs that are not typically mentioned in traditional work-family programming for the general workforce, such as job sharing to promote work-life balance [70]. In addition, although realistic job previews (RJPs) are discussed as a general best practice across workplaces, hospitality researchers have noted the increased importance of RJPs specifically geared towards the work-life context (i.e., previewing hours and scheduling to help workers proactively anticipate potential work-life issues) in the hospitality industry. That is, while RJPs can be broadly considered a turnover-reducing measure, in the hospitality industry they are regarded as an intervention related to both turnover and work-family conflict [70]. In these cases, the uses of job sharing and RJPs to specifically target work-life issues acknowledge the realities of the hospitality industry. Hotels are open 24 h per day, including all holidays when the general public does not work, and consumer demand peaks when many other industries' business hours wane [70]. Were more generalized solutions to work-family conflict be implemented in the hospitality industry in these instances, those initiatives would likely not account for these constraints.

6. Moving towards a Context-Informed Future of Work

The paper addresses timely and important topics, with illustrative examples presented from an industry that is a priority for safety and health research and practice. However, we must also acknowledge that the conclusions in this paper could be limited by the scope of the content analysis performed and that the two illustrative examples presented may not represent every opportunity for industry-informed solutions. The ideas discussed in this paper have implications for both research and practice in OHP and broader OSH disciplines. From a research perspective, to bridge the gap between the current industry agnostic OHP literature and a future body of literature that intentionally incorporates industry context to address the changing nature of work challenges and solutions, it is

important to identify potential facilitators of this shift. We assert that further attention to the differences between multidisciplinary, interdisciplinary, and transdisciplinary collaboration structures will be an important facilitator. Multidisciplinary research draws from multiple disciplines, interdisciplinary work is associated with interaction across disciplines (i.e., working in parallel), and transdisciplinary research transcends traditional disciplinary boundaries with each discipline informing the approaches, methods, and theories of the other [9]. We assert that as OSH-informing disciplines evolve to address the future of work, it is important that each discipline strike a balance of breadth and depth in their understanding of challenges and solutions.

While tremendous progress has been made in bringing research out of disciplinary silos, we believe that a transdisciplinary collaboration structure, with a greater degree of disciplinary integration in which each discipline actively informs the other through collaborative research, would facilitate the systematic study of context. A transdisciplinary team might develop more comprehensive and impactful research, weaving together both generalized work-related phenomena and the way industry context shapes a worker's experience of this phenomenon, with benefits for richer theory and research across OSH disciplines.

In addition to these existing facilitating trends, we encourage OHP researchers to promote other conditions that may pave a way for more industry-informed research. For example, journal editors and reviewers may develop criteria to help facilitate a more frequent consideration of context. Whereas prestigious journals evaluate submissions based on theoretical and empirical contributions, an author could also craft a compelling argument for how context impacts theories, empirical findings, and practice. Similarly, extramural funding agencies could emphasize criteria for reviewers that assess both the generalized and context-specific features of a proposal and encourage transdisciplinary teams and proposed deliverables that are likely to promote shared knowledge across disciplines rather than outlets in disciplinary silos. Facilitators of context could be developed in more localized settings as well. Universities tend to regard collaborations with community partners as mutually beneficial [72], and as such could develop criteria for tenure and promotion committees or performance evaluators that weight a strong publication with contributions related to industry context on the similar level as a publication with more generalized contributions. Incorporating these facilitators into publication, funding, and evaluation systems will work to create an incentive structure that encourages contributions in both broad and specific domains.

In terms of implications for practice, recent reviews of international OSH trends reveal that ensuring global consistency in industry-contextualized regulation of work hazards should be a major priority. Workplace safety regulations only cover about 10% of hazardous industries in developing countries worldwide, and variation in regulations by industry and geographic region present a challenge for the protection of workers [73]. These authors also advocated for more frequent "inter—collaborations of external industries" in practice to protect worker safety [73]. Thus, although this paper presents a primarily U.S.-centric view of industry for the purposes of this Special Issue, there clearly value in ensuring widespread attention to industry context in practice.

Adding to the implications for both research and practice, we also argue that a continued focus on research-to-practice will facilitate greater attention to industry. As the OHP literature develops a more comprehensive portfolio of interventions to address safety and health concerns in the workplace [74], there will likely also be an increase in the need to replicate a successful intervention in another context, such as another industry. Studies that document the intervention adaptation process describe the steps by which and intervention is systematically modified to increase fit in a new context and evaluate its effectiveness [75]. Summaries of the practice of intervention adaptation recognize that an intervention represents a new event occurring within the pre-existing context of a system, and the intervention may need to be modified on geographic or sociocultural principles to promote transferability [76] or the available resources and competing demands of an organization or industry [77,78]. Strong academic–partitioner partnerships could facilitate the

more widespread use of this practice by allowing researchers to select evidence-based intervention and refer to practitioner guidance for modification in the local context; however, more research is needed on industry-related factors that could necessitate modification.

7. Conclusions

Across OSH-informing disciplines, norms vary to the extent of incorporating industry as meaningful context when studying or improving workplace safety, health, and well-being. As OSH is pivoting to address the complexities of the changing nature of the workplace, workforce, and work itself, now is an appropriate time to better understand the role of industry in OSH research and practice, especially in OSH disciplines that have not typically considered industry. As illustrated by our selected examples of future of work challenges and solutions within the hospitality industry, OSH necessitates a tailored approach as opposed to a "one-size-fits-every-industry" approach. By better understanding the way industry shapes work tasks and settings, shared values and assumptions, and individual and group identities of contemporary importance, we can ready researchers and practitioners for the future of occupational safety and health with expertise informed by both breadth and depth.

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References

1. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, R.; Guerin, R. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
2. Barling, J.; Griffiths, A. A history of occupational health psychology. In *Handbook of Occupational Health Psychology*; Quick, J.C., Tetrick, L.E., Eds.; American Psychological Association: Washington, DC, USA, 2003; pp. 19–31.
3. National Institute for Occupational Safety and Health (NIOSH). National Occupational Research Agenda (NORA): Sector-Based Approach, n.d. Available online: https://www.cdc.gov/nora/approach.html (accessed on 27 August 2021).
4. Johns, G. In praise of context. *J. Organ. Behav.* **2001**, *22*, 31–42. [CrossRef]
5. Johns, G. The essential impact of context on organizational behavior. *AMR.* **2006**, *31*, 386–408. [CrossRef]
6. Johns, G. Advances in the treatment of context in organizational research. *Annu. Rev. Organ. Psychol. Organ. Behav.* **2018**, *5*, 21–46. [CrossRef]
7. Burton, J.; World Health Organization. *WHO Healthy Workplace Framework and Model: Background and Supporting Literature and Practices*; World Health Organization: Geneva, Switzerland, 2010.
8. Shrestha, N.; Kukkonen-Harjula, K.T.; Verbeek, J.H.; Ijaz, S.; Hermans, V.; Pedisic, Z. Workplace interventions for reducing sitting at work. *Cochrane Database Syst. Rev.* **2016**, *3*, 1–143. [CrossRef] [PubMed]
9. Choi, W.D.; Kelly, T.; Walden, E.; MCCeel, B.; Oboyle, M. Emotional dissonance among frontline hospitality employees. *J. Hosp. Tour.* **2021**, 10963480211011633.
10. Britt, T.W.; McFadden, A.C. *Understanding Mental Health Treatment-Seeking in High Stress Occupations. Contemporary Occupational Health Psychology: Global Perspectives on Research and Practice*; Wiley-Blackwell Publishers: Hoboken, NJ, USA, 2012; Volume 2, pp. 57–73.
11. Szeto, A.; Dobson, K.S.; Knaak, S. The road to mental readiness for first responders: A meta-analysis of program outcomes. *Can. J. Psychiatry* **2019**, *64* (Suppl. S1), 18S–29S. [CrossRef] [PubMed]

12. Houdmont, J.; Leka, S. (Eds.) *CContemporary Occupational Health Psychology: Global Perspectives on Research and Practice*; John Wiley & Sons: West Sussex, UK, 2010.
13. Dyer, B. *Creating Good Jobs: An Industry-Based Strategy*; MIT Press: Cambridge, MA, USA, 2020.
14. Horan, K.A. You, me, and OHP: Applying the Sociocultural Self Model to OHP Interventions. *Occup. Health Sci.* **2021**, *5*, 25–53. [CrossRef]
15. Spector, P.E.; Pindek, S. The future of research methods in work and occupational health psychology. *Appl. Psychol.* **2016**, *65*, 412–431. [CrossRef]
16. Landers, R.N.; Behrend, T.S. An inconvenient truth: Arbitrary distinctions between organizational, Mechanical Turk, and other convenience samples. *Ind. Organ. Psychol.* **2015**, *8*, 142–164. [CrossRef]
17. Danna, K.; Griffin, R.W. Health and well-being in the workplace: A review and synthesis of the literature. *J. Manag.* **1999**, *25*, 357–384. [CrossRef]
18. Grawitch, M.J.; Gottschalk, M.; Munz, D.C. The path to a healthy workplace: A critical review linking healthy workplace practices, employee well-being, and organizational improvements. *Consult. Psych. J. Pract. Res.* **2006**, *58*, 129. [CrossRef]
19. Heaney, C.A. Worksite health interventions: Targets for change and strategies for attaining them. In *Handbook of Occupational Health Psychology*; American Psychological Association: Washington, DC, USA, 2011.
20. Campbell, J.P.; Wilmot, M.P. The functioning of theory in industrial, work and organizational psychology (IWOP). In *The SAGE Handbook of Industrial, Work and Organizational Psychology: Personnel Psychology and Employee Performance*; SAGE Publications Ltd.: Thousand Oaks, CA, USA, 2018; pp. 3–38.
21. Müller, A.; Heiden, B.; Herbig, B.; Poppe, F.; Angerer, P. Improving well-being at work: A randomized controlled intervention based on selection, optimization, and compensation. *J. Occup. Health Psychol.* **2016**, *21*, 169. [CrossRef]
22. Kunst, M.J.; Saan, M.C.; Bollen, L.J.; Kuijpers, K.F. Secondary traumatic stress and secondary posttraumatic growth in a sample of Dutch police family liaison officers. *Stress Health* **2017**, *33*, 570–577. [CrossRef]
23. Hoffman, B.J.; Shoss, M.K.; Wegman, L.A. (Eds.) *The Cambridge Handbook of the Changing Nature of Work*; Cambridge University Press: Cambridge, UK, 2020.
24. Howard, J. Artificial intelligence: Implications for the future of work. *Am. J. Ind. Med.* **2019**, *62*, 917. [CrossRef]
25. Schulte, P.A.; Streit, J.M.; Sheriff, F.; Delclos, G.; Felknor, S.A.; Tamers, S.L.; Fendinger, S.; Grosch, J.; Sala, R. Potential scenarios and hazards in the work of the future: A systematic review of the peer-reviewed and gray literatures. *Ann. Work Expo. Health* **2020**, *64*, 786–816. [CrossRef] [PubMed]
26. European Agency for Safety and Health at Work. Foresight on New and Emerging Occupational Safety and Health Risks Associated with Digitalisation by 2025: European Risk Observatory Report. 2018. Available online: https://osha.europa.eu/en/publications/foresight-new-and-emerging-occupational-safety-and-health-risks-associated/view (accessed on 27 August 2021).
27. Farber, H.S. Short (er) shrift: The decline in worker-firm attachment in the United States. In *Laid off, Laid Low: Political and Economic Consequences of Employment Insecurity*; Columbia University Press: New York City, NY, USA, 2008; pp. 10–37.
28. Hollister, M. Employment stability in the US labor market: Rhetoric versus reality. *Annu. Rev. Sociol.* **2011**, *37*, 305–324. [CrossRef]
29. Kalleberg, A.L. Precarious work, insecure workers: Employment relations in transition. *Am. Sociol. Rev.* **2009**, *74*, 1–22. [CrossRef]
30. Allan, B.A.; Autin, K.L.; Wilkins-Yel, K.G. Precarious work in the 21st century: A psychological perspective. *J. Vocat. Behav.* **2021**, *1*, 103491. [CrossRef]
31. Benach, J.; Vives, A.; Amable, M.; Vanroelen, C.; Tarafa, G.; Muntaner, C. Precarious employment: Understanding an emerging social determinant of health. *Annu. Rev. Pub. Health* **2014**, *35*, 229–253. [CrossRef]
32. Tschang, F.T.; Mezquita, E.A. Artificial intelligence as augmenting automation: Implications for employment. In *Academy of Management Perspectives*; Academy of Management: New York, NY, USA, 2020; pp. 1–41.
33. Raisch, S.; Krakowski, S. Artificial intelligence and management: The automation–augmentation paradox. *Acad. Manag. Rev.* **2021**, *46*, 192–210. [CrossRef]
34. Ravid, D.M.; Tomczak, D.L.; White, J.C.; Behrend, T.S. EPM 20/20: A review, framework, and research agenda for electronic performance monitoring. *J. Manag.* **2020**, *46*, 100–126. [CrossRef]
35. European Commission. Shaping Europe's Digital Future. 2021. Available online: https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence (accessed on 27 August 2021).
36. Rudolph, C.W.; Allan, B.; Clark, M.; Hertel, G.; Hirschi, A.; Kunze, F.; Shockley, K.; Shoss, M.; Sonnentag, S.; Zacher, H. Pandemics: Implications for research and practice in industrial and organizational psychology. *Ind. Organ. Psychol.* **2021**, *14*, 1–35. [CrossRef]
37. Shoss, M. Occupational health psychology research and the COVID-19 pandemic. *J. Occup. Health Psychol.* **2021**, *26*, 259–260. [CrossRef]
38. Eakin, J.M.; Cava, M.; Smith, T.F. From theory to practice: A determinants approach to workplace health promotion in small businesses. *Health Promot. Pract.* **2001**, *2*, 172–181. [CrossRef]
39. Campbell, M.K.; Tessaro, I.; DeVellis, B.; Benedict, S.; Kelsey, K.; Belton, L.; Sanhueza, A. Effects of a tailored health promotion program for female blue-collar workers: Health works for women. *Prev. Med.* **2002**, *34*, 313–323. [CrossRef]
40. Nelson, A.J.; Irwin, J. "Defining what we do—all over again": Occupational identity, technological change, and the librarian/Internet-search relationship. *Acad. Manag. J.* **2014**, *7*, 892–928. [CrossRef]
41. Recht, M.; Bryan, R.N. Artificial intelligence: Threat or boon to radiologists? *J. Am. Coll. Radiol.* **2017**, *14*, 1476–1480. [CrossRef]

42. Bureau of Labor Statistics (BLS). Industries at a Glance: Leisure and Hospitality. 2021. Available online: https://www.bls.gov/iag/tgs/iag70.htm (accessed on 27 August 2021).
43. The Ritz-Carlton. Gold Standards [Online]. 2021. Available online: https://www.ritzcarlton.com/en/about/gold-standards (accessed on 27 August 2021).
44. Rosenbaum, E. Panera Is Losing Nearly 100% of Its Workers Every Year as Fast-Food Turnover Crisis Worsens. CNBC: At Work [Online]. 2019. Available online: https://www.cnbc.com/2019/08/29/fast-food-restaurants-in-america-are-losing-100percent-of-workers-every-year.html (accessed on 27 August 2021).
45. Dean, G. 3 in 4 Independent Restaurants Are Still Struggling to Find Staff, Even as the Hospitality Industry Adds Hundreds of Thousands of Jobs, According to Poll. *Bus. Insider [Online]*. 2021. Available online: https://www.businessinsider.com/labor-shortage-independent-restaurants-staff-worker-small-businesses-2021--7 (accessed on 27 August 2021).
46. Rugaber, C. Desperate for Workers, US Restaurants and Stores Raise Pay. *Ap News [online]*. 2021. Available online: https://apnews.com/article/health-coronavirus-pandemic-business-5eb1432c117e217fea65bfaa138002e9 (accessed on 27 August 2021).
47. Sebastian, D. Staffing Shortages Pose a Threat to Hotels' Budding Recovery: Hotels Say They Are Struggling to Hire Enough Housekeepers, Kitchen Staff and Other Hourly Workers—Including Those Laid off Early in the Pandemic. *Wall Str. J. [Online]*. 2021. Available online: https://www.wsj.com/articles/staffing-shortages-pose-a-threat-to-hotels-budding-recovery-11621339209 (accessed on 27 August 2021).
48. Sönmez, S.; Apostolopoulos, Y.; Lemke, M.K.; Hsieh, Y.C. Understanding the effects of COVID-19 on the health and safety of immigrant hospitality workers in the United States. *Tour. Manag. Perspect.* **2020**, *35*, 100717. [CrossRef]
49. Zhang, T.C.; Torres, E.; Jahromi, M.F. Well on the way: An exploratory study on occupational health in hospitality. *Int. J. Hosp. Manag.* **2020**, *87*, 102382. [CrossRef]
50. Hsieh, Y.C.; Sönmez, S.; Apostolopoulos, Y.; Lemke, M.K. Perceived workplace mistreatment: Case of Latina hotel housekeepers. *Work.* **2017**, *56*, 55–65. [CrossRef]
51. Mejia, C.; Ciarlante, K.; Chheda, K. A wearable technology solution and research agenda for housekeeper safety and health. *Int. J. Contemp. Hosp. Manag.* 2021.
52. Sönmez, S.; Apostolopoulos, Y.; Lemke, M.K.; Hsieh, Y.C.; Karwowski, W. Complexity of occupational health in the hospitality industry: Dynamic simulation modeling to advance immigrant worker health. *Int. J. Hosp. Manag.* **2017**, *67*, 95–105. [CrossRef]
53. Berry, L.L.; Mirabito, A.M.; Baun, W.B. What's the hard return on employee wellness programs? *Harv. Bus. Rev.* **2010**, *88*, 104–112.
54. Solnet, D.; Subramony, M.; Golubovskaya, M.; Snyder, H.; Gray, W.; Liberman, O.; Verma, R. Employee wellness on the frontline: An interactional psychology perspective. *J. Serv. Manag.* 2020. [CrossRef]
55. Haddon, H.; Chen, T.-P.; Weber, L. Customers Are Back at Restaurants And Bars, but Workers Have Moved on: Pandemic Layoffs Pushed Many Employees in Hospitality to Find Jobs in New Growth Area -with Better Pay, Perks, Career Prospects. *The Wall Street Journal [Online]*. 2021. Available online: https://www.wsj.com/articles/customers-are-back-at-restaurants-and-bars-but-workers-have-moved-on-11626168601 (accessed on 27 August 2021).
56. Russo, A. Recession and Automation Changes Our Future of Work, but There Are Jobs Coming, Report Says. *World Econ Forum [Online]*. 2020. Available online: https://www.weforum.org/press/2020/10/recession-and-automation-changes-our-future-of-work-but-there-are-jobs-coming-report-says-52c5162fce/ (accessed on 27 August 2021).
57. Aratani, L. Robots on the Rise as Americans Experience Record Job Losses Amid Pandemic. *The Guardian [Online]*. 2020. Available online: https://www.theguardian.com/technology/2020/nov/27/robots-replacing-jobs-automation-unemployment-us (accessed on 27 August 2021).
58. Acemoglu, D.; Restrepo, P. The wrong kind of AI? Artificial intelligence and the future of labour demand. *Camb. J. Reg. Econ. Soc.* **2020**, *13*, 25–35. [CrossRef]
59. Acemoglu, D.; Restrepo, P. *8. Artificial Intelligence, Automation, and Work*; University of Chicago Press: Chicago, IL, USA, 2019.
60. Brand, J.E. *Enduring Effects of Job Displacement on Career Outcomes*; The University of Wisconsin-Madison: Madison, WI, USA, 2004.
61. Sullivan, D.; Von Wachter, T. Job displacement and mortality: An analysis using administrative data. *Q. J. Econ.* **2009**, *124*, 1265–1306. [CrossRef]
62. Ra, S.; Shrestha, U.; Khatiwada, S.; Yoon, S.W.; Kwon, K. The rise of technology and impact on skills. *Int. J. Train. Res.* **2019**, *17* (Suppl. S1), 26–40. [CrossRef]
63. Ivanov, S.H.; Webster, C. Adoption of Robots, Artificial Intelligence and Service Automation by Travel, Tourism and Hospitality Companies–A Cost-Benefit Analysis. In Proceedings of the International Scientific Conference "Contemporary Tourism—Traditions and innovations", Conference, Sofia University, Sofia, Bulgaria, 19–21 October 2017.
64. Kuo, C.M.; Chen, L.C.; Tseng, C.Y. Investigating an innovative service with hospitality robots. *Int. J. Contemp. Hosp. Manag.* **2017**, *29*, 1305–1321. [CrossRef]
65. Price, E.; Parker, A.J. Robots Recharging the Restaurant and Hotel Industries. *4 Hotel [Online]*. 2021. Available online: https://www.4hoteliers.com/features/article/14342 (accessed on 27 August 2021).
66. Frone, M.R.; Russell, M.; Cooper, M.L. Antecedents and outcomes of work-family conflict: Testing a model of the work-family interface. *J. Appl. Psychol.* **1992**, *77*, 65. [CrossRef]
67. Xiao, Q.; O'Neill, J.W. Work-family balance as a potential strategic advantage: A hotel general manager perspective. *J. Hosp. Tour. Res.* **2010**, *34*, 415–439. [CrossRef]

68. Blomme, R.J.; Van Rheede, A.; Tromp, D.M. Work-family conflict as a cause for turnover intentions in the hospitality industry. *Tour. Hosp. Res.* **2010**, *10*, 269–285. [CrossRef]
69. Pocock, B.; Skinner, N.; Pisaniello, S.L. How much should we work? Working hours, holidays and working life: The participation challenge. In *Adelaide: Centre for Work + Life*; University of South Australia: Adelaide, Australia, 2010.
70. Kidd, J.; Eller, C. Work life balance and work-family conflict in the hospitality industry: What do we know in 2012. In Proceedings of the Asia Pacific Coincil on Hotel, Restaurant and Institutional Education, Conference Manila, Philippines, 5 June 2012.
71. Bureau of Labor Statistics (BLS). Employer Costs for Employee Compensation–March 2021. Available online: https://www.bls.gov/news.release/pdf/ecec.pdf (accessed on 27 August 2021).
72. Percy, S.L.; Zimpher, N.L.; Brukardt, M.J.E. *Creating a New Kind of University: Institutionalizing Community-University Engagement*; Anker Publishing Company: Bolton, MA, USA, 2006.
73. Jilcha, K.; Kitaw, D. A literature review on global occupational safety and health practice & accidents severity. *Int. J. Qual. Res.* **2016**, *1*, 10.
74. Beehr, T.A. Interventions in occupational health psychology. *J. Occup. Health Psychol.* **2019**, *24*, 1. [CrossRef] [PubMed]
75. Chambers, D.A.; Norton, W.E. The adaptome: Advancing the science of intervention adaptation. *Am. J. Prev. Med.* **2016**, *51*, S124–S131. [CrossRef] [PubMed]
76. Evans, R.E.; Craig, P.; Hoddinott, P.; Littlecott, H.; Moore, L.; Murphy, S.; O'Cathain, A.; Pfadenhauer, L.; Rehfuess, E.; Segrott, J.; et al. When and How Do 'Effective'interventions Need to Be Adapted and/or Re-Evaluated in New Contexts? *The Need for Guidance.* Available online: https://jech.bmj.com/content/73/6/481.abstract (accessed on 27 August 2021).
77. Escoffery, C.; Lebow-Skelley, E.; Udelson, H.; Böing, E.A.; Wood, R.; Fernandez, M.E.; Mullen, P.D. A scoping study of frameworks for adapting public health evidence-based interventions. *Transl. Behav. Med.* **2019**, *9*, 1–10. [CrossRef]
78. McKleroy, V.S.; Galbraith, J.S.; Cummings, B.; Jones, P.; Harshbarger, C.; Collins, C.; Gelaude, D.; Carey, J.W.; ADAPT Team. *Adapting Evidence–Based Behavioral Interventions for New Settings and Target Populations*; AIDS Education & Prevention: New York, NY, USA, 2006; Volume 18, pp. 59–73.

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Commentary

Dissemination and Implementation Science Approaches for Occupational Safety and Health Research: Implications for Advancing Total Worker Health

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Abstract: Total Worker Health® (TWH), an initiative of the U.S. National Institute for Occupational Safety and Health, is defined as policies, programs, and practices that integrate protection from work-related health and safety hazards by promoting efforts that advance worker well-being. Interventions that apply the TWH paradigm improve workplace health more rapidly than wellness programs alone. Evidence of the barriers and facilitators to the adoption, implementation, and long-term maintenance of TWH programs is limited. Dissemination and implementation (D&I) science, the study of methods and strategies for bridging the gap between public health research and practice, can help address these system-, setting-, and worker-level factors to increase the uptake, impact, and sustainment of TWH activities. The purpose of this paper is to draw upon a synthesis of existing D&I science literature to provide TWH researchers and practitioners with: (1) an overview of D&I science; (2) a plain language explanation of key concepts in D&I science; (3) a case study example of moving a TWH intervention down the research-to-practice pipeline; and (4) a discussion of future opportunities for conducting D&I science in complex and dynamic workplace settings to increase worker safety, health, and well-being.

Keywords: dissemination and implementation science; Total Worker Health; translational science; occupational safety and health; evidence-based interventions; health equity

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1. Introduction

The Total Worker Health® (TWH) approach from the National Institute for Occupational Safety and Health (NIOSH), part of the U.S. Centers for Disease Control and Prevention (CDC), first arose in 2003. TWH is defined as policies, programs, and practices that integrate protection from work-related safety and health hazards by promoting efforts to advance worker well-being [1,2]. Interventions with a TWH focus have been demonstrated to improve workplace health effectively and more rapidly than wellness programs alone [3,4]. For example, the Wellworks-2 intervention integrated an occupational safety

and health (OSH) program targeted at reducing workplace exposure hazards with a health promotion (HP) program to reduce tobacco consumption and increase healthy eating [3,5]. Results from a randomized controlled trial of Wellworks-2 demonstrated, among a number of outcomes, significantly greater smoking quit rates and reduced hazardous substance exposure ratings than an HP-only program did [3,5]. Although TWH efforts and activities have increased in recent years and have generated both national and international attention and interest [2], TWH is still an emerging area with minimal research addressing interventions appropriate to the changing nature of work in the United States and worldwide. Complex OSH challenges—including large-scale public health crises such as the COVID-19 pandemic, the rise of globalization, automation, demographic shifts, increased psychosocial hazards (including high job demands, work-related fatigue, and job stress), and the interaction of work and nonwork factors [6]—require wider and faster adoption of TWH approaches that benefit workers, employers, and society [7].

To increase the impact (including representative reach to diverse worker populations), effectiveness, and integration (including the adoption, implementation, and maintenance [8,9]) of TWH activities, systematic approaches are needed to shed light on the complex processes involved in moving evidence-based TWH interventions into sustained practice [2,3,10–12]. Systematic and other reviews acknowledge the need for dissemination and implementation (D&I) science—defined as the study of methods and strategies for bridging the gap between public health research and practice [13]—to advance the TWH field. For example, Punnett and colleagues [12] suggest that D&I science can be utilized in TWH investigations to characterize factors affecting TWH program uptake, successful implementation, scale-up, and sustainment. Furthermore, Anger and colleagues [3] call for research in D&I science to "determine what works", and what should therefore be included in future TWH research agendas. D&I science inquiry can be expanded not only to explain the important question of "what works", but also to address key contextual issues such as what works, for whom, how, in what settings, and how it is sustained over time [14].

A helpful, plain language tool from Curran [15] to describe key, D&I concepts posits that:

- The intervention is THE THING;
- Effectiveness research looks at whether THE THING works;
- Implementation research looks at how best to help people (e.g., employers and workers)/(work)places DO THE THING;
- Implementation strategies are the stuff researchers do to try to help people/(work) places DO THE THING as designed/intended (i.e., with fidelity), such as provide training, technical assistance, and/or incentives;
- Main implementation outcomes are HOW MUCH and HOW WELL they DO THE THING.

Missing from the Curran definition is another critical consideration, and that is related to the context of the intervention. As mentioned above, context asks the question when, where, how, with whom, under what circumstances, and why does "the thing" work? [9,14,16,17]. Contextual factors identified in TWH studies include: (1) the legal–regulatory environment (e.g., state laws with respect to union representation); (2) employer characteristics, policies, or benefits (e.g., availability of health insurance coverage or paid sick leave); (3) work organization (e.g., shift work); and (4) social or economic factors (e.g., income or availability of community resources to support or promote health) [18]. Given the variety of contexts in which the TWH model can be implemented and studied—with variation in employers, work environments, and workers—understanding the factors that influence the effectiveness of integrated interventions is important. Currently, there is a gap in the TWH research in this area [10].

In sum, applications of D&I science hold promise for addressing major OSH challenges, [19,20] including those addressed through the TWH paradigm. More investment in resources tailored to meet the needs of TWH researchers are required to build capacity in D&I science theories, models, frameworks [21–24], designs, methods [25,26], and pragmatic measures [27,28] for conducting rigorous D&I studies.

The purpose of this paper is to draw upon the D&I literature to provide TWH researchers and practitioners with: (1) an overview of D&I science; (2) a plain language explanation of key concepts in D&I; (3) a case study example of moving a TWH intervention down the reseach-to-practice pipeline; and (4) future opportunites for D&I science in TWH. As more scientific knowledge has been generated to date about the methods that successfully promote implementation as compared to those that advance dissemination, the approaches discussed in this article are most relevant to the successful implementation of TWH programs. This paper fills several gaps in the TWH literature by providing an accessible overview of D&I science through a synthesis of key literature and proposing ideas for leveraging D&I to advance TWH in U.S. and global workpalces.

2. What Is D&I Science? A Brief Overview for TWH Researchers and Practitioners

Across many fields, the science of the systematic implementation of evidence-based interventions—broadly defined as the "7 Ps": programs, practices, principles, procedures, products, pills, and policies [25]—lags behind the science of developing the interventions themselves [29]. Many overlapping factors related to the characteristics of interventions (e.g., high cost or poor fit with stakeholder needs), the settings where programs are implemented (e.g., resource constraints, lack of regulatory/policy support), and the characteristics of recipients (e.g., lack of buy-in for the program) lead to limited uptake, implementation, and sustained use of these programs [30,31]. In OSH specifically, this research-to-practice lag has substantial implications for the health, safety, and well-being of the global workforce [20].

D&I science is a growing field of study that examines the processes by which scientific evidence is adopted, implemented, and sustained in community or clinical settings [13,30]. Although a relatively new and transdisciplinary field of study, D&I has a strong historical foundation [30,31]. The field is concerned with changing systems by understanding context, leveraging an established evidence base, documenting outcomes, and characterizing the underlying mechanisms of change so that positive results can be replicated in other community-based and especially low-resource settings [30,32].

Other key characteristics and implications of D&I science, adapted from Glasgow and Chambers [33], with tailored considerations for TWH researchers are presented in Table 1.

Table 1. Considerations for the use of D&I science approaches for rigorous, rapid, and relevant TWH initiatives (adapted from Glasgow and Chambers [12]).

Characteristics	Implications	TWH Considerations
Systems Perspective		
Context is critical	Research should focus on and describe context	What are the key circumstances and factors within and outside of the workplace that influence the uptake, implementation, and sustained use of TWH programs?
Multilevel complexity needs to be considered	Most problems and interventions are dynamic, multilevel, and complex	What levels of influence (policy/regulatory, community, organizational, managers/supervisors, worksite/team, and individual workers) are addressed?
Focus on systems characteristics	More emphasis needed on interrelationships among system elements and system rules	Were there specific resources, values, or missions that drove the success or hindrance of the TWH effort? Are there unintended consequences?
Robust, Practical Goals		
Representativeness and reach	Focus on reaching broader segments of the population and those most in need	Of the eligible workers, who participated? What recruitment efforts could be made for more equity and inclusion?
Generalizability	Study generalization and replication (or lack of such) across workplace settings	What efforts are made to ensure the TWH intervention can be scaled to other settings and delivered by other staff?
Pragmatic and practical	Producing answers to specific questions relevant to stakeholders at reasonable costs	What needs assessments were conducted? How is the fit of the TWH effort with stakeholder needs measured/assessed? Are the costs realistic/feasible?

Table 1. *Cont.*

Characteristics	Implications	TWH Considerations
Scalability and sustainability	From the outset, a greater focus on scale-up potential and likelihood of sustainability (designing for dissemination and sustainment [34])	What are the startup and sustainability resources and costs the setting will need to consider for full institutionalization? What adaptations will need to be made (iteratively) to support continued use of the TWH program and scale-up to other setting/systems?
Research Methods to Enhance Relevance		
Rigorous	Identifying and addressing plausible threats to validity in context of questions and a greater focus on replication	What is the best research design to answer the specific TWH question? What are the details necessary for replication?
Rapid	Approaches that produce faster answers	What is the current translational lag time? In what ways are research efforts speeding up that process?
Adaptive	The best solutions usually evolve over time, as a result of informed hypotheses and iterative mini-tests with feedback	What are the core elements of the TWH effort (things that cannot change) and what things need iterative assessment? How are these core components communicated to those external to the team? How much guidance is provided for adaptation to local context?
Integration of methods; triangulation	For greater understanding, integrated quantitative and qualitative methods are often required	Who and what experiences in the TWH effort need to be captured to understand the richer context and outcomes? What are the best methods for this?
Relevant	Relevance to stakeholders should be a top priority	Do stakeholders find the TWH effort a high priority, feasible, acceptable, and appropriate? What are strategic ways to obtain unbiased responses?
Equitable	All stakeholders and relevant community sectors are represented and engaged	Does the intervention advance/support occupational health equity? Are hard-to-reach and hardly reached worker groups engaged? Are program outcomes equitable? Can the intervention be conducted in settings frequented by and serving disadvantaged populations? Does it unintentionally enhance OSH disparities?
Respect for diverse approaches; humility	Different perspectives, goals, methods and approaches are needed. Continuing the same existing approaches will produce the same unsatisfactory results	What about the research is novel, comprehensive, and holistic? How is this communicated to various stakeholders? Are multiple disciplines involved?

Another useful concept from Brownson and colleagues [34] is referred to as designing for dissemination, implementation, and sustainment (D4DIS). D4DIS is a process to ensure that the products of research (such as new technologies, training, and health communication messages) are developed with the needs, resources, and time frames of the target audience in mind. It is believed that these efforts will increase the dissemination, implementation, and sustainment potential of programs in real-world settings. Practical tools exist for helping researchers to plan D4DIS and engage stakeholders in these efforts (see, for example, [35] and https://dicemethods.com/tool, accessed on 13 October 2021).

In summary, D&I science approaches can be used to systematically address the research-to-practice lag by actively engaging stakeholders in the design of interventions that fit the changing context and needs of end users—such as the economic climate when implementing a TWH program [36]—and examining the processes by which these interventions are adopted, implemented, and sustained in workplaces [30].

Translational Science vs. D&I Science: Where Do They Overlap?

The proliferation of terminology to describe D&I activities has been explored extensively in the literature [37]. In the international OSH field, the terms knowledge translation, knowledge transfer, and knowledge transfer and exchange have been used [19,37–41] to describe similar or synonomous processes. At NIOSH [20,42], and in the context of TWH [11], the term translation(al) research is used, and while overlapping with the term D&I, it has important differences, as described below.

Translational science has been defined as, "the field of investigation which seeks to understand the scientific and operational principles underlying each step of the transla-

tional process" [43] (p. 456). As Fort et al. [44] state succinctly, translational research takes scientific discoveries "from the bench to the bedside and back again". Or perhaps more appropriately for OSH, from the lab to the field (i.e., the worksite/workplace) and back again. Whereas traditional scientific inquiry is primarily concerned with creating new knowledge, translational science is ultimately focused on the process of applying existing evidence to address health-related problems to generate generalizable knowledge [43,45].

Translational science has been conceptualized as crossing all translational or "T" phases of the research continuum, from scientific discovery (T0), to efficacy (T1), effectiveness (T2), D&I (T3), and the outcomes and effectiveness of research in populations (T4) [44,46]. However, in practice, translational science has largely focused on barriers to intervention development at the efficacy and effectiveness stages (T1 and T2), while D&I science has focused on barriers to intervention adoption, use and sustainment (T3 and T4) [45]. More and better integration of D&I science across the translational continuum has therefore been called for [45,47].

Increasingly, OSH researchers in the United States are adopting the terminology of mainstream D&I science [19,42]. More work is needed to harmonize terminology so that research in this area can be characterized and synthesized to enhance the impact and understanding of it.

The following sections use the Curran [15] tool to expand on important concepts in the D&I field for TWH researchers to consider when planning/conducting D&I studies.

3. D&I in Plain Language

3.1. Does "the Thing" Work? Efficacy and Effectiveness Research

Research in D&I is related to, but distinct from, traditional efficacy and effectiveness research. Referring to the Curran definition [15], efficacy research evaluates the initial impact of an intervention ("the thing") when it is delivered under optimal, controlled conditions. Effectiveness research looks at whether "the thing" works, determining the impact of an intervention with demonstrated efficacy to obtain more externally valid (generalizable) results [37]. As Anger and colleagues note in their systematic review of TWH interventions [3], the first step in identifying programs to disseminate and implement is to establish their effectiveness. As stated previously, while efficacy and effectiveness research are concerned with investigating specific interventions and health or safety outcomes in either ideal or real-world settings, D&I research is particularly concerned with the adoption, successful implementation, and sustainability of the intervention [48]. However, it is important to mention the integration study designs at the intersection of effectiveness and implementation research. These are referred to as hybrid effectiveness–implementation designs [49]. They exist on a spectrum with sub-types depending on the relative emphasis on effectiveness and/or implementation, with a primary focus on effectiveness regarded as type 1, equal attention to effectiveness and implementation referred to as type 2, and primary emphasis on implementation regarded as type 3 [49–51]. These hybrid designs relate to the aforementioned "designing for dissemination and sustainability" [34] and better integration of D&I science across the translational continuum [45,47]. This integration is important because if efficacy and effectiveness studies focus only on achieving the maximum effect, this will likely and unintentionally limit their application in real-world settings due to issues of cost, burden, poor fit with local context, lack of buy-in and available expertise for program implementation.

3.2. How Best to Do "the thing" ? A Very Brief Overview of D&I Models, Theories, Frameworks, Methods, and Measures

Once the "thing" (i.e., the intervention) is developed and tested, the focus of D&I efforts is on "doing the thing" well, which entails the selection of an appropriate theory, model, or framework (TMF) to guide the research. While the terms "theory", "model", and "framework" have distinct meanings, they are often used interchangeably [52]. TMFs generally describe tools to plan, evaluate, or understand barriers and facilitators (known

as determinants) to D&I processes [16,53,54]. These tools help researchers on the front-end to plan, organize, and understand D&I phenomena, and on the back-end to understand why/how D&I strategies succeed or fail [24]. Table 2 highlights select D&I TMFs such as the Consolidated Framework for Implementation Research (CFIR) [55], the RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance) framework [8,9], the EPIS (Exploration, Planning, Implementation, Sustainment) framework [56], the diffusion of innovations theory [31], and the Theoretical Domains Framework (TDF) [57]. The CDC's Knowledge to Action Framework [58] is another example of a tool developed for use by public health researchers to explore how evidence-based interventions can be translated into effective programs, policies, and practices. More than 150 D&I TMFs have been identified in the literature [21–23], and TWH researchers may wonder how to select an appropriate one. Fortunately, several efforts have focused on collecting and synthesizing the proliferation of TMFs available for D&I research. A key, publicly available resource, the D&I Models in Health (Table 2), provides an interactive webtool for study planning, combining and adapting TMFs, and selecting measurement tools to assess important D&I constructs [24].

Table 2. Select D&I theories, models, frameworks, tools, and resources.

Tool/Resource	Brief Description
Select D&I Theories, Models, and Frameworks (TMFs)	
Consolidated Framework for Implementation Research (CFIR) [55]	A widely used D&I framework that considers a range of implementation determinants (i.e., barriers and facilitators). The CFIR comprises five major domains (the intervention, inner and outer settings, the individuals involved, and the implementation process). Within these domains, multiple constructs reflect determinants of implementation. For example, complexity and cost are constructs within the intervention characteristics domain; external policies are a construct in the outer setting domain; culture is a construct within the inner setting domain; planning and engaging are constructs within the process domain; and the characteristics of the individuals involved domain focuses on individual-level constructs such as self-efficacy and knowledge, attitudes, and beliefs about the intervention [55].
RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance) framework [8,9]	A widely used D&I framework that includes five key dimensions: Adoption, Reach, Implementation, Effectiveness, and Maintenance. RE-AIM was designed to enhance the quality, efficiency, and public health impact of interventions. Cutting across all five of the RE-AIM implementation outcomes are equity concerns related to the representativeness of those who participate or benefit from evidence-based programs. The RE-AIM framework can be used for intervention planning, evaluation, and (iteratively) guiding adaptations to implementation strategies.
Practical, Robust, Implementation, and Sustainability Model (PRISM) [9,59,60].	An extension of the RE-AIM framework, PRISM considers key contextual factors that influence implementation at multiple socioecological levels. PRISM contextual factors include: the program characteristics from the perspective of organizational and individual recipients, the characteristics of diverse, multilevel recipients of the program, the implementation and sustainability infrastructure, and the external environment. PRISM may be used to guide researchers during the program planning, implementation, evaluation, and dissemination phases.
EPIS (Exploration, Planning, Implementation, Sustainment) framework [56,61]	The EPIS framework consists of four phases (Exploration, Planning, Implementation, Sustainment) that align with the implementation process, the identification of outer system and inner organizational contexts, and "bridging and innovation factors" that are concerned with the intervention being implemented and the interaction between outer and inner contexts.
Diffusion of innovations theory [31]	A widely used theory that seeks to explain the processes and factors influencing the spread and adoption of innovations through certain channels over time, considering components such as perceived characteristics of the innovation; innovativeness of the adopter; social system(s); individual adoption processes; and the diffusion system.
Theoretical Domains Framework (TDF) [57]	A compilation of theories relevant to implementation that resulted from a systematic review of published D&I frameworks.
CDC Knowledge to Action (K2A) Framework for Public Health [58]	A framework that can be used to explore how evidence-based interventions are translated into effective (public health) programs and practices. The framework consists of three phases: research, translation, and institutionalization. Under each of the three phases are supporting structures and evaluation.
D&I Models in Health: www.dissemination-implementation.org (accessed on 13 October 2021)	A free interactive webtool for the selection of TMFs that can be used for study planning, combining and adapting TMFs, and selecting measurement tools to explore D&I constructs.

Table 2. *Cont.*

Tool/Resource	Brief Description
Examples/Select D&I Measures, Instruments, and Tools	
Acceptability of Intervention Measure (AIM), Intervention Appropriateness Measure (IAM), and Feasibility of Intervention Measure (FIM)	Measures by Weiner and colleagues [62] to assess intervention acceptability, appropriateness and feasibility (12 items, four for each construct).
The Program Sustainability Assessment Tool (PSAT): https://sustaintool.org/psat/	A reliable, 40-item instrument from Luke and colleagues [63] with eight domains (5 items per domain) that can be used to assess the capacity for the sustainability of public health programs.
The EPIS framework website: https://episframework.com/measures (accessed on 13 October 2021)	Provides examples of and free access to webinars and other quantitative measures that assess constructs for inner (such as individual program adopter characteristics) and outer (such as sociopolitical and economic contexts that influence the process of implementation) contexts [56,61].
The Society for Implementation Research Collaboration Instrument Review Project: https://societyforimplementationresearchcollaboration.org/sirc-instrument-project (accessed on 13 October 2021)	Provides an overview of measures for both implementation outcomes and multilevel contextual domains. This resource requires a membership for access.
The National Cancer Institute, Grid-Enabled Measures Database (GEM): https://www.gem-measures.org/Public/Home.aspx (accessed on 13 October 2021)	Houses tools to enhance the quality and harmonization of measures for D&I [64].
The CFIR website: cfirguide.org (accessed on 13 October 2021)	Provides free access to data collection tools based on CFIR constructs [55].
The RE-AIM and PRISM frameworks website: https://www.re-aim.org (accessed on 13 October 2021)	Provides free templates of focus group and one-on-one interview guides for assessing RE-AIM constructs [8,9] before, during, and after program implementation. The website also includes videos, interactive tools, and presentations on PRISM/RE-AIM.

While there have been a large number of D&I TMFs proposed, leading some scholars to perceive the field as a "Tower of Babel" [65], there are more commonalities than differences across TMFs on factors known to affect the adoption, implementation, and sustainment of evidence-based interventions [66]. Key constructs commonly considered include multilevel contexts (i.e., inner and outer contexts with multiple layers within each, as described above) [8,9,56,61], characteristics of recipients at multiple levels [9,55], intervention and implementation strategy characteristics, and considerations for the various stages or phases of D&I (e.g., exploration, preparation, reach, adoption, implementation, sustainment, and important outcomes) [8,9,56,61].

An example of the use of D&I models in OSH is from Tinc et al. [67], who employed the CFIR [55] to evaluate, among key stakeholders, the success of implementing a national program to prevent tractor rollover deaths in the United States with the use of a rollover protection structure (ROPS). The study used stakeholder surveys to assess short- and long-term outcome measures (intakes, funding progress, and tractor retrofits) and identify which CFIR components correlated with these outcomes. Results indicated that eight CFIR survey items reflecting four constructs—access to knowledge and information, leadership engagement, engaging (in fundraising and funding requests), and reflecting and evaluating—were highly correlated with at least one of the outcomes. In the TWH literature, Nobgrea and colleagues [36] used the RE-AIM framework [8,9] to iteratively develop and evaluate a toolkit to enable workplace safety and health practitioners to implement their own participatory TWH programs. An example from Europe [68] involves a process of using a D&I framework to systematically assess adaptations to an occupational health intervention. While these studies describe promising applications of D&I in OSH/TWH, more work is needed to generate generalizable knowledge about "how best to do the thing" in diverse types of workplaces with multilevel stakeholders, such as workers, employers and supervisors, union representatives, and regulators/policy makers.

Another critical aspect of "doing the thing" is selecting the correct methods, designs, and measures. D&I science methods are varied, include both qualitative and quantitative techniques [25,26], and increasingly focus on the use of pragmatic, participatory, and mixed-method approaches [69]. Hybrid effectiveness–implementation designs [49–51] mentioned previously, promote the examination of both effectiveness and implementation

outcomes within the same study to speed-up the research-to-practice process. Brown and colleagues [25] compiled a useful compendium of other D&I study designs. These include within-site designs to evaluate the success of intervention implementation inside a workplace or community, between-site designs that compare implementation processes among sites having different exposure conditions, within- and between-site comparisons with rollout designs where intervention start times are staggered, and factorial designs to examine multiple implementation strategies.

Examples of D&I measures that can be used for "doing the thing" that are reliable, have validity data, and are considered to be pragmatic [28] are presented in Table 2, as are resources for identifying commonly used D&I tools, instruments and measures. In the D&I field, using previously developed measures is encouraged so that intervention findings may be compared across studies [64]. While it is not possible to characterize the full extent of available and appropriate D&I methods, designs, and measures, the above-mentioned resources are a starting point for TWH investigators to learn more about what considerations are needed when conducting rigorous D&I studies. It is also important to note more recent calls to integrate a health equity perspective across and within D&I TMFs, methods, and measures, whether health equity is a central focus of the D&I study or not [70].

3.3. D&I Strategies: The "Stuff" Researchers Do to Help Others Do "the Thing"

Referring again to the Curran's [15] plain language explanation, implementation strategies are "the stuff" researchers do to try to help people (e.g., workers and employers)/(work)places "do the thing" as designed/intended. Dissemination and implementation strategies are a collection of methods or techniques to enhance the adoption, implementation, and sustainability of an evidence-based intervention [71,72]. In other words, D&I strategies are activities, approaches, and processes used to spread/deliver interventions to target populations and/or integrate interventions in target settings [73–75]. Key strategies have been classified in the Expert Recommendations for Implementing Change (ERIC) compilation, which identified 73 distinct strategies across nine domains: (1) use evaluative and iterative strategies; (2) provide interactive assistance; (3) adapt and tailor context; (4) develop stakeholder interrelationships; (5) train and educate stakeholders; (6) support clinicians; (7) engage consumers; (8) utilize financial strategies; and (9) change infrastructure [76]. The ERIC strategies have been adapted for school settings [77] and may be modified for use in workplaces. Determining which implementation strategies (or bundles of strategies) are the most appropriate is context dependent. Research to identify effective implementation strategies to "do the thing" within workplace settings is nascent [78], as are efforts to capture implementation outcomes, as is described in the next section.

3.4. D&I Outcomes: How Much and How Well They "Do the Thing"

Implementation outcomes reflect how much and how well intervention implementers "do the thing" [15]. It is important to note that implementation outcomes, described in Table 3, are distinct from multilevel effectiveness outcomes which are often assessed in TWH studies. These effectiveness outcomes may include well-being, physical and mental health, occupational injuries, illness and fatalities, work-related fatigue, work stress, job performance, job satisfaction, safety climate, work–life balance [3] and occupational health equity [79].

Table 3. Examples of implementation outcomes adapted for TWH interventions.

Acceptability	Perception among key stakeholders that the TWH program or practice is agreeable or satisfactory
Adoption	Agreement among key stakeholders and settings to use a TWH intervention (i.e., "uptake")
Appropriateness	Perceived fit of the TWH intervention for a given context/population/health and safety problem
Costs	Resources needed for the uptake, implementation, and sustainment of TWH interventions
Feasibility	Extent to which the TWH intervention can be used successfully within a given workplace setting
Fidelity	Degree to which a TWH intervention is implemented as intended by program developers
Penetration	Extent of integration of a TWH intervention within a workplace, community, or system
Reach	Absolute number, proportion, and representativeness of individuals who are willing to participate in a given TWH initiative, intervention, or program, and reasons why or why not
Adaptation	Degree to which evidence-based TWH initiatives are modified to better fit with the local context
Sustainability	Extent to which a newly implemented TWH intervention is maintained or institutionalized within an organization/workplace

Sources: Adapted from Glasgow et al. and Proctor et al. [9,48]. For more details and comprehensive definitions see Rabin and Brownson [37].

As described previously, studies in D&I are typically conducted after program efficacy and effectiveness are demonstrated and an evidence base has been established. Building on the effectiveness evidence base, D&I science outcomes focus on for whom and in what contexts the intervention works [14,80]. A focus on health equity and pragmatic research methods and measures is also important [25,27,28], as discussed previously in this paper. Furthermore, research on mechanisms of change/action that describe the process by which implementation strategies bring about specified implementation outcomes (i.e., mediational analyses) is recommended [81]. Without understanding how implementation strategies work, they will likely fail to achieve a positive impact [82].

3.5. Context Matters

As stated, although not included in the Curran [15] conceptualization, another key feature of D&I is the importance of context, which has been defined as the unique circumstances within which intervention implementation is embedded [83]. Context is dynamic, multilevel, and cuts across economic, political, social, and temporal domains [17,84,85]. Factors at the system, organizational, worksite, and individual levels can serve as facilitators or barriers to implementation [85]. Characteristics of the intervention itself [31,86], as well as the intervention–context fit, can also have an impact on implementation outcomes, and all of these contextual influences may be present/active at different stages of the implementation process [75].

Despite its importance, context is one of the least often reported elements in research [17,85]. A recent scoping review of 17 determinant frameworks in implementation science indicates that most frameworks provide only a limited description and definition of context, and there is inconsistency with regard to which contextual determinants are addressed [16]. As May and colleagues [87] note, context "is a problem" as many efficacy/effectiveness studies and even some D&I research designs try to "control out" contextual confounders, even though these represent the real-world conditions into which interventions must be integrated. Traditional randomized controlled trials do not typically answer the question about why or how intervention impact varies by setting, focusing instead on questions related to internal validity [33]. Despite the challenges and tensions noted, gaining an understanding of context is critical for determining program/policy outcomes [33], including in TWH studies.

While researchers have demonstrated the value of considering multilevel contexts and stakeholder engagement in designing TWH interventions [2,11,36,88], a systematic review of TWH studies by Feltner and colleagues [18] identified only a limited number of interventions focusing on multilevel contextual factors, such as work organization and union membership status, health insurance status, access to primary care services, management support, availability of resources, and employee stress or strain related to company downsizing. No studies were identified that systematically assessed possible variation in intervention effectiveness by individual, worksite, organizational, or community factors [10]. Given the variety of contexts in which the TWH model can be implemented and

studied—with variations in employers, work environments, and workers—understanding the factors that influence the effectiveness of integrated interventions is important, and more research is needed in this area [10].

Moreover, it has been suggested that TWH studies should include a focus on complex systems approaches [89] to gain a deeper understanding of the multilevel influences within the TWH framework acting on intervention outcomes. Understanding context as a "process" rather than a "place" (i.e., the physical environment in which a practice is embedded) acknowledges that the setting in which implementation occurs is the product of "continuous accomplishments" and requires constant negotiation and iteration [87] (p. 4). D&I approaches can help address some of the complex, non-linear systems issues that impact TWH and OSH more generally.

3.6. Putting It All Together: A Logic Model for D&I in TWH

To illustrate the D&I process for TWH as described throughout this paper, a logic model is presented in Figure 1. Referring to the model, D&I outcomes (and ultimately work-related health, safety, and well-being outcomes) are conceptualized to be influenced by (a) the intervention (the evidence-based/informed program), (b) the D&I strategies, (c) mechanisms/mediators, or the "how and why" an implementation strategy operates [81], and (d) adaptations to context [9,90], such as modifications that will need to be made iteratively to sustain the initiative over time (e.g., lower cost, different staff/expertise, staff attitudes/buy-in, and different settings). The logic model displays both proximal outcomes, such as adoption and fidelity [37,48], and more distal outcomes and impacts, such as reduced occupational morbidity and mortality, enhanced well-being, and occupational health equity.

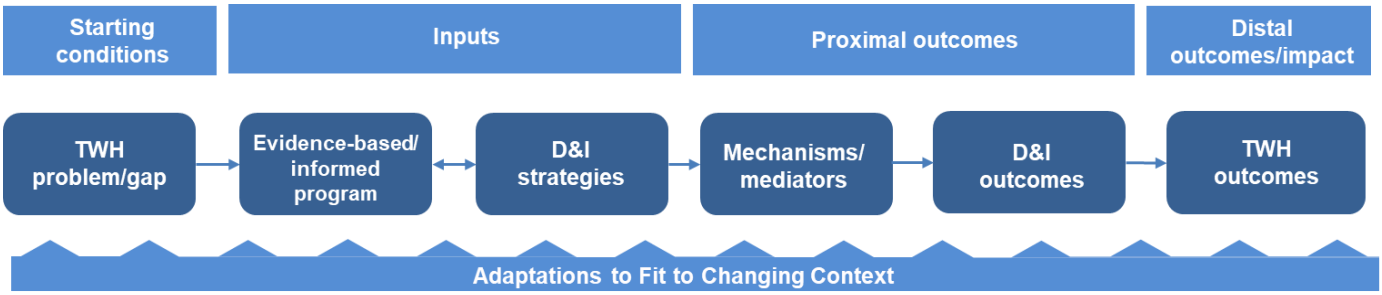


Figure 1. Logic model of a D&I study for TWH. Source: adapted from [91].

3.7. A Few Other Important D&I Distinctions for TWH Researchers

Despite calls for increasing the emphasis of D&I in TWH studies [3,11,18], the application of these approaches has been limited [10,18]. One reason may be due to a lack of clarity among TWH researchers on what D&I science is—and is not. Recent papers for the broader D&I community elaborate on this issue, addressing misconceptions about specific D&I frameworks [92]. The following section presents a few concepts potentially requring clarification for the TWH context, as garnered from the literature.

D&I is not r2p (but there is overlap). At NIOSH, r2p (research to practice) is an approach to communicate and transfer NIOSH "knowledge, interventions, or technologies" to relevant stakeholders for use in workplaces to contribute to reducing and eliminating injuries, illness, and fatalities [93]. In short, the NIOSH r2p program focuses on the transfer of interventions into effective practice. In contrast, D&I—or part of what NIOSH currently refers to as translation research—is the systematic study of these efforts [19,94]. While there are areas of overlap, including the focus on engaging stakeholders, r2p and translation research should be considered as separate, albeit complementary, areas of focus and effort.

D&I is not the same as program evaluation (but there is overlap). CDC defines program evaluation as the systematic collection of information on the activities, characteristics, and results of programs in a specific setting to inform local knowledge and practice [95].

Examples of program evaluation may include formative, process, or summative activities [96]. While the boundaries are unclear, an important distinction can be made between the science of improvement (program evaluation) versus the science of dissemination and implementation [96]. Whereas program evaluation might consider intervention outcomes (and even in different settings), the focus is on how to make the intervention itself (i.e., "the thing") better. In contrast, D&I outcomes relate to how to integrate the intervention into a variety of settings with a focus on methods and measures and the impact of implementation strategies [25,80]. For example, whereas program evaluation may focus on organizational and behavioral outcomes of a worksite injury prevention program, D&I is focused on the outcomes of acceptability, integration, and sustainability of the specific program/policy/practice [9,37,48] in different workplaces and community settings.

In summary, D&I science is concerned with dynamic, multilevel contextual factors related to the characteristics of the intervention, implementation strategies, individual, program provider, organizational (workplace), and policy/regulatory levels; pragmatism; and sustainability [47,86]. D&I processes should be considered as a set of complex, non-linear, and iterative accomplishments that are emergent and dynamic [87]. Given this multilevel and systems-level approach, D&I is well-aligned with the OSH field. As noted previously, D&I (also referred to as translation(al) research) has been integrated into strategic NIOSH initiatives [19,20,42]. The case study presented below provides an extended example of identifying an evidence-based, OSH program, adapting it for TWH, and moving it along the translational research continuum [20,97–100]. Such work sets the stage for future opportunities for D&I science.

4. Translating an Evidence-Based, Young Worker Program for TWH: A Case Study Example

In the United States, young workers (aged 15–24 years) experience higher rates of job-related injury than adult workers (aged 25–44 years) [101]. During 2012–2018, an estimated 3.2 million nonfatal injuries to young workers were treated in hospital emergency departments [101]. Work-related injuries may be life-altering, and young people hurt at work may experience a "cumulative burden of morbidity" over their lifetimes [102]. Data from the U.S. Bureau of Labor Statistics, Census of Fatal Occupational Injuries, indicate that 2349 young workers died on the job during the 2011 through to 2017 period [103]. Although employers are required by law to provide basic safety training to all workers, the lack of quality safety training has been shown to be a contributor to occupational injury among young workers [104,105].

To address this public health problem, NIOSH and its partners developed the classroom-based, "Youth @ Work: Talking Safety" curriculum [106–108] to provide youth with a foundation of OSH competencies before they enter the workforce [109]. Results from quasi-experimental and (on-going) randomized trials indicate the effectiveness of the NIOSH curriculum to have a positive impact on adolescent students' work safety knowledge, attitudes, norms, self-efficacy, and intention to enact safety behaviors in the workplace [110,111].

Building on the evidence base for the "Youth @ Work: Talking Safety" curriculum, Promoting U through Safety and Health (PUSH), an online training tool for young workers, was developed by researchers with the Oregon Healthy Workforce Center, a NIOSH Total Worker Health Center of Excellence [112]. PUSH expands "Talking Safety" to include TWH concepts in an online format (versus the classroom format of "Talking Safety") and for delivery in a different context (city park departments versus middle schools and high schools). The adaptation was based on inputs gathered through a needs assessment conducted with young people aged 14–24 years employed as aquatics workers in a city parks and recreation program in Portland, Oregon [112–114]. This work allowed the project team to qualitatively assess the acceptability and fit of the proposed OSH and health promotion content for the target population and establish the feasibility of an online delivery model [112,113]. To assess intervention outcomes, an individual-level randomized controlled trial was conducted with 140 young aquatics workers [114]. Most intervention workers (compared to the control group) reported learning new information (95%), liking

the training (59%), and indicated that they had adopted new healthy behaviors (63%). Furthermore, the parks program indicated that the online format was practical and easy to administer.

In a subsequent project phase, the PUSH training was scaled out (or disseminated in D&I terms) to young workers in a range of occupations, including cashiers, accountants, service managers, counselors, and lifeguards [115].

Referring to the translational research pipeline described earlier in this paper [43–46,97–100], the "Youth @ Work: Talking Safety" curriculum was developed and tested in T0 and T1, with further effectiveness testing conducted in T2. The evidence base established for the curriculum was leveraged to develop PUSH with a TWH focus and tested it with other target groups in different contexts, focusing largely on barriers to intervention development at the efficacy and effectiveness stages (T1 and T2). Future D&I studies (T3) involving PUSH could, for example, focus on the testing of theories, models, and frameworks for D&I processes, some of which have been described in this article [21–24]. Research could be conducted to systematically identify, develop, test, evaluate, and/or refine strategies [73,76] to disseminate and implement PUSH interventions in new community/workplace contexts where young workers are employed. Another example of future opportunities for D&I research would include a systematic investigation of the local adaptations [90,116,117] of PUSH in the context of its implementation within various settings that employ young workers. Studies of influences on the development, packaging, transmission, and reception [118] of PUSH in various settings and contexts where young workers can be reached would also help to move this promising TWH research into (sustained) practice.

5. Discussion

The aim of D&I is to gain an understanding of the contextual factors—including the needs and priorities of stakeholders at each level [119]—that facilitate and hinder the successful uptake of evidence-based interventions. Although D&I science holds promise for speeding up the translation of TWH interventions to enhance the health and well-being of the global workforce, research in this area remains limited. One barrier to the widespread uptake of D&I may be the need to identify interventions that are ready for translation. As Anger and colleagues [3] note, "Perhaps it is premature to press for dissemination of the TWH programs until their effectiveness is better established." (p. 243). However, waiting for interventions to meet evidence standards may contribute to the translational lag time while also generating interventions that are not replicable in the real world [84,120]. Types of evidence more typical in OSH than that generated through highly controlled trials include guidelines, recommendations, and observational as well as worker case studies [121]. Communicating which TWH initiatives are promising (i.e., evidence-informed versus evidence-based [37,122]) may speed-up practical and empirical outcomes.

To ensure that TWH interventions are replicable in real-world settings, efficacy and effectiveness studies should be designed and conducted with an eye toward feasibility, generalization, dissemination, equity, and sustainability at every phase of the research continuum [9,45]. The concept of designing for dissemination, implementation, and sustainment (D4DIS), mentioned previously, is a process that can be used to ensure that the products of research are developed with the needs, resources, and time frames of the target audience in mind [34]. Practical tools exist to help researchers plan D4DIS and engage stakeholders in these efforts (see, for example, DICEmethods.org). Moreover, D&I science TMFs such as RE-AIM [8,9,92], CFIR [55], and EPIS [56,61] can be used not only for evaluating interventions but can also guide their planning with stakeholders (e.g., workers, employers, and community members), be used iteratively during implementation to adapt the program/practice to better fit the context (e.g., local workplaces), and respond to emerging implementation data. More and better integration of D&I across the translational science continuum has been called for to move research more rapidly into practice to benefit the public [45,47], including workers [42]. Moreover, by integrating D&I early in

the research process, activities related to getting scientific innovations into the hands of end users may not be viewed as a burdensome, add-on activity [42], as someone else's role [34,123,124], or as up to the stakeholders to figure out [125].

Consistency in how terminology is applied will also help to facilitate the uptake of D&I science in TWH and to develop generalizable knowledge about D&I outcomes. Rabin and colleagues [37] have assembled extensive glossaries to capture and harmonize the D&I "Tower of Babel" [65]. A project being conducted under the NIOSH Evaluation Capacity-Building initiative [126] is to develop, with D&I science scholars and internal and external stakeholders, a glossary of D&I research terms for OSH researchers. As with any developing field, there are minor differences in terminology and a relative emphasis on different theories, models and frameworks. However, within D&I, there is general agreement on key principles, factors, and methods (see Table 1; also [66]).

Another challenge may be limited D&I expertise in the TWH field, as is the case more generally [127]. Furthermore, although the broader D&I science field has expanded and diversified over the years, more investment in resources tailored to meet the needs of OSH and TWH researchers are required to build capacity with D&I science models, theories, frameworks [21–24], methods and designs [25,26], and pragmatic measures [27,28]. These tools can be used to conduct rigorous studies that bridge the gap between the lab, the field, and public health impact.

Another important area of focus for D&I in TWH is how to critically infuse an equity approach into all research endeavors [79,128–130]. This includes focusing on equitable reach from the beginning of the intervention planning and development; designing and selecting programs for populations at disproportionate risk for work-related injury, illness and reduced well-being; implementing what works; and developing implementation strategies that can help reduce inequities in OSH [129]. Practical issues—such as the complexity of accessing many workplaces and workers, especially those in smaller and low-resource businesses and who may experience multiple OSH inequities [129,131]—make conducting D&I research challenging [42]. However, D&I research in TWH can help to build the necessary evidence base for employers to adopt a more holistic, feasible, and sustainable approach to promote (current and future) employee health and well-being.

Finally, D&I approaches that consider multilevel contextual factors in TWH that influence intervention outcomes [18] are needed to address the dynamic, complex and emergent nature of twenty-first-century challenges in OSH [6,7,90], including global pandemics. TWH research is needed that systematically considers the factors at the system, organizational, worksite, and individual level that serve as facilitators or obstacles to implementation [31,75]. Designing implementation strategies to address contextual barriers [75] may help TWH researchers to consider multilevel influences (such as regulatory changes, or individual worker acceptance of new technologies) as well as other complex phenomena that influence the effectiveness, equity, adoption, implementation and sustainability of TWH programs, both in the United States and internationally [130].

6. Conclusions

Applications of D&I hold promise for addressing the limited movement of intergrated worker protection and health promotion interventions into widespread and sustained practice. Several reasons, including the need to identify promising TWH interventions that are ready to be moved along the research to practice continuum and limited D&I capacity, have been identified that may be potential barriers to the uptake of D&I approaches. However, numerous opportunities also exist. This paper drew upon a synthesis of the D&I science literature to provide TWH researchers and practitioners with an overview of the D&I field and a plain language explanation of key concepts. This analysis also presents D&I examples and resources, and discusses how D&I tools can be used to more rapidly deploy effective TWH programs. The end goal is to improve the current and future safety, health and well-being of working people and enhance occupational health equity in an increasingly dynamic and complex global economy.

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References

1. NIOSH. What Is Total Worker Health? Available online: https://www.cdc.gov/niosh/twh/totalhealth.html (accessed on 17 April 2021).
2. Tamers, S.L.; Chosewood, L.C.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.C. Total Worker Health® 2014–2018: The novel approach to worker safety, health, and well-being evolves. *Int. J. Environ. Res. Public Health* **2019**, *16*, 321. [CrossRef]
3. Anger, W.K.; Elliot, D.L.; Bodner, T.; Olson, R.; Rohlman, D.S.; Truxillo, D.M.; Kuehl, K.S.; Hammer, L.B.; Montgomery, D. Effectiveness of Total Worker Health interventions. *J. Occup. Health Psychol.* **2015**, *20*, 226–247. [CrossRef]
4. Carr, L.J.; Leonhard, C.; Tucker, S.; Fethke, N.; Benzo, R.; Gerr, F. Total Worker Health intervention increases activity of sedentary workers. *Am. J. Prev. Med.* **2016**, *50*, 9–17. [CrossRef] [PubMed]
5. Sorensen, G.; Stoddard, A.M.; LaMontagne, A.D.; Emmons, K.; Hunt, M.K.; Youngstrom, R.; McLellan, D.; Christiani, D.C. A comprehensive worksite cancer prevention intervention: Behavior change results from a randomized controlled trial (United States). *J. Public Health Policy* **2003**, *24*, 5–25. [CrossRef] [PubMed]
6. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef] [PubMed]
7. Schulte, P.A.; Delclos, G.; Felknor, S.A.; Chosewood, L.C. Toward an expanded focus for occupational safety and health: A commentary. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4946. [CrossRef] [PubMed]
8. Glasgow, R.E.; Vogt, T.M.; Boles, S.M. Evaluating the public health impact of health promotion interventions: The RE-AIM framework. *Am. J. Public Health* **1999**, *89*, 1322–1327. [CrossRef] [PubMed]
9. Glasgow, R.E.; Harden, S.M.; Gaglio, B.; Rabin, B.A.; Smith, M.L.; Porter, G.C.; Ory, M.G.; Estabrooks, P.A. RE-AIM planning and evaluation framework: Adapting to new science and practice with a twenty-year review. *Front. Public Health* **2019**, *7*, 64. [CrossRef]
10. Bradley, C.J.; Grossman, D.C.; Hubbard, R.A.; Ortega, A.N.; Curry, S.J. Integrated interventions for improving Total Worker Health: A panel report from the National Institutes of Health Pathways to Prevention Workshop: Total Worker Health-what's work got to do with it? *Ann. Intern. Med.* **2016**, *165*, 279–283. [CrossRef]
11. Tamers, S.L.; Goetzel, R.; Kelly, K.M.; Luckhaupt, S.; Nigam, J.; Pronk, N.P.; Rohlman, D.S.; Baron, S.; Brosseau, L.M.; Bushnell, T.; et al. Research methodologies for Total Worker Health®: Proceedings from a workshop. *J. Occup. Environ. Med.* **2018**, *60*, 968. [CrossRef]
12. Punnett, L.; Cavallari, J.M.; Henning, R.A.; Nobrega, S.; Dugan, A.G.; Cherniack, M.G. Defining 'integration' for Total Worker Health®: A new proposal. *Ann. Work Expo. Health* **2020**, *64*, 223–235. [CrossRef]
13. NIH. Dissemination and Implementation Research in Health, PAR-19-274. Available online: https://grants.nih.gov/grants/guide/pa-files/PAR-19-274.html (accessed on 7 May 2021).
14. Pawson, R. *The Science of Evaluation: A Realist Manifesto*; Sage: Thousand Oaks, CA, USA, 2013.

15. Curran, G.M. Implementation science made too simple: A teaching tool. *Implement. Sci. Commun.* **2020**, *1*, 27. [CrossRef]
16. Nilsen, P.; Bernhardsson, S. Context matters in implementation science: A scoping review of determinant frameworks that describe contextual determinants for implementation outcomes. *BMC Health Serv. Res.* **2019**, *19*, 1–21. [CrossRef] [PubMed]
17. Stange, K.C.; Breslau, E.S.; Dietrich, A.J.; Glasgow, R.E. State-of-the-art and future directions in multilevel interventions across the cancer control continuum. *J. Natl. Cancer Inst. Monogr.* **2012**, *44*, 20–31. [CrossRef] [PubMed]
18. Feltner, C.; Peterson, K.; Palmieri Weber, R.; Cluff, L.; Coker-Schwimmer, E.; Viswanathan, M.; Lohr, K.N. The effectiveness of Total worker health interventions: A systematic review for a National Institutes of Health pathways to prevention workshop. *Ann. Intern. Med.* **2016**, *165*, 262–269. [CrossRef] [PubMed]
19. Dugan, A.G.; Punnett, L. Dissemination and implementation research for occupational safety and health. *Occup. Health Sci.* **2017**, *1*, 29–45. [CrossRef]
20. Schulte, P.A.; Cunningham, T.R.; Nickels, L.; Felknor, S.; Guerin, R.; Blosser, F.; Chang, C.C.; Check, P.; Eggerth, D.; Flynn, M.; et al. Translation research in occupational safety and health: A proposed framework. *Am. J. Ind. Med.* **2017**, *60*, 1011–1022. [CrossRef]
21. Birken, S.A.; Powell, B.J.; Shea, C.M.; Haines, E.R.; Alexis Kirk, M.; Leeman, J.; Rohweder, C.; Damschroder, L.; Presseau, J. Criteria for selecting implementation science theories and frameworks: Results from an international survey. *Implement. Sci.* **2017**, *12*, 124. [CrossRef]
22. Strifler, L.; Cardoso, R.; McGowan, J.; Cogo, E.; Nincic, V.; Khan, P.A.; Scott, A.; Ghassemi, M.; MacDonald, H.; Lai, Y.; et al. Scoping review identifies significant number of knowledge translation theories, models, and frameworks with limited use. *J. Clin. Epidemiol.* **2018**, *100*, 92–102. [CrossRef]
23. Tabak, R.G.; Khoong, E.C.; Chambers, D.; Brownson, R.C. Models in dissemination and implementation research: Useful tools in public health services and systems research. *Front. Public Health Serv. Syst. Res.* **2013**, *2*, 8. [CrossRef]
24. Tabak, R.G.; Hook, M.; Chambers, D.A.; Brownson, R.C. The conceptual basis for dissemination and implementation research. In *Dissemination and Implementation Research in Health: Translating Science to Practice*, 2nd ed.; Brownson, R.C., Colditz, G.A., Proctor, E.K., Eds.; Oxford University Press: New York, NY, USA, 2018; pp. 73–88.
25. Brown, C.H.; Curran, G.; Palinkas, L.A.; Aarons, G.A.; Wells, K.B.; Jones, L.; Collins, L.M.; Duan, N.; Mittman, B.S.; Wallace, A.; et al. An overview of research and evaluation designs for dissemination and implementation. *Annu. Rev. Public Health* **2017**, *38*, 1–22. [CrossRef]
26. Landsverk, J.; Brown, C.H.; Smith, J.D.; Chamberlain, P.; Curran, G.M.; Palinkas, L.; Ogihara, M.; Czaja, S.; Goldhaber-Fiebert, J.D.; Vermeer, W.; et al. Design and analysis in dissemination and implementation research. In *Dissemination and Implementation Research in Health: Translating Science to Practice*, 2nd ed.; Brownson, R.C., Colditz, G.A., Proctor, E.K., Eds.; Oxford University Press: New York, NY, USA, 2018; pp. 201–227.
27. Glasgow, R.E.; Riley, W.T. Pragmatic measures: What they are and why we need them. *Am. J. Prev. Med.* **2013**, *45*, 237–243. [CrossRef] [PubMed]
28. Stanick, C.F.; Halko, H.M.; Nolen, E.A.; Powell, B.J.; Dorsey, C.N.; Mettert, K.D.; Weiner, B.J.; Barwick, M.; Wolfenden, L.; Damschroder, L.J.; et al. Pragmatic measures for implementation research: Development of the Psychometric and Pragmatic Evidence Rating Scale (PAPERS). *Transl. Behav. Med.* **2021**, *11*, 11–20. [CrossRef] [PubMed]
29. Fixsen, D.L.; Naoom, S.F.; Blase, K.A.; Friedman, R.M.; Wallace, F. *Implementation Research: A Synthesis of the Literature*; The National Implementation Research Network, FMHI Publication No. 231; University of South Florida, Louis de la Parte Florida Mental Health Institute: Tampa, FL, USA, 2005.
30. Estabrooks, P.A.; Brownson, R.C.; Pronk, N.P. Dissemination and implementation science for public health professionals: An overview and call to action. *Prev. Chronic Dis.* **2018**, *15*, 180525. [CrossRef]
31. Rogers, E.J. *Diffusion of Innovations*, 5th ed.; Free Press: New York, NY, USA, 2003.
32. Luke, D.A.; Morshed, A.B.; McKay, V.R.; Combs, T.B. Systems science methods in dissemination and implementation research. In *Dissemination and Implementation Research in Health: Translating Science to Practice*, 2nd ed.; Brownson, R.C., Colditz, G.A., Proctor, E.K., Eds.; Oxford University Press: New York, NY, USA, 2018; pp. 157–174.
33. Glasgow, R.E.; Chambers, D. Developing robust, sustainable, implementation systems using rigorous, rapid and relevant science. *Clin. Transl. Sci.* **2012**, *5*, 48–55. [CrossRef] [PubMed]
34. Brownson, R.C.; Jacobs, J.A.; Tabak, R.G.; Hoehner, C.M.; Stamatakis, K.A. Designing for dissemination among public health researchers: Findings from a national survey in the United States. *Am. J. Public Health* **2013**, *103*, 1693–1699. [CrossRef] [PubMed]
35. Bridging the Science and Practice of Designing for Dissemination: Going from Unicorns to Workhorses (Workshop). Available online: https://www1.ucdenver.edu/docs/librariesprovider94/di-docs/guides-and-tools/2018-d4d-workbook_revised2.pdf?sfvrsn=463c06b9_2 (accessed on 2 October 2021).
36. Nobrega, S.; Kernan, L.; Plaku-Alakbarova, B.; Robertson, M.; Warren, N.; Henning, R.; CPH-NEW Research Team. Field tests of a participatory ergonomics toolkit for Total Worker Health. *Appl. Erg.* **2017**, *60*, 366–379. [CrossRef]
37. Rabin, B.A.; Brownson, R.C. Terminology for dissemination and implementation research. In *Dissemination and Implementation Research in Health: Translating Science to Practice*, 2nd ed.; Brownson, R.C., Colditz, G.A., Proctor, E.K., Eds.; Oxford University Press: New York, NY, USA, 2018; pp. 19–45.
38. Crawford, J.O.; Davis, A.; Walker, G.; Cowie, H.; Ritchie, P. Evaluation of knowledge transfer for occupational safety and health in an organizational context: Development of an evaluation framework. *Policy Pract. Health Saf.* **2016**, *14*, 7–21. [CrossRef]

39. Duryan, M.; Smyth, H.; Roberts, A.; Rowlinson, S.; Sherratt, F. Knowledge transfer for occupational health and safety: Cultivating health and safety learning culture in construction firms. *Accid. Anal. Prev.* **2020**, *139*, 105496. [CrossRef]
40. Rondinone, B.M.; Boccuni, F.; Iavicoli, S. Trends and priorities in occupational health research and knowledge transfer in Italy. *Scand. J. Work Environ. Health* **2010**, *36*, 339–348. [CrossRef]
41. Van Eerd, D.; Saunders, R. Integrated knowledge transfer and exchange: An organizational approach for stakeholder engagement and communications. *Sch. Res. Commun.* **2017**, *8*. [CrossRef]
42. Cunningham, T.R.; Tinc, P.; Guerin, R.J.; Schulte, P.A. Translation research in occupational health and safety settings: Common ground and future directions. *J. Saf. Res.* **2020**, *74*, 161–167. [CrossRef]
43. Austin, C.P. Translating translation. *Nat. Rev. Drug Discov.* **2018**, *17*, 455–456. [CrossRef]
44. Fort, D.G.; Herr, T.M.; Shaw, P.L.; Gutzman, K.E.; Starren, J.B. Mapping the evolving definitions of translational research. *J. Clin. Transl. Sci.* **2017**, *1*, 60–66. [CrossRef]
45. Leppin, A.L.; Mahoney, J.E.; Stevens, K.R.; Bartels, S.J.; Baldwin, L.M.; Dolor, R.J.; Proctor, E.K.; Scholl, L.; Moore, J.B.; Baumann, A.A.; et al. Situating dissemination and implementation sciences within and across the translational research spectrum. *J. Clin. Transl. Sci.* **2019**, *4*, 152–158. [CrossRef] [PubMed]
46. NIH. National Center for Advancing Translational Sciences (NCATS), Translational Science Spectrum. Available online: https://ncats.nih.gov/translation/spectrum (accessed on 17 April 2021).
47. Shelton, R.C.; Lee, M.; Brotzman, L.E.; Wolfenden, L.; Nathan, N.; Wainberg, M.L. What is dissemination and implementation science?: An introduction and opportunities to advance behavioral medicine and public health globally. *Int. J. Behav. Med.* **2020**, *27*, 3–20. [CrossRef] [PubMed]
48. Proctor, E.; Silmere, H.; Raghavan, R.; Hovmand, P.; Aarons, G.; Bunger, A.; Griffey, R.; Hensley, M. Outcomes for implementation research: Conceptual distinctions, measurement challenges, and research agenda. *Adm. Policy Ment. Health* **2011**, *38*, 65–76. [CrossRef] [PubMed]
49. Curran, G.M.; Bauer, M.; Mittman, B.; Pyne, J.M.; Stetler, C. Effectiveness-implementation hybrid designs: Combining elements of clinical effectiveness and implementation research to enhance public health impact. *Med. Care* **2012**, *50*, 217. [CrossRef]
50. Kemp, C.G.; Wagenaar, B.H.; Haroz, E.E. Expanding hybrid studies for implementation research: Intervention, implementation strategy, and context. *Front. Public Health* **2019**, *7*, 325. [CrossRef]
51. Landes, S.J.; McBain, S.A.; Curran, G.M. An introduction to effectiveness-implementation hybrid designs. *Psychiatry Res.* **2020**, *283*, 112630. [CrossRef]
52. Bauer, M.S.; Damschroder, L.; Hagedorn, H.; Smith, J.; Kilbourne, A.M. An introduction to implementation science for the non-specialist. *BMC Psychol.* **2015**, *16*, 32. [CrossRef]
53. Damschroder, L.J. Clarity out of chaos: Use of theory in implementation research. *Psychiatry Res.* **2020**, *283*, 112461. [CrossRef] [PubMed]
54. Nilsen, P. Making sense of implementation theories, models and frameworks. *Implement. Sci.* **2015**, *10*, 53. [CrossRef] [PubMed]
55. Damschroder, L.J.; Aron, D.C.; Keith, R.E.; Kirsh, S.R.; Alexander, J.A.; Lowery, J.C. Fostering implementation of health services research findings into practice: A consolidated framework for advancing implementation science. *Implement. Sci.* **2009**, *4*, 1–15. [CrossRef] [PubMed]
56. Aarons, G.A.; Hurlburt, M.; Horwitz, S.M. Advancing a conceptual model of evidence-based practice implementation in public service sectors. *Adm. Policy Ment. Health* **2011**, *38*, 4–23. [CrossRef] [PubMed]
57. Michie, S.; Johnston, M.; Abraham, C.; Lawton, R.; Parker, D.; Walker, A. Making psychological theory useful for implementing evidence based practice: A consensus approach. *Qual. Saf. Health Care* **2005**, *14*, 26–33. [CrossRef] [PubMed]
58. Wilson, K.M.; Brady, T.J.; Lesesne, C.; NCCDPHP Work Group on Translation. An organizing framework for translation in public health: The Knowledge to Action Framework. *Prev. Chronic Dis.* **2011**, *8*, A46.
59. Feldstein, A.C.; Glasgow, R.E. A practical, robust implementation and sustainability model (PRISM) for integrating research findings into practice. *Jt. Comm. J. Qual. Patient Saf.* **2008**, *34*, 228–243. [CrossRef]
60. McCreight, M.S.; Rabin, B.A.; Glasgow, R.E.; Ayele, R.A.; Leonard, C.A.; Gilmartin, H.M.; Frank, J.W.; Hess, P.L.; Burke, R.E.; Battaglia, C.T. Using the Practical, Robust Implementation and Sustainability Model (PRISM) to qualitatively assess multilevel contextual factors to help plan, implement, evaluate, and disseminate health services programs. *Transl. Behav. Med.* **2019**, *9*, 1002–1011. [CrossRef]
61. Moullin, J.C.; Dickson, K.S.; Stadnick, N.A.; Rabin, B.; Aarons, G.A. Systematic review of the Exploration, Preparation, Implementation, Sustainment (EPIS) framework. *Implement. Sci.* **2019**, *14*, 1. [CrossRef]
62. Weiner, B.J.; Lewis, C.C.; Stanick, C.; Powell, B.J.; Dorsey, C.N.; Clary, A.S.; Boynton, M.H.; Halko, H. Psychometric assessment of three newly developed implementation outcome measures. *Implement. Sci.* **2017**, *12*, 1–12. [CrossRef]
63. Luke, D.A.; Calhoun, A.; Robichaux, C.B.; Elliott, M.B.; Moreland-Russell, S. The program sustainability assessment tool: A new instrument for public health programs. *Prev. Chronic Dis.* **2014**, *11*, 130184. [CrossRef] [PubMed]
64. Rabin, B.A.; Purcell, P.; Naveed, S.; Moser, R.P.; Henton, M.D.; Proctor, E.K.; Brownson, R.C.; Glasgow, R.E. Advancing the application, quality and harmonization of implementation science measures. *Implement. Sci.* **2012**, *7*, 1–11. [CrossRef] [PubMed]
65. McKibbon, K.A.; Lokker, C.; Wilczynski, N.L.; Ciliska, D.; Dobbins, M.; Davis, D.A.; Haynes, R.B.; Straus, S.E. A cross-sectional study of the number and frequency of terms used to refer to knowledge translation in a body of health literature in 2006: A Tower of Babel? *Implement. Sci.* **2010**, *5*, 16. [CrossRef]

66. Reilly, K.L.; Kennedy, S.; Porter, G.; Estabrooks, P. Comparing, Contrasting, and Integrating Dissemination and Implementation Outcomes Included in the RE-AIM and Implementation Outcomes Frameworks. *Front. Public Health* **2020**, *8*, 430. [CrossRef] [PubMed]
67. Tinc, P.J.; Jenkins, P.; Sorensen, J.A.; Weinehall, L.; Gadomski, A.; Lindvall, K. Key factors for successful implementation of the National Rollover Protection Structure Rebate Program: A correlation analysis using the consolidated framework for implementation research. *Scand. J. Work Environ. Health* **2020**, *46*, 85–95. [CrossRef] [PubMed]
68. von Thiele Schwarz, U.; Hasson, H.; Lindfors, P. Applying a fidelity framework to understand adaptations in an occupational health intervention. *Work* **2015**, *51*, 195–203. [CrossRef]
69. Palinkas, L.A.; Cooper, B.R. Mixed methods evaluation in dissemination and implementation science. In *Dissemination and Implementation Research in Health: Translating Science to Practice*, 2nd ed.; Brownson, R.C., Colditz, G.A., Proctor, E.K., Eds.; Oxford University Press: New York, NY, USA, 2018; pp. 336–353.
70. Brownson, R.C.; Kumanyika, S.K.; Kreuter, M.W.; Haire-Joshu, D. Implementation science should give higher priority to health equity. *Implement. Sci.* **2021**, *16*, 28. [CrossRef]
71. Golden, C.A. A Dissemination Strategy to Identify Communities Ready to Implement a Pediatric Weight Management Intervention in Medically Underserved Areas. *Prev. Chronic Dis.* **2021**, *18*, E10. [CrossRef]
72. Wolfenden, L.; Foy, R.; Presseau, J.; Grimshaw, J.M.; Ivers, N.M.; Powell, B.J.; Taljaard, M.; Wiggers, J.; Sutherland, R.; Nathan, N.; et al. Designing and undertaking randomised implementation trials: Guide for researchers. *BMJ* **2021**, 372. [CrossRef]
73. Powell, B.J.; Beidas, R.S.; Lewis, C.C.; Aarons, G.A.; McMillen, J.C.; Proctor, E.K.; Mandell, D.S. Methods to improve the selection and tailoring of implementation strategies. *J. Behav. Health Serv. Res.* **2017**, *44*, 177–194. [CrossRef] [PubMed]
74. Proctor, E.K.; Powell, B.J.; McMillen, J.C. Implementation strategies: Recommendations for specifying and reporting. *Implement. Sci.* **2013**, *8*, 1–11. [CrossRef] [PubMed]
75. Wolk, C.L.; Powell, B.J.; Beidas, R.S. Contextual influences and strategies for dissemination and implementation in mental health. *Dep. Pap. (Psychiatry)* **2015**. [CrossRef]
76. Powell, B.J.; Waltz, T.J.; Chinman, M.J.; Damschroder, L.J.; Smith, J.L.; Matthieu, M.M.; Proctor, E.K.; Kirchner, J.E. A refined compilation of implementation strategies: Results from the Expert Recommendations for Implementing Change (ERIC) project. *Implement. Sci.* **2015**, *10*, 21. [CrossRef]
77. Cook, C.R.; Lyon, A.R.; Locke, J.; Waltz, T.; Powell, B.J. Adapting a compilation of implementation strategies to advance school-based implementation research and practice. *Prev. Sci.* **2019**, *20*, 914–935. [CrossRef]
78. Wolfenden, L.; Goldman, S.; Stacey, F.G.; Grady, A.; Kingsland, M.; Williams, C.M.; Wiggers, J.; Milat, A.; Rissel, C.; Bauman, A.; et al. Strategies to improve the implementation of workplace-based policies or practices targeting tobacco, alcohol, diet, physical activity and obesity. *Cochrane Database Syst. Rev.* **2018**, *11*. [CrossRef]
79. Ahonen, E.Q.; Fujishiro, K.; Cunningham, T.; Flynn, M. Work as an inclusive part of population health inequities research and prevention. *Am. J. Public Health* **2018**, *108*, 306–311. [CrossRef]
80. Gaglio, B.; Glasgow, R.E. Evaluation approaches for dissemination and implementation research. In *Dissemination and Implementation Research in Health: Translating Science to Practice*, 2nd ed.; Brownson, R.C., Colditz, G.A., Proctor, E.K., Eds.; Oxford University Press: New York, NY, USA, 2018; pp. 317–334.
81. Lewis, C.C.; Klasnja, P.; Powell, B.J.; Lyon, A.R.; Tuzzio, L.; Jones, S.; Walsh-Bailey, C.; Weiner, B. From classification to causality: Advancing understanding of mechanisms of change in implementation science. *Front. Public Health* **2018**, *6*, 136. [CrossRef]
82. Grimshaw, J.M.; Eccles, M.P.; Lavis, J.N.; Hill, S.J.; Squires, J.E. Knowledge translation of research findings. *Implement. Sci.* **2012**, *7*, 1–17. [CrossRef]
83. Movsisyan, A.; Arnold, L.; Evans, R.; Hallingberg, B.; Moore, G.; O'Cathain, A.; Pfadenhauer, L.M.; Segrott, J.; Rehfuess, E. Adapting evidence-informed complex population health interventions for new contexts: A systematic review of guidance. *Implement. Sci.* **2019**, *14*, 1–20. [CrossRef]
84. Chambers, D.A.; Glasgow, R.E.; Stange, K.C. The dynamic sustainability framework: Addressing the paradox of sustainment amid ongoing change. *Implement. Sci.* **2013**, *8*, 117. [CrossRef]
85. Neta, G.; Glasgow, R.E.; Carpenter, C.R.; Grimshaw, J.M.; Rabin, B.A.; Fernandez, M.E.; Brownson, R.C. A framework for enhancing the value of research for dissemination and implementation. *Am. J. Public Health* **2015**, *105*, 49–57. [CrossRef]
86. Glasgow, R.E.; Emmons, K.M. How can we increase translation of research into practice? Types of evidence needed. *Annu. Rev. Public Health.* **2007**, *28*, 413–433. [CrossRef]
87. May, C.R.; Johnson, M.; Finch, T. Implementation, context and complexity. *Implement. Sci.* **2016**, *11*, 1–12. [CrossRef]
88. Henning, R.; Warren, N.; Robertson, M.; Faghri, P.; Cherniack, M.; CPH-NEW Research Team. Workplace health protection and promotion through participatory ergonomics: An integrated approach. *Public Health Rep.* **2009**, *124* (Suppl. 1), 26–35. [CrossRef]
89. Lemke, M.K. Is the Total Worker Health Program missing its mark?: Integrating complex systems approaches to unify vision and epistemology. *J. Occup. Environ. Med.* **2021**, *63*, e304–e307. [CrossRef]
90. Rabin, B.A.; McCreight, M.; Battaglia, C.; Ayele, R.; Burke, R.E.; Hess, P.L.; Frank, J.W.; Glasgow, R.E. Systematic, multimethod assessment of adaptations across four diverse health systems interventions. *Front. Public Health* **2018**, *6*, 102. [CrossRef] [PubMed]
91. Dissemination & Implementation Models in Health Research & Practice. Available online: https://dissemination-implementation.org/content/plan.aspx (accessed on 2 October 2021).

92. Holtrop, J.S.; Estabrooks, P.A.; Gaglio, B.; Harden, S.M.; Kessler, R.S.; King, D.K.; Kwan, B.M.; Ory, M.G.; Rabin, B.A.; Shelton, R.C.; et al. Understanding and applying the RE-AIM framework: Clarifications and resources. *J. Clin. Transl. Sci.* **2021**, *5*, e126. [CrossRef] [PubMed]
93. NIOSH. Research to Practice (r2p). Available online: https://www.cdc.gov/niosh/r2p/default.html (accessed on 2 October 2021).
94. NIOSH. Translation Research. Available online: https://www.cdc.gov/niosh/topics/translationresearch/default.html (accessed on 2 October 2021).
95. Introduction to Program Evaluation for Public Health Programs: A Self-Study Guide; Centers for Disease Control and Prevention (CDC): Atlanta, GA, USA. Available online: https://www.cdc.gov/eval/guide/introduction/index.htm (accessed on 2 October 2021).
96. Granger, B.B. Science of improvement versus science of implementation: Integrating both into clinical inquiry. *AACN Adv. Crit. Care* **2018**, *29*, 208–212. [CrossRef] [PubMed]
97. Khoury, M.J.; Gwinn, M.; Yoon, P.W.; Dowling, N.; Moore, C.A.; Bradley, L. The continuum of translation research in genomic medicine: How can we accelerate the appropriate integration of human genome discoveries into health care and disease prevention? *Genet. Med.* **2007**, *10*, 665–674. [CrossRef]
98. Westfall, J.M.; Mold, J.; Fagnan, L. Practice-based research—"Blue Highways" on the NIH roadmap. *JAMA* **2007**, *297*, 403–406. [CrossRef]
99. Woolf, S.H. The meaning of translational research and why it matters. *JAMA* **2008**, *299*, 211–213. [CrossRef]
100. Dougherty, D.; Conway, P.H. The "3T's" road map to transform U.S. health care: The "how" of high-quality care. *JAMA* **2008**, *299*, 2319–2321. [CrossRef] [PubMed]
101. Guerin, R.J.; Reichard, A.A.; Derk, S.; Hendricks, K.J.; Menger-Ogle, L.M.; Okun, A.H. Nonfatal occupational injuries to younger workers—United States, 2012–2018. *MMWR Morb. Mortal. Wkly. Rep.* **2020**, *69*, 1204–1209. [CrossRef]
102. Koehoorn, M.; Breslin, F.C.; Xu, F. Investigating the longer-term health consequences of work-related injuries among youth. *J. Adolesc. Health* **2008**, *43*, 466–473. [CrossRef] [PubMed]
103. Guerin, R.J.; Castillo, D.; Hendricks, K.J.; Howard, J.; Piacentino, J.; Okun, A.H. Preparing the future workforce for safe and healthy employment. *Am. J. Public Health* **2020**, *110*, 69–71. [CrossRef] [PubMed]
104. Runyan, C.W.; Schulman, M.; Dal Santo, J.; Bowling, J.M.; Agans, R.; Ta, M. Work-related hazards and workplace safety of U.S. adolescents employed in the retail and service sectors. *Pediatrics* **2007**, *119*, 526–534. [CrossRef] [PubMed]
105. Zierold, K.M. Teen worker safety training: Methods used, lessons taught, and time spent. *New Solut.* **2015**, *25*, 25–41. [CrossRef]
106. Miara, C.; Gallagher, S.; Bush, D.; Dewey, R. Developing an effective tool for teaching teens about workplace safety. *Am. J. Health Educ.* **2003**, *34*, 30–34. [CrossRef]
107. NIOSH. *Promoting Safe Work for Young Workers—A Community-Based Approach*; U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health: Cincinnati, OH, USA, 1999; DHHS (NIOSH) Publication No. 1999-141.
108. NIOSH. Youth@Work—Talking Safety: A Safety and Health Curriculum for Young Workers. Available online: http://www.cdc.gov/niosh/talkingsafety/states/ok/2015-168/default.html (accessed on 2 October 2021).
109. Okun, A.H.; Guerin, R.J.; Schulte, P.A. Foundational workplace safety and health competencies for the emerging workforce. *J. Saf. Res.* **2016**, *59*, 43–51. [CrossRef] [PubMed]
110. Guerin, R.J.; Toland, M.D.; Okun, A.H.; Rojas-Guyler, L.; Bernard, A.L. Using a modified theory of planned behavior to examine adolescents' workplace safety and health knowledge, perceptions, and behavioral intention: A structural equation modeling approach. *J. Youth Adolesc.* **2018**, *47*, 1595–1610. [CrossRef] [PubMed]
111. Guerin, R.J.; Okun, A.H.; Barile, J.P.; Emshoff, J.G.; Ediger, M.D.; Baker, D.S. Preparing teens to stay safe and healthy on the job: A multilevel evaluation of the Talking Safety curriculum for middle schools and high schools. *Prev. Sci.* **2019**, *20*, 510–520. [CrossRef] [PubMed]
112. Rohlman, D.S.; Parish, M.; Elliot, D.L.; Montgomery, D.; Hanson, G. Characterizing the needs of a young working population: Making the case for Total Worker Health in an emerging workforce. *J. Occup. Environ. Med.* **2013**, *55*, S69–S72. [CrossRef] [PubMed]
113. Elliot, D.; Rohlman, D.; Parish, M. Focus groups move online: Feasibility of Tumblr use for ehealth curriculum development. *JMIR Res. Protoc.* **2015**, *4*. [CrossRef]
114. Rohlman, D.S.; Parish, M.; Elliot, D.L.; Hanson, G.; Perrin, N. Addressing younger workers' needs: The Promoting U through Safety and Health (PUSH) trial outcomes. *Healthcare* **2016**, *4*, 55. [CrossRef]
115. Aryal, A.; Parish, M.; Rohlman, D.S. Generalizability of Total Worker Health® online training for young workers. *Int. J. Environ. Res. Public Health* **2019**, *16*, 577. [CrossRef]
116. Baumann, A.A.; Cabassa, L.J.; Stirman, S.W. Adaptation in dissemination and implementation science. In *Dissemination and Implementation Research in Health: Translating Science to Practice*, 2nd ed.; Brownson, R.C., Colditz, G.A., Proctor, E.K., Eds.; Oxford University Press: New York, NY, USA, 2018; pp. 285–300.
117. Stirman, S.W.; Baumann, A.A.; Miller, C.J. The FRAME: An expanded framework for reporting adaptations and modifications to evidence-based interventions. *Implement. Sci.* **2019**, *14*, 1–10. [CrossRef]
118. Brownson, R.C.; Eyler, A.A.; Harris, J.K.; Moore, J.B.; Tabak, R.G. Getting the word out: New approaches for disseminating public health science. *J. Public Health Manag. Pr.* **2018**, *24*, 102–111. [CrossRef]

119. Huebschmann, A.G.; Leavitt, I.M.; Glasgow, R.E. Making health research matter: A call to increase attention to external validity. *Annu. Rev. Public Health* **2019**, *40*, 45–63. [CrossRef] [PubMed]
120. Kessler, R.; Glasgow, R.E. A proposal to speed translation of healthcare research into practice: Dramatic change is needed. *Am. J. Prev. Med.* **2011**, *40*, 637–644. [CrossRef] [PubMed]
121. Howard, J.; Piacentino, J.; MacMahon, K.; Schulte, P. Using systematic review in occupational safety and health. *Am. J. Ind. Med.* **2017**, *60*, 921–929. [CrossRef] [PubMed]
122. Miles, A.; Loughlin, M. Models in the balance: Evidence-based medicine versus evidence-informed individualized care. *J. Eval. Clin. Pr.* **2011**, *17*, 531–536. [CrossRef] [PubMed]
123. Knoepke, C.E.; Ingle, M.P.; Matlock, D.D.; Brownson, R.C.; Glasgow, R.E. Dissemination and stakeholder engagement practices among dissemination & implementation scientists: Results from an online survey. *PLoS ONE* **2019**, *14*, e0216971. [CrossRef]
124. Tabak, R.G.; Stamatakis, K.A.; Jacobs, J.A.; Brownson, R.C. What predicts dissemination efforts among public health researchers in the United States? *Public Health Rep.* **2014**, *129*, 361–368. [CrossRef]
125. Beidas, R.S.; Edmunds, J.M.; Marcus, S.C.; Kendall, P.C. Training and consultation to promote implementation of an empirically supported treatment: A randomized trial. *Psychiatr. Serv.* **2012**, *63*, 660–665. [CrossRef]
126. NIOSH. Evaluation Capacity-Building Plan 2021–2025. Available online: https://www.cdc.gov/niosh/programs/review/ecb (accessed on 17 April 2021).
127. Proctor, E.K.; Chambers, D.A. Training in dissemination and implementation research: A field-wide perspective. *Transl. Behav. Med.* **2017**, *7*, 624–635. [CrossRef]
128. Baumann, A.A.; Cabassa, L.J. Reframing implementation science to address inequities in healthcare delivery. *BMC Health Serv. Res.* **2020**, *20*, 190. [CrossRef]
129. Flynn, M.A.; Eggerth, D.E.; Keller, B.M.; Check, P. Reaching "hard to reach" workers: Evaluating approaches to disseminate worker safety information via the Mexican consular network. *J. Occup. Environ. Hyg.* **2021**, *18*, 180–191. [CrossRef]
130. Jaramillo, D.; Krisher, L.; Schwatka, N.V.; Tenney, L.; Fisher, G.G.; Clancy, R.L.; Shore, E.; Asensio, C.; Tetreau, S.; Castrillo, M.E.; et al. International Total Worker Health: Applicability to Agribusiness in Latin America. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2252. [CrossRef] [PubMed]
131. NIOSH/ASSE. *Overlapping Vulnerabilities: The Occupational Safety and Health of Young Workers in Small Construction Firms*; Flynn, M.A., Cunningham, T.R., Guerin, R.J., Keller, B., Chapman, L.J., Hudson, D., Salgado, C., Eds.; NIOSH/ASSE, National Institute for Occupational Safety and Health and American Society of Safety Engineers: Cincinnati, OH, USA, 2015; U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2015-178. Available online: https://www.cdc.gov/niosh/docs/2015-178/pdfs/2015-178.pdf?id=10.26616/NIOSHPUB2015178 (accessed on 13 October 2021).

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Here for My Peer: The Future of First Responder Mental Health

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Abstract: Workplace interventions that leverage social tactics to improve health and well-being are becoming more common. As an example, peer mental health support interventions aim to reduce stigma and promote treatment seeking in first responder populations. Given the social nature of these interventions, it is important to consider how the preexisting social context influences intervention outcomes. A peer mental health support intervention was delivered among first responders, and self-efficacy and intention to have supportive peer conversations were measured pre-and post-intervention. Trust in peers was measured prior to the intervention. Results suggest a floor effect may exist for self-efficacy, in which a foundational level of trust and pre-intervention self-efficacy may be needed to maximize intervention effectiveness. As the future of work brings complex safety and health challenges, collaborative solutions that engage multiple stakeholders (employees, their peers, and their organization) will be needed. This study suggests that more frequent attention to pre-existing intervention context, particularly social context in peer-focused intervention, will enhance intervention outcomes.

Keywords: peer support; mental health; first responders; process evaluation

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1. Introduction

First responder professionals face increased job hazards, injuries, and fatalities on the job [1]. In addition to the dangers faced on the job, there are hidden consequences. A recent study found that firefighters are more likely to die of suicide than die on-the-job (even considering underreporting of first responder suicides) [2]. Focusing solely on the physical risks of the job is a disservice to these professionals. Therefore, a dual focus on the physical and mental health of first responders is imperative.

Barriers exist that often prevent first responders from seeking mental health treatment [3]. One such barrier is social stigma related to treatment-seeking [4], which is driven by a high value placed on mental toughness [5]. To reduce social stigma barriers peer-directed interventions exist that target the social environment to encourage treatment-seeking behavior [6]. However, little is known about how the existing social environment influences an intervention that targets peers as a mechanism of change. Trust in workplace social relationships may influence the effectiveness of an intervention that depends on social actors to ultimately influence the target behavior. The present study will examine both outcomes and process for a peer mental health support intervention for first responders. The process evaluation component will focus on the influence of both pre-existing individual differences (self-efficacy) and pre-existing social context (levels of interpersonal trust in the workplace) on intervention outcomes. In doing so, we address calls for more research on how pre-existing context may influence intervention outcomes [7] and provide insight into factors that may help or hinder valuable intervention efforts aimed as first responder mental health.

2. Interventions in the Context of the Future of Work

A consideration of pre-existing intervention context, particularly in the context of a first responder mental health intervention, is timely as researchers and practitioners respond to the changing nature of work. As the Future of Work Task Force points out, more research is needed on how organizational design can be used to address work stress and work-life issues [8]. Peer-directed interventions represent aspects of organizational design in that they leverage both formal and informal support systems to promote employee health and safety (including informal, naturally occurring supportive relationships, formal programs complimenting traditional mental health services such as employee assistance programs (EAPs), and peers employed in a dedicated peer-support role) [9]. These programs also integrate work and nonwork domains as they address a wide range of behavioral health issues affecting first responders [10], which can emerge on the job, at home, or both [11]. As work-life boundaries become increasingly blurred, organizational design programming that addresses the interplay between these domains becomes more important [8].

Additionally, the Future of Work Task Force also asserts that as workplaces and work stressors evolve, collaborative solutions that engage both leadership and employees become more important [8]. Borrowing from this logic that safety and health is not the employee's sole responsibility, we extend the general idea of collaborative solutions to also include work peers as catalysts of change. In doing so, we examine the feasibility and efficacy of including the work peer as a key stakeholder in protecting and promoting employee quality of work life. Finally, the Future of Work Task Force points out that employee quality of work life and organizational ethical responsibility is perceived as increasingly intertwined. They assert that qualities of workplace relationships, including trust, will grow in their importance in organizational design to support employee health [8], meaning that employees may or may not trust their employer to fulfill their ethical responsibility to promote safe and healthy work. This paper examines trust in work peers as social context that influences outcomes in a peer-focused workplace intervention. Although such an approach applies to a wide range of work populations, work stressors, or health and safety outcomes, in this instance, we train work peers to protect and promote employee mental health in first responder populations.

3. Mental Health & Suicide among First Responders

Interest in the psychological and physical effects of job-related stress for first responders is growing, given that first responders have high rates of on-the-job exposure to traumatic events due to the nature of their job [12]. Critical incidents refer to events that pose a significant risk for physical or psychological harm [13]. For many employees in the general population, the experience of a critical incident would be highly unusual, for first responders, they are routine [3]. For example, up to 60% of police officers witnessed or were involved in five or more critical incidents on the job during the past year, with 75% reporting that a critical incident occurred within the past month [14]. Similarly, 90% in a sample of firefighters reported at least one critical incident in the past year, with the average number of exposures being over six per year [15]. As a result of these high exposures, first responders may develop mental health disorders. First responders display symptoms of anxiety, depression, substance use disorders, post-traumatic and stress disorder [16], as well as suicidal ideation and suicide attempts [17] at rates higher than the general population.

To address these high rates of mental health concerns, efforts have been developed and implemented to address the effects of trauma due to occupational exposure. Traditional efforts include critical incident debriefing [18], programs to promote healthy lifestyle [19], and clinical treatment that can take place through an EAP program or behavioral health units of their agency or municipality [20]. Britt and McFadden [21] describe a dilemma for first responder mental health treatment. That is, in many cases receiving treatment depends on treatment-seeking on the part of the first responder, yet a critical barrier exists that discourages treatment-seeking behavior in first responder populations. These occupations

tend to value mental toughness and first responders have historically perceived a stigma associated with seeking treatment for mental health concerns [21]. When first responders perceive stigma associated with treatment seeking, they are less likely to initiate care and continue to experience distress.

4. Stigma as a Barrier to Treatment-Seeking

Rates of treatment-seeking behaviors among first responders experiencing mental health concerns are low. Sixty percent of first responders in a large representative sample reported a need for care, but among those reporting a need, less than half reported treatment-seeking behavior [22]. Although more research is needed on the topic of service utilization, existing literature suggests that first responders may expect or actually experience negative consequences as a result of treatment-seeking [4,23,24]. Although some other barriers do exist (i.e., lacking time to seek treatment or lack of trust in providers), perceived or experienced stigma is often reported as a reason for not utilizing services, such as an EAP [4]. That is, first responders who do not utilize these services when there is a need report not wanting to appear weak, not wanting to be treated differently by peers and leaders, and not wanting to experience career repercussions [4,21,23–26].

Perceived or experienced stigma for treatment-seeking in first responder populations originate from cues within the environment about expected behavior, with many messages espousing the idea that if the responder cannot "just get over it," that is a sign of weakness [27,28]. When asking police officers what they think most people believe, 45.9% reported that most people would see being treated for a mental illness as a sign of personal failure [29]. This perception has negative consequences for treatment-seeking, as in the same sample of police officers, 44.4% reported that most first responders would not seek professional help when appropriate.

5. Peer Support Interventions to Promote Treatment-Seeking

Clearly, interventions are needed to encourage treatment-seeking behavior in first responders when appropriate. Although workplace interventions can vary in their targets and strategies [30], one method that warrants further attention is to leverage work peers to promote healthy behaviors in an employee [31]. Peer-focused strategies can involve peer modeling, in which peers who already possess or demonstrate the target skill, behavior, and health status are paired with someone who is at risk or needs improvement in the target variable [32]. This intervention method leverages observational learning theory [33] to motivate self-improvement through upward comparison. That is, the employee is inspired by their healthy peers. Other peer-focused interventions could leverage more direct forms of peer involvement. For example, most peer-based interventions feature components of instrumental and emotional support [34]. Although this strategy has been applied in community settings, it is currently underutilized in workplaces. This is surprising, given the strong influence of work peers on employee health [35].

Peer-focused interventions could be particularly useful in this context given that social norms within close social networks, including norms among co-workers, influence perceptions of stigma and ultimately treatment-seeking behavior [36]. A peer-focused intervention could promote perceptions that treatment-seeking behavior is encouraged when needed, rather than a sign of weakness. Peer support is defined as "a system of giving and receiving help founded on key principles of respect, shared responsibility, and mutual agreement of what is helpful" and these programs are not specific to a single condition or setting [37]. Peer support interventions are efficacious as a method of secondary prevention [38,39] and can be applied in a variety of occupations or settings. For example, peer support interventions have been used with success as a method of first-line psychological intervention in high-risk groups such as military personnel [40,41] and firefighters [6].

Evidence suggests that peer-focused interventions may be preferred to other forms of interventions in high-risk occupations for several reasons. First, work peers can better understand the features of the job, which promotes the expression of genuine empathy for

the intervening peer [39]. The fact that the supporter "really gets the job" and "has walked in their shoes" can also promote buy-in for the first responder with mental health concerns. Second, first responders tend to prefer informal post-incident intervention methods [42] and peers may achieve a relatable, informal tone over other sources. Finally, first responders tend to trust their peers more than mental health professionals [39]. In the context of mental health, peers are not providing therapy, but rather they provide support, normalize the use of services, and encourage and assist the first responder in accessing a higher level of care, such as an EAP [39].

Research shows that peer support programs are associated with increases in inclusion, team cohesion and success, and building social networks at work [39] and have important implications for both behavioral outcomes and safety outcomes [43]. This is particularly encouraging given that worry over social exclusion is such a salient barrier to treatment-seeking. That is, it seems that leveraging the social environment can not only be effective modifying individual behavior, but it may improve the social environment itself. However, there has been little attention in the literature on peer support interventions to how pre-existing conditions may influence the success of these interventions.

6. Individual and Interpersonal Intervention Context

All workplace interventions, peer-focused or otherwise, take place against the backdrop of existing context, such as the pre-existing social environment. Qualities of the pre-existing social context are relevant to a workplace intervention for several reasons. First, the social environment can influence the target of a workplace intervention. For example, interventions seek to modify health behavior or safety behavior, which are shaped by social norms [44,45], or health and safety outcomes, which are influenced by social relationships [46]. Second, an intervention could use social tactics to achieve desired health and safety outcomes. Such interventions are based on socio-cognitive foundations and acknowledge the social determinants of health and safety [47]. Finally, the social environment can represent a confounding factor that can either help or hurt intervention implementation [48]. Few intervention studies directly measure implementation factors that can influence outcomes, but among those that do, notable social factors are present. These include perceived motivation for offering the intervention, employee support, and leader support [48]. Recent examinations of low uptake of peer-directed social support interventions in high-risk occupations supports the notion of preexisting social environments being an important process variable. Jessiman-Perreault and colleagues [48] adopt a theoretical approach to demonstrate how features of the job itself, structural conditions, and pre-existing social capital among peers will influence intervention success for better or worse.

There would be benefits to more frequent consideration of the preexisting context surrounding an intervention. It is well situated within the best practice of process evaluation, which examines when and why an intervention achieves desired outcomes [49]. For example, a widely used model of process evaluation for organizational interventions recommends measuring and accounting for shared mental models among groups of participants [50], highlighting the importance of social processes in promoting the success or failure of an intervention. It is possible that existing individual differences or interpersonal perceptions may create a floor effect in an intervention, wherein a participant must possess a certain level of the dependent variable or a contextual variable in order to benefit from the intervention. There have been calls for more research on ceiling and floor effects in interventions in occupational health psychology [51], given that pre-intervention circumstances may promote or hinder intervention success for certain groups. These circumstances could include pre-intervention levels of the target variable. Nielsen and colleagues [51] discuss that organizations may need a certain level of "healthiness or readiness" for an intervention to be successful (i.e., a floor effect). The same could be true of an individual intervention participant. A pre-existing level of efficacy or related personal resource could serve as a foundation for the intervention to thrive.

7. The Present Study

As peer-focused interventions are growing in popularity [52], there is a need to better understand contextual factors that will lend to the success of these interventions in a variety of occupational contexts. This is especially true in high-risk occupational settings, where both mental health burden and treatment-seeking stigma are high. This paper will first present an outcome evaluation, replicating previous research demonstrating that peer mental health support interventions are effective in increasing self-efficacy to have supportive conversations with a first responder peer in distress.

Hypothesis 1 (H1). *There will be a significant increase in (a) intention to use and (b) self-efficacy to use intervention concepts from pre-intervention to post-intervention.*

We will also consider the pre-intervention levels of the target variable (e.g., pre-intervention self-efficacy) and the preexisting workplace social environment as an intervention process variable, examining their influence on the outcomes of a peer support intervention for first responders. Although several variables exist that capture the quality of social relationships in the workplace, trust has been named in intervention process models as an important contextual factor that can help or hinder intervention implementation [53]. Trust is defined as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party" [54]. High levels of trust in peers would likely increase intervention participants' confidence in the "other actor" (their peer) in a conversation about mental health, as they may be more sure that their experiences will remain confidential and that their peer's reassurance and guidance is well-intentioned.

Hypothesis 2 (H2). *Pre-intervention levels of intention and interpersonal trust in peers will influence post-intervention levels of intention to use intervention concepts.*

Hypothesis 3 (H3). *Pre-intervention levels of self-efficacy and interpersonal trust in peers will influence post-intervention levels of self-efficacy to use intervention concepts.*

8. Methods

8.1. Participants

Participants were first responders in the Central Florida community who participated in a peer mental health support paraprofessional training. According to a trainee census maintained by the training organization, 280 first responders completed the training from March 2019 to February 2020. Among those trainees, 197 first responders completed pre-intervention and post-intervention surveys, earning a response rate of 70%. Due to concerns over the sensitive nature of data collected, demographic characteristics were not assessed in the survey. However, data from the trainee census (which is not connected to survey responses) revealed that the entire pool of intervention trainees were primarily male (71.42%) and primarily employed in fire (58.93%) and police services (30.36%). Although data are nested within agency, ICCs (-0.03 for post-intervention self-efficacy; -0.09 for post-intervention intention;) revealed that the majority of variance exists at the within-department level rather than the between-department level, which warrants an analysis without a multilevel component.

8.2. Procedure

All research activities were approved by the University of Central Florida Institutional Review Board. Trainees completed an eight-hour, group-based, in-person peer mental health support intervention. REACT (Recognize, Evaluate, Advocate, Coordinate, and Track) is a paraprofessional program designed to train the first responder stakeholders to deliver peer support. REACT was developed in partnership with public safety agencies to

address the need for promoting psychological health among first responders and facilitated by licensed clinical psychologists and doctoral students in clinical psychology. Details regarding intervention development, implementation, and pilot evidence for efficacy are documented by Marks and colleagues [6] and a short description of training procedures are described below.

Training content included psychoeducation regarding mental health, including content specifically related to mental health in first responders. This portion of the trainees introduced the idea of critical incidents as having the potential to produce mental health distress (referred to as stress injuries in the training). Trainees were then instructed on the recognition and evaluation of severity of behavioral health indicators of stress injuries (e.g., substance abuse, anger management issues, performance or attendance issues, etc.). They were given communication tools from motivational interviewing to facilitate a supportive conversation and to encourage their peer to seek a higher level of care. These tools included asking open-ended questions, providing validating and empathetic responses, and directly asking about intent to harm self or others when applicable to the severity of the behavioral health problem. Following didactic content, trainees participated in role-play exercises designed to reinforce these intervention targets and increase self-efficacy to provide peer support. A doctoral student or faculty member in Clinical Psychology observed the role-play scenarios and provided real-time feedback to the first responders. In some sessions, all trainees belonged to a single agency, while in others multiple agencies were present for a single training.

The research design was a quasi-experimental one-group pre-test post-test design. At the beginning of the training, the clinicians explained that trainees were invited to participate in a voluntary research study about factors that could influence their experience in the training. Interested participants provided informed consent and completed the pre-intervention survey, either on paper or on their mobile device depending on their preferences. Immediately after the training, trainees were given the opportunity to complete the post-intervention survey in a similar manner. Responses were anonymous and pre- and post-intervention surveys were linked using a participant-generated ID code. As mentioned above, 197 matched pre- and post-test surveys were completed. Reasons for non-response could include a lack of interest in the research study, only completing one out of the two surveys, or misremembering their ID code, preventing the matching of surveys.

8.3. Measures

Interpersonal trust. Interpersonal trust in peers was included in the pre-intervention survey as an intervention process variable. Three items by Cook and Wall [55] were included (α = 0.83). Initial work with this scale provided evidence for reliability, the hypothesized factor structure, and construct validity [55]. The items are: "I can trust the people I work with to lend me a hand when I need it," "Most of my workmates can be relied upon to do as they say they will do," and "I have full confidence in the skills of my workmates." Participants rated their level of agreement with each statement on a Likert scale from one to five ("strongly disagree" to "strongly agree"). Responses were averaged with higher scores representing higher levels of trust in peers. General interpersonal trust was measured, as opposed to trust related specifically to mental health concerns.

Self-efficacy to use intervention concepts. Self-efficacy to use intervention concepts was measured at pre-intervention and post-intervention as an intervention outcome variable. REACT has been previously evaluated using this outcome variable [6]. The 25-item scale was created based on a published guide for creating self-efficacy scales [56] (pre-intervention α = 0.97; post-test α = 0.97). The item stems referred to the behavioral targets of the intervention (e.g., "I can motivate a peer to seek a higher level of care"). Given that scales constructed using this guide will have unique reference points (i.e., another researcher could have used this guide to create a "self-efficacy to detach from work" scale, while we created a "self-efficacy to use intervention concepts to communicate with peers regarding mental health" scale), there is no single validation of this exact scale that we can

cite. However, the guide contains comprehensive recommendations regarding content, predictive, construct, and face validity [56]. Participants were instructed to rate their level of certainty that they could perform the action on a scale from 0 ("cannot do at all") to 100 ("highly certain I can do"). Similar to Marks and colleagues [6], participants completed a practice self-efficacy scale in which they rated their certainty that they could complete a familiar task, lifting a weight of increasing difficulty. Responses on the self-efficacy scale were averaged, with higher scores representing higher self-efficacy to perform intervention targets in the future.

Intention to use intervention concepts. As confidence to perform an action and intentions to perform an action are related, yet distinct concepts (and both important for behavioral change in an intervention context [57]), intention to use intervention concepts was measured pre- and post-intervention as an intervention outcome variable. The five-item scale that was constructed based on the intervention learning objectives (pre-intervention $\alpha = 0.76$; post-intervention $\alpha = 0.89$). An example item includes "I intend to use open-ended questions when talking to my coworkers"). Participants rated their likelihood to perform the action on a scale from one ("very unlikely") to five ("very likely"). Responses were averaged with higher scores representing a stronger intention to perform intervention targets in the future.

9. Results

Descriptive statistics and correlations among study variables can be found in Table 1. To test Hypothesis One, paired samples t-tests were conducted comparing intention and self-efficacy at pre- and post-intervention. Results revealed that both intention, $t(166) = 15.15$, $p < 0.01$, and self-efficacy, $t(161) = 23.30$, $p < 0.01$, significantly increased following the intervention. Thus, Hypothesis 1a,b were supported.

Table 1. Descriptive Statistics and Correlations.

	Mean	SD	(1)	(2)	(3)	(4)	(5)
1. Peer Trust	4.04	0.67	(0.83)				
2. Pre SE	6.64	2.42	0.12	(0.97)			
3. Post SE	10.66	1.91	0.16 *	0.41 **	(0.97)		
4. Pre Int	3.81	0.60	0.12	0.42 **	0.26 **	(0.76)	
5. Post Int	4.69	0.56	0.03	0.03	0.17 *	0.25	(0.89)

Note: N = 197 first responders who completed pre and post surveys for a peer mental health support intervention; SE refers to self-efficacy and Int refers to intentions; * indicates $p < 0.05$, ** indicates $p < 0.01$.

To test Hypotheses Two and Three, median splits were calculated to create the following categorical variables: pre-intervention intention (low and high), pre-intervention self-efficacy (low and high), and interpersonal trust in peers (low and high). Means in dependent variables among each group can be found in Table 2. A univariate ANCOVA was conducted in the low and high pre-intervention intention groups that specified post-intervention intention as a dependent variable, pre-intervention intention as a control variable, and the categorical interpersonal trust in peers variable as a fixed factor. The same analysis was repeated for self-efficacy. Such an analysis examines whether or not group membership into high and low interpersonal trust in peer groups predicts post-intervention scores after controlling for pre-intervention scores. We first tested to ensure that the data met assumptions necessary to perform an ANOVA-based analytical approach; the dependent variables were continuous, independent variables were categorical groups, observations were independent, and there were no meaningful outliers. Although Shapiro–Wilke tests revealed that dependent variables were not normally distributed, F and T family tests are typically robust against this violation as long as the sample size exceeds 30. Levene's Test of Homogeneity of Variances revealed that variances were equal among the median split groups for the fixed factor, interpersonal trust in peers ($F(1163) = 2.70$, $p = 0.10$).

Table 2. Means Among Median Split Groups.

	Dependent Variable: Post SE		Dependent Variable: Post Int	
	Low Pre SE	**High Pre SE**	**Low Pre Int**	**High Pre Int**
Low Peer Trust	10.53 (N = 31)	10.85 * (N = 14)	4.55 (N = 24)	4.83 (N = 21)
High Peer Trust	10.37 (N = 62)	11.54 * (N = 53)	4.64 (N = 56)	4.78 (N = 64)

Note: N = 197 first responders who completed pre and post surveys for a peer mental health support intervention; SE refers to self-efficacy and Int refers to intentions; * indicates that groups were significantly different based on ANCOVA.

Results for intention to use intervention concepts revealed that in the group with low pre-intervention intention levels, membership to high and low interpersonal trust in peers groups was not related post-intervention intention levels, $F(1,77) = 0.51$, $p = 0.48$. The same was true in the group with high pre-intervention intention levels, $F(1,82) = 0.15$, $p = 0.70$. Thus, Hypothesis Two was not supported.

Results for self-efficacy to use intervention concepts revealed that in the group with low pre-intervention self-efficacy levels, membership to high and low interpersonal trust in peers groups was not related to post-intervention self-efficacy levels, $F(1,90) = 0.11$, $p = 0.74$. However, in the group with high pre-intervention self-efficacy levels, membership to high and low interpersonal trust in peer groups was related post-intervention self-efficacy levels, $F(1,64) = 4.43$, $p < 0.05$. Post-intervention means were higher in the group with high levels of interpersonal trust in peers (M = 11.54), compared to the group with low levels of interpersonal trust in peers (M = 10.84). Thus, Hypothesis Three was supported.

10. Discussion

In this study, we first sought to replicate previous research supporting the peer mental health support interventions in first responder populations. This is particularly important given the high burden associated with cumulative stress from critical incidents in first responder populations, high rates of mental health distress and associated behavioral health issues, and high rates of suicide. Consistent with previous research, the results suggest that a peer mental health support intervention may be efficacious in producing changes in self-efficacy and intention to communicate with peers regarding mental health, directly assess intent to harm self or others, and to encourage treatment seeking in peers in first responder populations.

We also sought to extend previous research on peer mental health support interventions by examining how pre-existing contextual variables could influence the intervention process. That is, this peer-focused intervention is conducted in a group format and target changes that leverage interpersonal interactions, such as lending a supportive ear to a peer in need. It stands to reason that the intervention is implemented within a historical individual and social context that could help or hinder the intervention. In this study, we examined how pre-existing levels of intervention target variables (self-efficacy and intentions) and pre-existing levels of interpersonal trust relate to intervention outcomes. Results provide initial insight into the possible importance of attention to pre-existing context surrounding a peer-focused intervention; although differences are not observed for intention to use intervention concepts, baseline levels of the target variable and contextual supports may influence how confident a first responder feels in using intervention concepts. Post-intervention self-efficacy levels are significantly greater when high levels of pre-intervention self-efficacy are accompanied by high levels of trust in peers.

The use of peer-focused intervention strategies and a focus on the social work environment are timely for several reasons. In light of several trends related to the future of work, these practices are likely needed to address the increased importance of solutions based in organizational design to address work-related stresses, the need to collaboratively engage

employees and leaders in safety and health approaches, and the value of fostering trust between employees and organizations to fulfill corporate ethical responsibilities [8]. These results lend support to the notion that trust in organizations (or parties representative of the organization) matter and that this trust could influence the ways in which organizational design features to support employees (such as EAPs) are used or not used. As the workplace continues to change and complexities arise in work, workplaces, and workers, context will continue to prove important as we ensure that valuable interventions are not implemented in environments in which they would not thrive.

10.1. Implications for Research and Practice

These results bear a number of implications for research. If using a general framework of process evaluation as examinations of when and why an intervention works, these results bolster previous findings that it is important to consider both process and outcomes in intervention evaluation. Although not comparable to more comprehensive and rigorous process evaluation models, the findings of this study may shed light on the importance of process evaluation models that contain categories of social contextual variables. Although discussions of floor effects in this study are tempered based on the limitations of the study design, the results could suggest the importance of further research on floor or ceiling effects in intervention implementation. Interventions are rarely delivered to a "blank canvas;" instead the intervention is interpreted in light of existing psychosocial context. Both discussions of floor and ceiling effects and guidance on how to detect them are in their infancy in occupational health psychology, and more attention to this phenomenon could help our field promote positive intervention outcomes for all groups of participants.

These results also have important implications for practice. These results add to a growing body of evidence that peer-focused programming can protect safety and health in the workplace, even in occupations with a history of stigma surrounding vulnerable topics (as evidenced by the use of a peer-focused strategy to improve mental health treatment-seeking in first responders). These results suggest that the effectiveness of these strategies could be helped or hurt by the preexisting social environment in the agency. Practitioners could consider addressing social issues that would negatively influence trust before the implementation of a peer-focused intervention, to ensure that the environment supports the intervention. Efforts to ready an environment for an intervention, such as improving social capital prior to intervention implementation, could build contextual influences support rather than subdue an intervention.

10.2. Strengths, Limitations, and Future Research Directions

This study is strengthened by its focus on a timely topic of great significance, mental health distress in first responder populations and methods to reduce stigma and foster treatment seeking. It is also strengthened by its attention to not only the outcomes of an intervention, but the way context helps or hinders the intervention. This is based on the logic of process evaluation methodology, which is considered a best practice in intervention evaluation [58]. This study builds upon previous intervention work that examines interpersonal trust as context by examining trust along with individual difference variables, pre-existing levels of the intervention's target variable.

Despite these strengths, there are several limitations that should be noted. First, the evaluation methods relied on self-report measures and did not include behavioral outcome variables. Although intentions are an important predictor of behavior [59], future research should examine how social context influences behavioral outcome variables (such as actual use of intervention concepts over time) or objective outcomes variables (such as employee assistant program utilization rates for participating agencies). Additionally, it is a limitation that we were unable to control for department affiliation, even considering the low ICC values, given that agency is an important aspect of context. Finally, the study design limits the nature of conclusions that can be made from this study. The lack of a control group and random assignment prohibit causal conclusions about intervention effectiveness

or the influence of contextual variables, and the lack of follow-up measures limit our interpretations about the sustained success of the intervention.

Future research should examine intervention outcomes over a longer period of follow-up and randomization into a control group. Not only is this necessary to support causal claims about intervention efficacy, but this would also allow researchers to assess the influence of trust with more sophisticated statistical approaches (for example, based on a helpful reviewer's suggestion, a randomized experiment would allow for the intervention to serve as an independent variable (treatment vs. control or varying levels of the intervention) and trust could be treated as a moderator). We also note that the use of median splits is not the only method of creating groups based on pre-intervention levels of various constructs. We chose a median split to mimic the comparison of two groups in earlier works that discuss ceiling and floor effects [51]. However, future research should aim to identify the most effective methods of group comparison in examinations of floor and ceiling effects. In addition, the sample of this study is relatively small and due to the anonymous nature of data collection, we were unable to examine how social processes or intervention process and outcomes might vary as a function of sociodemographic variables. Finally, this study focuses on how social context influences an intervention, but it could be possible that an intervention could in turn modify the social environment. Interpersonal trust was only measured in the pre-intervention survey because we found it unlikely that intervention-induced social change would permeate an agency immediately after a single-day intervention. We found it more likely that over time participants would adhere to the intervention's behavioral recommendations in interpersonal interactions, shaping trust over time after the intervention. Future research could investigate the potential reciprocal relationship between intervention and environment, by including interpersonal trust in a follow-up survey that occurs weeks or months after the intervention.

10.3. Conclusions

Peer-focused interventions have been used with some success to improve occupational safety, health, and well-being. Peer support interventions have been used to promote treatment-seeking for mental health among first responders, a population that struggles with high levels of depression, PTSD, and suicide paired with high levels of mental health stigma. However, research has not yet accounted for how the pre-existing context may influence the success of these interventions. We found evidence for the efficacy of the peer support interventions to increase self-efficacy and intention to communicate with peers regarding mental health, directly assess intent to harm self or others, and to encourage treatment seeking in first responders. We also found that pre-existing conditions matter; self-efficacy to use intervention concepts was highest when pre-existing self-efficacy and trust in peers was high. These results support an increased consideration of individual and interpersonal context prior to and during an intervention in order to maximize intervention success.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to the sensitive nature of mental health topics and job attitudes collected in the survey.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. National Occupational Research Agenda Public Safety Council. National Occupational Research Agenda for Public Safety. 2019. Available online: https://www.cdc.gov/nora/councils/pubsaf/pdfs/National_Occupational_Research_Agenda_for_Public_Safety_Feb_2019-508.pdf (accessed on 15 February 2021).
2. Heyman, M.; Dill, J.; Douglas, R. *The Ruderman White Paper on Mental Health and Suicide of First Responders*; Ruderman Family Foundation: Newton, MA, USA, 2018.
3. Haugen, P.T.; Evces, M.; Weiss, D.S. Treating posttraumatic stress disorder in first responders: A systematic review. *Clin. Psychol. Rev.* **2012**, *32*, 370–380. [CrossRef] [PubMed]
4. Haugen, P.T.; McCrillis, A.M.; Smid, G.E.; Nijdam, M.J. Mental health stigma and barriers to mental health care for first responders: A systematic review and meta-analysis. *J. Psychiatr. Res.* **2017**, *94*, 218–229. [CrossRef] [PubMed]
5. Crowe, A.L.; Glass, J.S.; Lancaster, M.; Raines, J.; Waggy, M. Mental illness stigma among first responders and the general population. *J. Mil. Gov. Couns.* **2015**, *3*, 132–228.
6. Marks, M.R.; Bowers, C.; DePesa, N.S.; Trachik, B.; Deavers, F.E.; James, N.T. REACT: A paraprofessional training program for first responders—A pilot study. *Bull. Menn. Clin.* **2017**, *81*, 150–166. [CrossRef] [PubMed]
7. Hammer, L.B.; Truxillo, D.M.; Bodner, T.; Pytlovany, A.C.; Richman, A. Exploration of the impact of organisational context on a workplace safety and health intervention. *Work Stress* **2019**, *33*, 192–210. [CrossRef]
8. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef]
9. Repper, J.; Aldridge, B.; Gilfoyle, S.; Gillard, S.; Perkins, R.; Rennison, J. *Peer Support Workers: Theory and Practice*; Centre for Mental Health: London, UK, 2013.
10. International Association of Fire Fighters [IAFF]. Ten Steps to Build Your Peer Support Program. Available online: https://www.iaff.org/wp-content/uploads/2019/04/41972_How_to_Build_Your_Peer_Support_Program.pdf (accessed on 15 February 2021).
11. Garner, N.; Baker, J.; Hagelgans, D. The private traumas of first responders. *J. Individ. Psychol.* **2016**, *72*, 168–185. [CrossRef]
12. Marmar, C.R.; McCaslin, S.E.; Metzler, T.J.; Best, S.; Weiss, D.S.; Fagan, J.; Liberman, A.; Pole, N.; Otte, C.; Yehuda, R.; et al. Predictors of Posttraumatic Stress in Police and Other First Responders. Annals of the New York Academy of Sciences 1071 (1 Psychobiology of Posttraumatic Stress Disorder: A Decade of Progress): 1–18. Available online: http://hdl.handle.net/2027.42/74485 (accessed on 15 February 2021). [CrossRef]
13. Department of Human Services [DHS]. Critical Incident Reporting Policy. Available online: https://www.nd.gov/dhs/info/pubs/mfp/docs/critical-incidents-reporting-policy.pdf (accessed on 15 February 2021).
14. Hartley, T.A.; Sarkisian, K.; Violanti, J.M.; Andrew, M.E.; Burchfiel, C.M. PTSD symptoms among police officers: Associations with frequency, recency, and types of traumatic events. *Int. J. Emerg. Ment. Health* **2013**, *15*, 241.
15. Corneil, W.; Beaton, R.; Murphy, S.; Johnson, C.; Pike, K. Exposure to traumatic incidents and prevalence of posttraumatic stress symptomatology in urban firefighters in two countries. *J. Occup. Health Psychol.* **1999**, *4*, 131. [CrossRef]
16. Kleim, B.; Westphal, M. Mental health in first responders: A review and recommendation for prevention and intervention strategies. *Traumatology* **2011**, *17*, 17–24. [CrossRef]
17. Vigil, N.H.; Grant, A.R.; Perez, O.; Blust, R.N.; Chikani, V.; Vadeboncoeur, T.F.; Spaite, D.W.; Bobrow, B.J. Death by suicide—The EMS profession compared to the general public. *Prehospital Emerg. Care* **2019**, *23*, 340–345. [CrossRef] [PubMed]
18. Everly, G.S., Jr.; Boyle, S.H. Critical incident stress debriefing (CISD): A meta-analysis. *Int. J. Emerg. Ment. Health* **1999**, *1*, 165–168. [PubMed]
19. MacMillan, F.; Karamacoska, D.; El Masri, A.; McBride, K.A.; Steiner, G.Z.; Cook, A.; Kolt, G.S.; Klupp, N.; George, E.S. A systematic review of health promotion intervention studies in the police force: Study characteristics, intervention design and impacts on health. *Occup. Environ. Med.* **2017**, *74*, 913–923. [CrossRef]
20. Donnelly, E.; Valentine, C.; Oehme, K. Law enforcement officers and employee assistance programs. *Polic. Int. J. Police Strateg. Manag.* **2015**, *38*, 206–220. [CrossRef]
21. Britt, T.W.; McFadden, A.C. Understanding mental health treatment-seeking in high stress occupations. *Contemp. Occup. Health Psychol. Glob. Perspect. Res. Pract.* **2012**, *2*, 57–73.
22. Rikkers, W.; Lawrence, D. Mental health help-seeking experiences and service use among Australian first responders. *Aust. J. Psychol.* **2021**, *73*, 125–133. [CrossRef]
23. DePierro, J.; Lowe, S.; Katz, C. Lessons learned from 9/11: Mental health perspectives on the COVID-19 pandemic. *Psychiatry Res.* **2020**, *288*, 113024. [CrossRef]
24. Drew, J.M.; Martin, S. A National Study of Police Mental Health in the USA: Stigma, Mental Health and Help-Seeking Behaviors. *J. Police Crim. Psychol.* **2021**, *36*, 295–306. [CrossRef]
25. Corrigan, P. How stigma interferes with mental health care. *Am. Psychol.* **2004**, *59*, 614. [CrossRef]
26. Hoge, C.W.; Auchterlonie, J.L.; Milliken, C.S. Mental health problems, use of mental health services, and attrition from military service after returning from deployment to Iraq or Afghanistan. *JAMA* **2006**, *295*, 1023–1032. [CrossRef] [PubMed]

27. Ricciardelli, R.; Carleton, R.N.; Groll, D.; Cramm, H. Qualitatively unpacking Canadian public safety personnel experiences of trauma and their well-being. *Can. J. Criminol. Crim. Justice* **2018**, *60*, 566–577. [CrossRef]
28. Adams, T.M.; Stewart, L.D. Chaos theory and organizational crisis: A theoretical analysis of the challenges faced by the New Orleans Police Department during Hurricane Katrina. *Public Organ. Rev.* **2015**, *15*, 415–431. [CrossRef]
29. Stuart, H. Mental illness stigma expressed by police to police. *Isr. J. Psychiatry Relat. Sci.* **2017**, *54*, 18–23.
30. Heaney, C.A. Worksite health interventions: Targets for change and strategies for attaining them. In *Handbook of Occupational Health Psychology*; Quick, J.C., Tetrick, L.E., Eds.; American Psychological Association: Washington, DC, USA, 2003; pp. 305–323. [CrossRef]
31. Linnan, L.; Fisher, E.B.; Hood, S. The power and potential of peer support in workplace interventions. *Am. J. Health Promot. AJHP* **2013**, *28*, TAHP2–TAHP10.
32. Rowland, S.A.; Berg, K.E.; Kupzyk, K.A.; Pullen, C.H.; Cohen, M.Z.; Schulz, P.S.; Yates, B.C. Feasibility and effect of a peer modeling workplace physical activity intervention for women. *Workplace Health Saf.* **2018**, *66*, 428–436. [CrossRef]
33. Festinger, L. A theory of social comparison processes. *Hum. Relat.* **1954**, *7*, 117–140. [CrossRef]
34. Simoni, J.M.; Franks, J.C.; Lehavot, K.; Yard, S.S. Peer interventions to promote health: Conceptual considerations. *Am. J. Orthopsychiatry* **2011**, *81*, 351. [CrossRef]
35. Pruckner, G.J.; Schober, T.; Zocher, K. The company you keep: Health behavior among work peers. *Eur. J. Health Econ.* **2020**, *21*, 251–259. [CrossRef]
36. Vogel, D.L.; Wade, N.G.; Hackler, A.H. Perceived public stigma and the willingness to seek counseling: The mediating roles of self-stigma and attitudes toward counseling. *J. Couns. Psychol.* **2007**, *54*, 40. [CrossRef]
37. Mead, S.; Hilton, D.; Curtis, L. Peer support: A theoretical perspective. *Psychiatr. Rehabil. J.* **2001**, *25*, 134. [CrossRef]
38. Davidson, L.; Chinman, M.; Kloos, B.; Weingarten, R.; Stayner, D.; Tebes, J.K. Peer support among individuals with severe mental illness: A review of the evidence. *Clin. Psychol. Sci. Pract.* **1999**, *6*, 165. [CrossRef]
39. Repper, J.; Carter, T. A review of the literature on peer support in mental health services. *J. Ment. Health* **2011**, *20*, 392–411. [CrossRef] [PubMed]
40. Nash, W.P. *Operational Stress Control and Readiness (OSCAR): The United States Marine Corps Initiative to Deliver Mental Health Services to Operating Forces*; Headquarters Marine Corps for Manpower and Reserve Affairs: Quantico, VA, USA; Defense Technical Information Center: Fort Belvoir, VA, USA, 2006. Available online: https://apps.dtic.mil/sti/citations/ADA472703 (accessed on 15 February 2021).
41. Money, N.; Moore, M.; Brown, D.; Kasper, K.; Roeder, J.; Bartone, P.; Bates, M. Best practices identified for peer support programs. *Def. Cent. Excell. Psychol. Health Trauma. Brain Inj.* **2011**, 1–50.
42. Jeannette, J.M.; Scoboria, A. Firefighter preferences regarding post-incident intervention. *Work Stress* **2008**, *22*, 314–326. [CrossRef]
43. Solomon, P. Peer support/peer provided services underlying processes, benefits, and critical ingredients. *Psychiatr. Rehabil. J.* **2004**, *27*, 392. [CrossRef]
44. Fugas, C.S.; Meliá, J.L.; Silva, S.A. The "is" and the "ought": How do perceived social norms influence safety behaviors at work? *J. Occup. Health Psychol.* **2011**, *16*, 67. [CrossRef]
45. Zimmerman, R.S.; Connor, C. Health promotion in context: The effects of significant others on health behavior change. *Health Educ. Q.* **1989**, *16*, 57–75. [CrossRef]
46. Karanika-Murray, M.; Weyman, A.K. Optimising workplace interventions for health and well-being: A commentary on the limitations of the public health perspective within the workplace health arena. *Int. J. Workplace Health Manag.* **2013**, *6*, 104–117. [CrossRef]
47. Egan, M.; Bambra, C.; Petticrew, M.; Whitehead, M. Reviewing evidence on complex social interventions: Appraising implementation in systematic reviews of the health effects of organisational-level workplace interventions. *J. Epidemiol. Community Health* **2009**, *63*, 4–11. [CrossRef]
48. Jessiman-Perreault, G.; Smith, P.M.; Gignac, M.A. Why Are Workplace Social Support Programs Not Improving the Mental Health of Canadian Correctional Officers? An Examination of the Theoretical Concepts Underpinning Support. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2665. [CrossRef]
49. Biron, C.; Karanika-Murray, M. Process evaluation for organizational stress and well-being interventions: Implications for theory, method, and practice. *Int. J. Stress Manag.* **2014**, *21*, 85. [CrossRef]
50. Nielsen, K.; Randall, R. Opening the black box: Presenting a model for evaluating organizational-level interventions. *Eur. J. Work Organ. Psychol.* **2013**, *22*, 601–617. [CrossRef]
51. Nielsen, K.; Fredslund, H.; Christensen, K.B.; Albertsen, K. Success or failure? Interpreting and understanding the impact of interventions in four similar worksites. *Work Stress* **2006**, *20*, 272–287. [CrossRef]
52. Golan, M.; Bacharach, Y.; Bamberger, P. Peer assistance programs in the workplace. *Contemp. Occup. Health Psychol. Glob. Perspect. Res. Pract.* **2010**, *1*, 169–187.
53. van Berkel, J.; Boot, C.R.; Proper, K.I.; Bongers, P.M.; van der Beek, A.J. Process evaluation of a workplace health promotion intervention aimed at improving work engagement and energy balance. *J. Occup. Environ. Med.* **2013**, *55*, 19–26. [CrossRef] [PubMed]
54. Mayer, R.C.; Davis, J.H.; Schoorman, F.D. An integrative model of organizational trust. *Acad. Manag. Rev.* **1995**, *20*, 709–734. [CrossRef]

55. Cook, J.; Wall, T. New work attitude measures of trust, organizational commitment, and personal need nonfulfillment. *J. Occup. Psychol.* **1980**, *53*, 39–52. [CrossRef]
56. Bandura, A. Guide for constructing self-efficacy scales. *Self-Effic. Beliefs Adolesc.* **2006**, *5*, 307–337.
57. Reuter, T.; Ziegelmann, J.P.; Wiedemann, A.U.; Geiser, C.; Lippke, S.; Schüz, B.; Schwarzer, R. Changes in intentions, planning, and self-efficacy predict changes in behaviors: An application of latent true change modeling. *J. Health Psychol.* **2010**, *15*, 935–947. [CrossRef]
58. Nielsen, K.; Abildgaard, J.S. Organizational interventions: A research-based framework for the evaluation of both process and effects. *Work Stress* **2013**, *27*, 278–297. [CrossRef]
59. Webb, T.L.; Sheeran, P. Does changing behavioral intentions engender behavior change? A meta-analysis of the experimental evidence. *Psychol. Bull.* **2006**, *132*, 249. [CrossRef] [PubMed]

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Article

Community Resident Perceptions of and Experiences with Precarious Work at the Neighborhood Level: The Greater Lawndale Healthy Work Project

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Abstract: Work is a key social determinant of health. Community health and well-being may be impacted in neighborhoods with high proportions of people engaged in precarious work situations compounded by health inequities produced by other social determinants associated with their residential geography. However, little is known about how community residents experience work at the neighborhood level nor how work impacts health at the community-level, particularly in communities with a high proportion of residents engaged in precarious work. We sought to understand, through participatory research strategies, how work is experienced at the community level and to identify community interventions to establish a culture of healthy work. As part of a mixed-methods community health assessment, community researchers conducted focus groups with residents in two high social and economic hardship neighborhoods on Chicago's southwest side. Community and academic researchers engaged in participatory data analysis and developed and implemented member-checking modules to engage residents in the data interpretation process. Twelve focus group discussions (77 community resident participants) were completed. Three major themes emerged: systematic marginalization from the pathways to healthy work situations; contextual and structural hostility to sustain healthy work; and violations in the rights, agency, and autonomy of resident workers. Findings were triangulated with findings from the concept-mapping research component of the project to inform the development of a community health survey focused on work characteristics and experiences. Listening to residents in communities with a high proportion of residents engaging in precarious work allows for the identification of nuanced community-informed intervention points to begin to build a culture of healthy work.

Keywords: precarious work; qualitative research; community health; community-based participatory research; occupational health; social determinants of health

1. Introduction

There is no specific definition of precarious employment, but several investigators have described features or characteristics of precarious work, including unstable or temporary work, low wages, exposure to hazardous working conditions, insufficient or uncertain hours with irregular and unpredictable schedules, a high risk of unemployment, lack of access to social protection and economic benefits (e.g., a living wage or health and retirement

benefits), little opportunity for advancement, legal and practical barriers to joining a union or bargaining collectively, limited protection from discrimination and exploitation, and powerlessness to exercise legally granted workplace rights [1–3]. Types of precarious employment include temporary work, direct hire on temporary labor contracts, hiring through temporary employment agencies, on call/daily hire work, contract work, outsourcing to other companies, independent contractors, and involuntary part-time work [4].

1.1. Health Impacts of Precarious Work

An accurate estimate of non-standard employment, including precarious employment, is difficult, but several sources indicate that this type of work arrangement is increasing [4–6], especially in certain segments of the economy. African Americans and Latinx and those who are foreign-born are over-represented in precarious employment. Workers in precarious jobs have lower levels of education [5,7], experience higher levels of stress, and work in dangerous conditions that put them at greater risk of occupational injury and illness [7] and workplace fatality [7,8]. Precarious employment is associated with a deterioration in occupational health and safety (OHS) in terms of injury rates, disease risk, hazard exposures, and worker (and manager) knowledge of OHS and regulatory responsibilities [9].

Limited data suggest that precarious jobs are more dangerous and adversely impact health away from work. Precarious jobs are similar to unemployment in their adverse impacts on mental health, causing anxiety and depression, and may be more debilitating in the long run than having no job [10,11]. Research shows that the prevalence of anxiety and depressive disorders is similar among those who have jobs of poor psychosocial quality (i.e., jobs that have high demand, low control, are insecure, and have poor job esteem, defined as the level of respect and dignity an individual believes is associated with his or her job [12]) and those who are unemployed [13–15]. A review of international research found overwhelming evidence that, compared to full time work, precarious work is associated with worse psychological strain and higher physical injury rates [9]. One reason for these higher rates may be high levels of exposure to psychosocial risk factors and the association of these risk factors with occupational illness and injury [16–22]. Workers in precarious jobs are relegated to positions of low status and power; the associated tendency for low-status workers to be depersonalized, devalued, and taken advantage of [23,24] greatly increases exposure to psychosocial stressors that are detrimental to worker health, most notably harassment, bullying, and discrimination. These exposures may be more detrimental to the health of workers in precarious jobs compared to those in traditional workplaces because those workers are less likely to have access to traditional sources of protection (e.g., a formal employer, a human resources department, a supportive supervisor, a labor union), and thus are less likely to be able to end these harmful abuses.

As others have observed, work as a determinant of health is complex but can be described as including both work arrangements and working conditions [1,25]. The nature of precarious employment leaves workers vulnerable to direct effects of the work arrangement (stress related to unemployment or employment insecurity) and indirect effects (adverse physical and psychosocial working conditions); it also makes them susceptible to the social factors outside of working conditions that lead to poorer health (insufficient or uncertain income, lack of access to health care and other social benefits) [26].

Addressing the health of people at work is now recognized as an important strategy to improve population health [27]; however, much attention is focused on interventions to reduce health hazards and promote healthy behaviors. Traditional approaches to workplace health and safety protections are employer- and worksite-based, as are traditional workplace health-promotion programs. Many workers with precarious jobs do not have a regular employer or worksite. For example, home care, domestic, and temporary workers may change jobs frequently, move in and out of employment, and work for multiple employers.

The CDC/NIOSH Future of Work initiative prioritizes the impacts of precarious employment arrangements on the workplace, workers, and the workforce [28] The initiative

promotes implementation of the Total Worker Health® (TWH) approach that integrates protection from work-related safety and health hazards with the promotion of injury- and illness-prevention efforts to advance worker well-being while also underscoring the inextricable relationships that exist between these issues both on- and off-the-job, including those which involve workers' families, communities, and society as a whole [29]. Current models of workplace culture of health [28–35] preclude communities of workers in non-traditional work settings, such as precarious work. Thus, while it is important to consider and advocate for workplace interventions, traditional workplace health and safety policies, programs, and practices may not be feasible for or reach the increasing number of people working in precarious jobs.

Interventions to address precarious employment arrangements need to move beyond those directly involving the workers and even beyond workplaces or employers; they must address the upstream economic, political, and social drivers of precarious employment by intervening for institutional changes [27,36–38], and they must include the voices of workers from communities experiencing high rates of precarious employment. Therefore, efforts should be focused at the fulcrum of the local level. Neighborhoods and communities where precarious work is an important feature of the employment landscape are vital to understanding the application of TWH principles by synergizing worker health protection and worker health-promotion programs with community stakeholders: local organizations that advocate for worker protection, i.e., worker centers and similar community-based organizations and unions that represent workers with precarious jobs; employer agencies that hire people into precarious work; community- and faith-based organizations and local government agencies involved in community health promotion efforts; and local healthcare delivery organizations.

1.2. Precarious Work at the Neighborhood Level

Opportunities for work in major cities are significantly influenced by zip code due to systemic racism embedded in historical processes that segregated urban communities in the United States, like Chicago, by race, ethnicity, and income [39,40]. Compounded by power differentials related to social position (at the intersections of race/ethnicity, class, gender, and immigration status), residents in urban neighborhoods that are predominantly Black and Latinx have higher proportions of residents engaged in precarious work [41,42]. Community health and well-being may be impacted in neighborhoods with high proportions of people engaged in precarious work situations compounded by health inequities produced by other social determinants associated with their residential geography. Precarious work alone causes stress due to unpredictability of work and working hours, less time to take care of family members, and even less time for civic engagement [26,43]. Low-income workers are less likely to be able to refuse work that they know is unsafe and exploitative. Given how work opportunities can be structured by where you live and that increasing knowledge on how where one is born, lives, works, and plays impacts one's health [44], neighborhoods are an underappreciated setting for worker health promotion. COVID-19 has had a significant impact on nearly all work situations but has most profoundly impacted those already in precarious work, resulting in sudden unemployment, severe underemployment, increase risk for exploitation, or sudden increased exposure to health hazards at work [45].

2. Background

2.1. The Greater Lawndale Healthy Work Project

The Greater Lawndale Healthy Work (GLHW) project in the University of Illinois at Chicago (UIC) Center for Healthy Work (a NIOSH Center of Excellence) is a community-driven, community-based participatory research (CBPR) project to determine the context of and barriers and pathways to healthy work in two high-hardship neighborhoods on Chicago's southwest side, North Lawndale and South Lawndale (known to residents as Little Village), which together are referred to as "Greater Lawndale (GL)". This participa-

tory research project in its sixth year of development is an outgrowth of the Little Village Participatory Community Health Assessment (LVCHA). The LVCHA was established in 2010 to be a sustained, student-engaged, reciprocal community–academic partnership with organic community-based organizational leadership for community health inquiry. Issues relating to work and occupation as determinants of resident and neighborhood health consistently emerged across research components in the LVCHA, which led to the focus on promoting healthy work at the neighborhood level in the GLHW project.

2.2. Partner Neighborhoods

North Lawndale and Little Village are two neighborhoods that are historically segregated. North Lawndale is comprised of 32,806 residents, with 86.8% identifying as Black. The median household income in North Lawndale is $28,897 compared to the Chicago median income of $55,703. About 14.41% of residents are unemployed [46]. Nearly half of North Lawndale and Little Village residents are not in the labor force compared to 33% in Chicago. A total of 55.7% of residents have no education beyond high school compared to 38.4% of Chicagoans [47]. Little Village has 72,091 residents and is the second most densely populated community area in Chicago. The median income is $33,622. Little Village ranks third highest in the percent of residents who identify as Latinx (82.6%), and nearly 40% are foreign born [46]. More than 76.5% of residents speak Spanish as their primary language at home [47]. About 9% of residents are unemployed, and 49.9% and 76% of residents have no education beyond high school [46].

North Lawndale is ranked 15th out of 77, and Little Village is ranked the 7th highest in social and economic hardship across the 77 community areas in Chicago [46] (Table 1). Both areas have relatively similar ratios between male and female populations. With respect to community social determinants of health indicators, GL experiences more crowded housing. The Chicago rate of crowded housing is 3.6%, whereas in LV, it is 10.4%. The life expectancy gap between North Lawndale and the rest of the city of Chicago is significant, as the Chicago average is 77 years, and the North Lawndale average is only 69 years old. Years of Potential Life Lost (YPLL) for the city is 8131, whereas North Lawndale has an estimate of almost double at 16,013 (LV at 4831) [46].

In terms of socio-economic indicators, individuals in Greater Lawndale (GL) report a higher proportion of employment in low-wage jobs that require less formal educational qualifications compared to the city of Chicago [48]. Residents of North Lawndale are mostly employed in retail trade and healthcare and social assistance, and residents of Little Village are mainly employed in manufacturing and accommodation and food services as well as administrative support and waste management. Some 80% of these jobs are in the private sector where more than 20% do not have any health insurance coverage. Non-standard work arrangements are associated with lack of benefits, low wages, and unstable employment with little to no safety regulation [48]. As such, they are largely unprotected by standard labor laws and workers' and communities' employment rights. Industries with the highest representation in GL also have higher incidences of injury and illness in comparison to average national and state (Illinois) injury/illness rate (Figure 1). When education level and individual earnings are considered, on average, individuals in the city of Chicago earn more money across all levels of education [47].

Table 1. Comparison of Socio-demographic Characteristics of North Lawndale, Little Village, and Chicago.

Category	Indicator	Units	Time Period	North Lawndale	North Lawndale Margin of Error	Little Village	Little Village Margin of Error	Chicago	Chicago Margin of Error
Demography	Foreign born	% of residents	2015–2019	4.08	1.18	39.92	2.79	20.64	0.11
Demography	Limited English proficiency	% of residents	2015–2019	1.56	1.23	21.2	2.59	7.64	0.08
Population	Non-Hispanic White	% of residents	2015–2019	4.52	1.72	3.98	0.85	33.28	0.1
Population	Non-Hispanic Black	% of residents	2015–2019	86.8	5.9	12.9	2	30.1	0.2
Population	Latinx	% of residents	2015–2019	9.4	0.2	82.6	4.1	29.3	0.2
Population	Asian or Pacific Islander	% of residents	2015–2019	0.2	0.2	0.1	0.2	6.7	0.1
Population	Population	residents	2015–2019	32,086	1964	72,091	3254	2,709,534	66
Quality of Life	Years of Potential Life Lost (YPLL)		2013–2017	16,013	159	4831	58	8131	29
Quality of Life	Life expectancy	years	2019	69.1		78.9		77.3	
Infectious Disease	COVID-19 deaths	deaths	2020	77		194		4704	
Infectious Disease	COVID-19 death rate	rate per 100,000 population	2020	240.1		268.9		174.6	
Housing & Transit	Crowded housing	% of occupied housing units	2015–2019	3.19	1.94	10.41	4.67	3.62	0.09
Housing & Transit	Rent-burdened	% of renter-occupied housing units	2015–2019	58.63	6.17	60.31	13.17	45.97	0.32
Housing & Transit	Vacant	% of housing units	2015–2019	24.51	2.71	12.89	3.73	12.16	0.14
Education	High school graduation rate	% of residents	2015–2019	77.56	5.59	56.33	4.16	85.12	0.26
Education	College graduation rate	% of residents	2015–2019	12.5	1.91	7.85	2	39.48	0.18
Education	Preschool enrollment (0–4 years)	% of toddlers	2015–2019	53.35	26.04	52.21	13.24	57.89	0.92
Employment	Unemployment rate	percentage	2015–2019	14.41	3.64	8.7	5.32	8.06	0.1
Income	Hardship Index	score	2015–2019	88.7		94.1		62.2	
Income	Median household income	Income	2015–2019	$28,897	$4275	$33,622	$5185	$55,703	$342
Income	Per capita income	Income	2015–2019	$14,849	$1261	$12,364	$1109	$35,482	$195
Income	Poverty rate	% of residents	2015–2019	38.14	5.17	27.97	6.29	18.39	0.19
Public Assistance	Food stamps (SNAP)	% of households	2015–2019	44.6	4.19	24.36	5.58	18.26	0.15
Public Assistance	Households in poverty not receiving food stamps	% of households below the poverty line	2015–2019	34.69	6.98	47.43	13.49	48.05	0.42

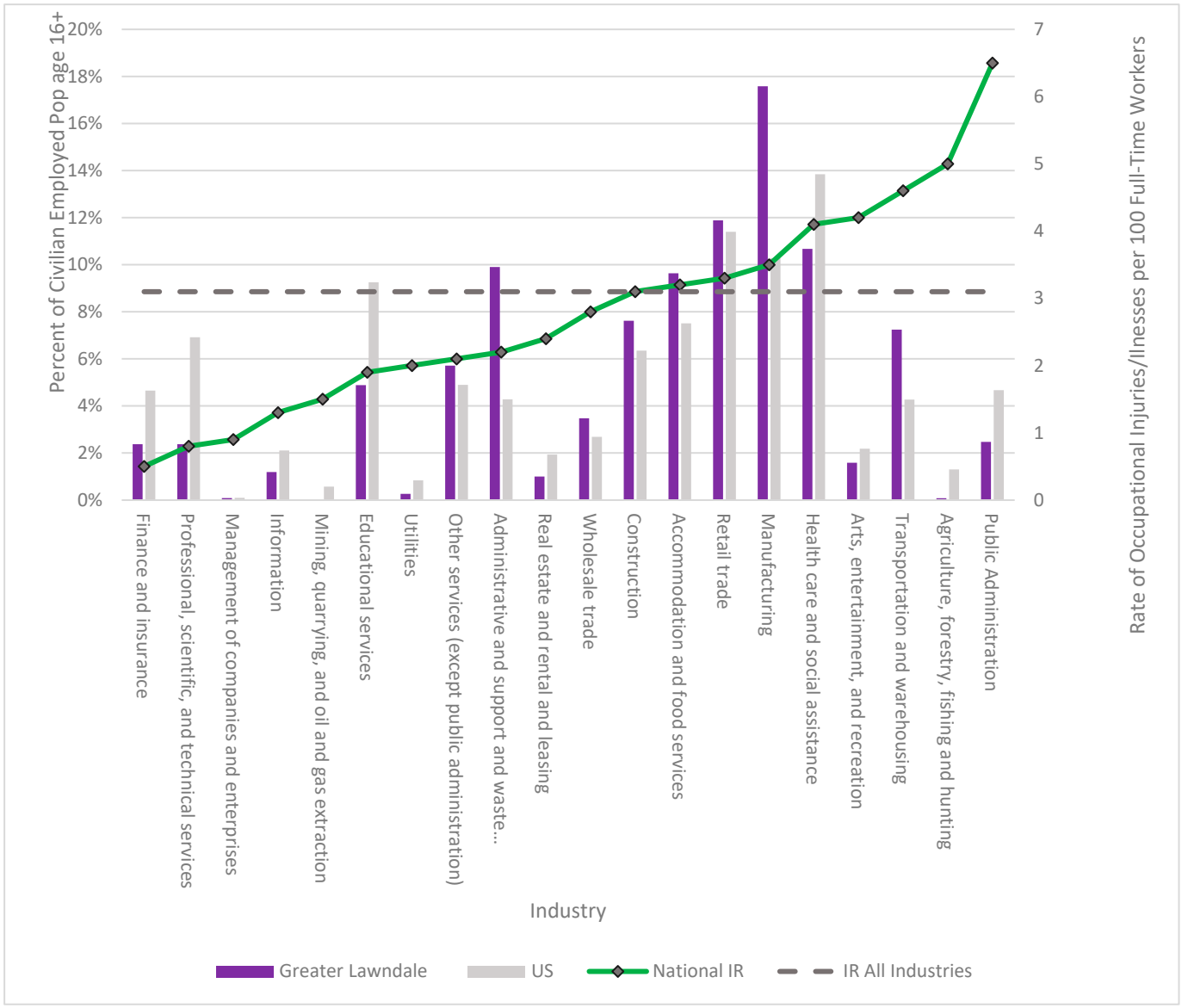


Figure 1. Industry Employment for Greater Lawndale and the United States compared to the Occupational Injury and Illness Rate for the United States.

The opportunity for economic advancement is limited in GL. Lack of access to quality education, citizenship status, and language differences are barriers to obtaining healthy work. Additionally, low-wage jobs subject workers to the risk of occupational injury and illness, which can be devastating to workers and their families, particularly those already facing poverty. The lack of opportunity hinders an individual's social position by influencing access to basic resources, such as food, housing, transportation, computing/internet, and other resources that may help them obtain healthy work. This continuous cycle of unhealthy work influencing opportunity and affecting healthy work has consequences for the general health and wellbeing of the neighborhood.

This pattern is demonstrative of the structural violence that Chicago neighborhoods on the southwest side of Chicago, like Greater Lawndale, have experienced for decades. Violence is structural when it is in the form of invisible manifestations of violence, including harm that is built into the fabric of society, creating and maintaining inequalities within and between different social groups [49,50].

2.3. Greater Lawndale Healthy Work Academic–Community Partnership

This academic–community partnership [51], now almost a decade old, is comprised on the academic side of national leaders in occupational and community health sciences; an expert in psychosocial research on workplace harassment, discrimination, and worker health; and a legal scholar who brings a transformative justice framework, the solidarity economy—a set of economic activities that aim to prioritize social profitability instead of purely financial profits—for sustainably addressing the root causes of precarious work [52]. The team also includes post-doctoral fellows, staff, and students who are community residents and/or are bicultural and bilingual. On the community side, the partnership is currently led by the GLHW Council comprised of 17 community stakeholders bringing expertise in the community, community health work, faith-based leadership, worker centers advocacy, and community development. Community-Based Participatory Research approaches [53] offer grounded, mixed-methods, participatory, exploratory research strategies that involve researchers and community participants working together to identify the mechanisms through which precarious work impacts neighborhood health and change it for the better.

In our research, we used a CBPR approach that strives to equitably involve community partners—community members and representatives of local community-based organizations and institutions—in such a way that all partners contribute their expertise and share the decision making and ownership of the research. CBPR allows for research reciprocity, leveraging existing strength and building capacity of both the community and the academic partner [53–56]. All of our activities are conducted in English and Spanish so that monolingual Spanish-speaking residents can participate. This includes simultaneous translation of our meetings and events by a professional translator who has been a GLHW partner since its origins. Community partners, residents, or representatives of GL serve as co-researchers, known as community researchers (CRs), at every stage in the research process.

The GLHW project aims to build community capacity to recognize and promote worker health through the development and piloting of community-level interventions. The project uses a mixed-methods, exploratory, sequential study design involving interviews, focus groups, concept mapping, and community health-survey methodology to characterize the experience of residents with precarious work. To date, data have been used to map the employment landscape, build an evidence-informed Conceptual Model and a community-grounded Theory of Change, and develop community interventions via an action-mapping process resulting in a community-tailored Action Roadmap (manuscript in development). In this paper, we present findings from one of our mixed-methods research components—our focus group study with residents, which explored how residents perceive and experience work at the neighborhood level in a neighborhood with high social and economic hardship.

3. Materials and Methods

Within our mixed-method, exploratory, sequential study design, we identified the need for community-driven qualitative inquiry to explore how residents perceive and experience work at the neighborhood level in a neighborhood with high social and economic hardship. Our team chose focus group methodology for our exploratory research, as it is best suited to understand the rich quality of respondent interactions to exploring common/divergent trends and/or beliefs and exploration of social norms and cultural and institutional influences [57]. This study was reviewed by an ethics board and approved by the University of Illinois Chicago Institutional Review Board (IRB) assuring best practices in respect for persons, beneficence, and justice.

3.1. Instrument Development and Training

Aligning with principles of CBPR, our academic–community partnership team co-developed the focus group guide emphasizing four domains of interest with respect to

our research question: perceptions of health, barriers to work, challenges at work, and worker's rights. We also asked about ideas for how to promote healthy work at the neighborhood level. We initially developed the focus group guide in English and then translated the instrument into Spanish. We tested the English and Spanish versions of the focus group guide in mock focus groups moderated by CRs serving as focus group moderators practicing each question and probe. When the questions on the Spanish focus group guide were not testing well (i.e., they were not understood well or failed to produce productive discourse), several of our Spanish-speaking CRs recreated the guide from scratch aligning FG questions with our overall research questions and domains. We then translated the final version of the guide from Spanish to English.

We trained 10 CRs and 2 graduate students to conduct the focus groups using the finalized versions of the focus group guide. Trainings were conducted as in-person training in English and Spanish to ground the group in qualitative research and best practice in focus group methodology. Each focus group was moderated by two CRs and/or one CR and one graduate students. All moderators were training in human subjects research.

3.2. Recruitment

The CRs led the recruitment using an IRB-approved focus group script to identify groups of residents with a shared social context. Recruitment was focused on residents with knowledge of and experience with precarious work. Purposeful sampling approaches were employed. Participants were consented to participate in the focus group and were provided with a gift card for their time. All but two focus groups (n = 12 groups) took place in GL in neighborhood settings (i.e., a church, a community meeting space, a community-based organization).

3.3. Participatory Data Analysis

We used a constructivist grounded theory approach to analysis, which provided a flexible "set of principles and practices" for co-analyzing qualitative data (as opposed to stricter rules and requirements prescribed by traditional, non-participatory, grounded theory approaches [58]. In line with a constructivist grounded theory approach, we acknowledge that our understanding of the data is an interpretation, or construction, of the lived experiences and opinions of our participants and their communities rather than an exact representation. We believe this approach to analysis is most appropriate for answering our key research question given its emphasis on interpretation rather than representation as well as its focus on understanding processes and its utility in developing theories about phenomena of interest [58,59]. Rather than relying on a priori codes, as is common in other approaches to qualitative data analysis, in line with constructivist grounded theory, we used the process of memoing of audio segments to allow for the generation of a codebook. Coding is a systematic process of disaggregating text and reclassifying it by categories that represent views and experiences repeated within and across focus group interviews. Memoing entails making notations of researchers' conceptual and theoretical insights relating to the themes [60].

We formed an academic–community qualitative data analysis think tank [61] to engage in participatory memoing as part of the data analysis process to develop the codebook. We determined that the audio versions of the focus groups were better suited to memoing than verbatim transcripts, as we would be able to keep the data in their original language and preserve emotion, emphasis, richness. This would also enable us to avoid losing meaning in the data that may be lost in transcribing and translation. Developing the codebook through our think tank allowed for group code identification and processing of emergent themes, leveraging the expertise of all members (community and academic), and attended to issues of trustworthiness of the analysis, i.e., credibility [62]. The final codebook contained a few deductive, a priori codes but consisted mostly of more interpretive, grounded codes. Based on our participatory, iterative analytic process, we determined that we had developed a codebook suitable to the data and that theoretical saturation had been met. We used

Dedoose as our computer-assisted qualitative data analysis software. See Figure 2 for the steps to the analysis.

Qualitative Data Analysis Think Tank Analytic Steps

1) Academic researchers selected audio segments to memo based on the following:
    - Must relate to *how do residents experience work in their community* and/or relates to some element of health or work.
    - Is a coherent narrative with some sense of beginning, middle, and end.
    - Is a story or dialogue that is complex or comprehensive or compelling.
    - It helps answer the research question
    - Is under 5 minutes.
2) Academic and Community Researchers meet in small debriefing groups by language preference (English, Spanish)
3) Listen and debrief the meaning of the audio clip using memoing guide
    - The memoing guide instructed members to consider for each audio clip: What is happening? How does it help us understand how residents experience work? What language stands out to you? Why? What word(s) (code(s)) would you attach to the segment to describe its meaning?
4) Identify codes from the memoing
5) Build a codebook from the debriefing discussion
6) Apply codebook to the audio data

Figure 2. GLHW Qualitative Data Analysis Think Tank Analytic Steps.

Multiple codes (including the first, second, and fourth author) were debriefed regularly to ensure intercoder reliability i.e., dependability. After data were coded, we selected analytic codes to examine. We looked at code patterns and relationships, including code frequency, code co-occurrence, and focus group type by code count. We drafted the three themes and cross-cutting theme [58,59,63]. Think tank members shared the emergent themes with broader academic–community research team, and adjustments were made to specify the role that relationships play and how experiences are embodied by residents.

Our community–academic team then developed member-checking modules (MCM) to test the trustworthiness, i.e., confirmability, of our findings by engaging residents in data interpretation. We also used the MCMs to identify best ways to "tell the community's story." Recognizing that the constructivist grounded theory approach to the data would result in rich, nuanced, descriptive insight that may not be amenable to distribution to community members, story typologies were created as a dissemination output to disseminate the findings, typically just disseminated in academic literature, to community residents (manuscript detailing the translation of research findings to story typologies pending).

4. Results

4.1. Research Participants

Seventy-seven residents participated across 12 focus groups. Focus groups ranged from 5 to 12 participants, lasting between 38 min and 120 min. Participants included day laborers, street vendors, residents participating in English as a Second Language (ESL) and General Education (GED) programs, community health workers, church members, and members of a young adult group. Half had a high school degree or less, 36% were born outside the United States, and 41% spoke primarily Spanish (See Table 2).

Table 2. Focus Group Participant Characteristics.

	Total		Little Village		North Lawndale		Other	
	N	%	N	%	N	%	N	%
Community Area	77	100%	40	52%	34	42%	3	6%
Country of birth								
U.S.	40	52%	5	13%	29	91%	4	80%
Mexico	35	45%	32	80%	2	6%	1	20%
Other	1	1%	0	0%	1	3%	0	0%
Missing	1	1%	1	3%	0	0%	0	0%
Language spoken at home								
Spanish	28	36%	27	68%	2	6%	0	0%
More Spanish than English	4	5%	6	15%	1	3%	1	20%
Both equally	8	10%	5	13%	3	9%	0	0%
More English than Spanish	8	10%	1	3%	3	9%	0	0%
Only English	29	38%	1	3%	23	72%	4	80%
Education								
Less than HS	19	25%	17	43%	2	6%	0	0%
HS graduate	19	25%	13	33%	6	18%	0	0%
Some college	8	10%	4	10%	4	12%	0	0%
College graduate or higher	31	40%	6	15%	22	65%	3	100%

4.2. Insights

Overall, focus group participants emphasized the importance of the need for healthy work to promote health in GL and described that residents' negative experiences with seeking, getting, keeping, or dealing with issues at work impact their relationships, families, and the community as a whole. Three main themes emerged with one cross-cutting theme:

1. Systematic marginalization from the pathways to decent work situations
2. Contextual and structural hostility to sustain healthy work
3. Violations in the rights, agency, and autonomy of resident workers
4. Cross-Cutting Theme: Strained social resources that exist as a consequence of inequities experienced by community residents with respect to work

Text in italics below are verbatim language from focus group participants themselves. See Figure 3 for a visual depiction of the analytic codes. The larger the font size, the more frequently the code was used.



Figure 3. Analytic Code Word Cloud.

4.3. Systematic Marginalization from Pathways to Decent Work Situations

Focus group participants described obstacles to securing healthy work for community members that are structural and systemic. A participant explained:

"There are problems larger than [Greater Lawndale] that are robbing residents of jobs."

Residents face discrimination in identifying jobs, needing to rely on word of mouth from family and friends, and also face discriminatory hiring practices by documentation status, language, criminal record history, age, gender, and race/ethnicity. A research participant reflected:

"It's racism . . . lets be real."

Relying on one's social network for work is key ("*you have to know somebody to get in*"), but this leads to a common kind of work that is low wage, high risk, and unstable.

Lack of community resources to prepare residents for work were seen as the result of systems of oppression that result in economic and social disinvestment in Greater Lawndale. For example, participants noted the "*lack of investment in*" and poor quality of public education results in less skilled, prepared workers. There were some very good community resources noted, but they were described as insufficient, with few good job training opportunities in the community. It was also noted, especially among the focus group with young adults, that there are few healthy work mentors or apprentice opportunities, as most people are engaged in precarious work.

An inherent community-level disadvantage exists with community contextual barriers to healthy work: lack of affordable, quality child care (familial resources are already strained); limited affordable, reliable transportation (workers are exploited by employer transportation options); concerns for safety in getting to and from work that restrict options for some work; job type availability (most work at the community level is precarious in nature); few good jobs existing in the neighborhood (disinvested employers, many who live outside of the neighborhood, "*go back to their mansions in the suburbs*", and "*won't*" hire residents). One participant explained:

"There is just not the economic development [in GL] *that is needed."*

4.4. Contextual and Structural Hostility to Sustain Decent Work

Once secured, residents experience hostile work conditions that threaten job security. Contextual challenges are seen in the nature of work and conditions at work as well as the exploitive power of the employer.

The nature of work described was precarious in the unpredictable hours, unknown terms, low wage, and long hours. Low wage and poor terms require more work and restrict consumption potential and family/leisure time. Work conditions were described as difficult, hard labor, and repetitive, with insufficient information and protective gear. Challenges due to the power of the employer (which can be used to exploit) include overt sexual, racial/ethnic, language, and documentation status discrimination as well as a culture that prioritizes profits over people, relying on a disposable workforce (e.g., "*someone else is waiting in line for this job*") that does not need training or protection of rights. Some described no control at work in terms of safety, access to food and drink, and use of the bathroom as extreme exploitation that is not uncommon. Some community issues also threaten job stability. For example, fear and concerns for safety while traveling to jobs due to community crime and police harassment.

4.5. Violations in the Rights, Agency, and Autonomy of Resident Workers

Focus group participants emphasized that workers overall do not know their rights. However, participants questioned the relevance of knowing one's rights if (a) your human rights are already being violated, and (b) you are not able to exercise them without risking your job. Employers deliberately keep workers in the dark so as to keep them powerless. Employers face no consequences to their exploitation since it leads to profits. Dehumanizing

types of work and work conditions or treatment at work were described as compromising one's self-respect but endured to provide for themselves and their family. One focus group participant suggested that:

> *"Nothing's going to change . . . so I think it's about just getting used to it even though it is not right."*

Risk for exploitation prohibits self-advocacy. Healthy work as a human right brings dignity, satisfaction, and pride. When barriers are in place to healthy work, there are individual, family, and community health consequences. A research participant described that:

> *"Dehumanizing work leads workers to think that they are paid pennies, so they must deserve pennies."*

Power is central to experiencing work exploitation. The power of the employer to exploit is great, as is the power of the system to oppress and create barriers. One community member described the tension:

> *"These are structural issues but with a very personal affect*—[we both] *struggle with* [this] *and feel powerless against [it]."*

4.6. Cross-Cutting Theme: Strained Social Resources as a Consequence of Inequities

Across the three themes, the issue of stress on the individual and their social networks emerged as a consequence of the inequities resident' experience. The inability to get ahead despite excessive effort was exhausting and defeating. Impacts were described on one's physical health both in terms of hard labor since there are few options but to take difficult work ("*aqui todos trabajamos*") but also since one must ignore health due to lack of resources (health insurance) and time (cannot take off work or risk losing work) to care for oneself. This was depicted by one focus group participant explaining the phenomenon as follows:

> *"Feels like you are running on a hamster wheel and you are sprinting and not getting anywhere."*

Work-related stress results in family strain, with a worker either projecting frustration on one's family or deliberately keeping stressors from their family to protect them, also described as "*bottling up*" feelings. Participants described the strain in this way: "*you can give every bit of yourself every single day and still not come out ahead*". Excessive barriers to work and poor work conditions make informal, illicit work an option.

Workers are influenced by community contextual issues to stay in precarious work situations due to devotion to family and social norms of unfair work. This creates chronic strain on the community. Participants described that the pathways to healthy work are too fraught, and rare opportunities for healthy work were insufficient and not the norm and are perceived as "*not for me*" and are avoided. Strong social bonds between residents engaged in exploitive work situations serve to build resilience, but the common referents in the neighborhood may also set lower expectations and reduce opportunities for group action against the exploitation. Social cohesion and capital are useful for getting and keeping jobs but may also hold residents back from speaking out against injustices. Disrupting systematic barriers to healthy work and creating good jobs for all while building resiliency and solidarity among residents were described as critical actions to promote health in Greater Lawndale.

5. Discussion

Work and, more specifically, access to healthy, stable work is central to the health and well-being of communities. Findings from our focus groups with residents of Greater Lawndale (n = 77) suggest that residents in this high-hardship area of Chicago experience unique exposures to and within precarious work situations as well as barriers to obtaining healthy work, thereby threating individual- and community-level health. These exposures and barriers are systemic, including hostile job situations that threaten job security, lack of awareness among residents of their workers' rights, and violation of workers' rights. While

these experiences may be relatively unique to residents of Greater Lawndale relative to other community areas in Chicago, they align with exposures and barriers experienced by marginalized and minoritized people engaged in precarious work across work settings and jurisdictions at a national and international scale. For example, analyses of the nationally representative General Social Survey of adults in the United States find that precarity in work hours are ubiquitous across the labor market, but that workers who are Black, young, and without a college degree are the most exposed to precarious work, characterized by volatile work hours, limited schedule input, and short advance notice to work [64]. In addition, white workers who receive salaries are less likely than workers of other races/ethnicities, irrespective of salary/pay, to report little to no control over the number of hours they work. Both of these phenomena emerged as salient among participants across our focus groups.

Our data also demonstrate how the phenomena and context of precarious work strains community residents such that workers internalize or embody stressful work-related experiences, producing additional physical and mental health consequences. With so many people in the neighborhoods facing the same challenges, social norms are established that normalize, perpetuate, and sustain unjust and inequitable work experiences. Prior research consistently supports a link between precarious work and negative mental health at the individual level. [63,64]. Our study begins to elucidate this link at the neighborhood level.

The drivers of precarious and lack of healthy work intersect at multiple levels of social ecology, including classism, sexism, ableism, and structural racism. Indeed, standard, healthy work was initially available only to men and white people [65]. Thus, interventions to address the problems discussed by residents of Greater Lawndale and advance worker equity and well-being require multi-level approaches that address intersecting systems of inequity (e.g., structural racism) as well as more proximal determinants of proximate determinants of precarious employment (e.g., lack of jobs in the neighborhood, access to reliable and safe transportation, workforce training programs) and health simultaneously [66].

It is important to note that these data were collected and initially analyzed prior to the emergence of the COVID-19 pandemic. COVID-19 has predictably served as a clarifying event illuminating occupational inequities and health inequities in these communities in which a large proportion of residents are at high risk for infection at work (due to their status as essential workers) and who are already experiencing or are at risk for economic instability. COVID-19 case and death rates have consistently been disproportionately high in the partner communities' zip code (see Figure 2). Latinx and non-Latinx Black residents have been disproportionately affected by COVID-19 in Chicago, representing 40% and 33% of all COVID-19 Chicago deaths. From March 2020, there have been a total of 41,430 confirmed cases in Greater Lawndale zip codes. From March 2020, there had been a total of 777 deaths in Greater Lawndale zip codes [67] (Figure 4).

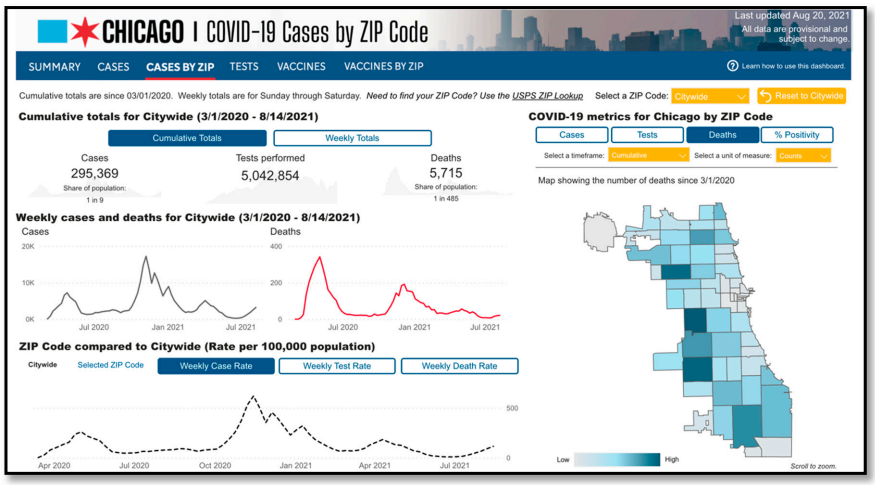


Figure 4. COVID Cases and Deaths in Greater Lawndale (zip codes 60623, 60624, 60608, 60612, 60632).

The experiences residents of Greater Lawndale described in the focus groups highlight many of the same experiences that precarious and essential workers reported during the pandemic. These include sudden unemployment, underemployment, and increased exploitation [43]. Furthermore, COVID-19 produced excessive stress and strain on both precarious and essential workers [67,68], something that residents of Greater Lawndale in our focus groups described as a regular occurrence.

Our findings complement increasing evidence that structural, upstream factors are responsible for the neighborhood level strains described [69,70]. Our study addresses a gap in research on how residents perceive and experience work opportunities in their neighborhoods. With increasing recognition of the need for qualitative research for health equity, few recent studies have examined perceptions of specific occupations within a neighborhood [71–73] or work transitions (due to age or gentrification) [74], but there remains little research on how work is experienced within a neighborhood.

6. Limitations

While our participatory approach to analyzing the audio data allowed for more equitable engagement of partners in the analytic process, academic researchers identified the audio segments to be memoed by the think tank members. This may have resulted in a biased collection of audio segments. However, of note were two conditions that addressed this potential limitation: several of our academic team members are also community members, and focus group moderators were community members and were able to request certain segments of the focus group to be memoed. Academic–community partnership team members who were monolingual English speakers were unable to participate in the data analysis that happened within Spanish-speaking groups. Focus groups were intended to be 90 min long. However, the average focus group was shorter, lasting only 72 min. Another limitation was the reliance on convenience sampling of residents. Given the influence of shared social context, it is possible that different stories would be heard if a randomized approach to sampling and recruitment had been employed.

Iterative Research Design

The findings from the focus group study examining how residents perceive and experience work at the neighborhood level were triangulated with findings from our concept-mapping study examining residents' perceptions on how work impacts health in GL. The combined findings informed the sections of the 119-item community health survey that provided more detailed description of work than is amenable through qualitative methods (manuscript under review).

The experience of the CR in serving as focus group moderators also led to the adaption of a trauma-informed approach to our iterative research, as the discussion of experiences with work in GL that were perceived as unfair and unjust became emotional for several groups (manuscript in preparation).

The findings from the focus groups triangulated across the other research methods informed the intervention-mapping process that resulted in an Action Roadmap for community intervention (manuscript in development). We have launched three of the six primary community interventions identified: an evidence-informed, historically grounded, worker-justice-centered *loteria* game (a traditional Mexican card game, similar to Bingo) to integrate into a community awareness campaign to shift perceptions and beliefs on how work impacts health, especially for workers in precarious employment situations; a local effort to influence accountability of temporary staffing companies; and conducting and evaluating an educational workshop for community members on opportunities to create wealth through worker cooperatives. Additionally, we launched a storytelling project in collaboration with youth residents to better understand how COVID-19 has impacted the lives of workers in GL.

7. Conclusions

We found that residents describe a sense that they are systematically excluded from healthy jobs and that existing jobs in the neighborhood that can be hostile job situations that threaten job security. We also found that residents are overall unaware of their workers' rights and/or unable or feel powerless to exercise their rights without risking job loss. Social norms that normalize unjust work experiences put an emphasis on individual change. Normalization of work requires systems-level change and culture shifts at upstream levels to effect change at individual levels. Our community-driven research agenda is positioned to continue to explore the pathways through which work situations impact neighborhood health. Community-driven interventions that promote healthy work at the neighborhood level by building power, capacity, and equity can result in the systems change needed such that everyone has access to fair and healthy work.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of the University of Illinois Chicago (protocol code 2013-0128, last amendment approved 20 July 2021).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are not publicly available due to the fact that they are audio files and voice is a identifier. Further, research participants did not consent to having their voice shared publicly.

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References

1. Ahonen, E.Q.; Baron, S.L.; Brosseau, L.M.; Vives, A. *Health and Safety Issues for Workers in Nonstandard Employment*; Oxford Research Encyclopedia of Global Public Health: New York, NY, USA, 2018.
2. Vives, A.; Amable, M.; Ferrer, M.; Moncada, S.; Llorens, C.; Muntaner, C.; Benavides, F.G.; Benach, J. The Employment Precariousness Scale (EPRES): Psychometric properties of a new tool for epidemiological studies among waged and salaried workers. *Occup. Environ. Med.* **2010**, *67*, 548–555. [CrossRef] [PubMed]
3. Jeannet, A.; Bodemer, A.; Vacotto, B.; Rubiano, C.; Hobden, C.; Hoffer, F.; Demaret, L.; Laliberte, P. *From Precarious Work to Decent Work. Policies and Regulations to Combat Precarious Employment*; International Labour Organization: Geneva, Switzerland, 2011; Report Number 978-92-2-125522-2.

4. Kalleberg, A.L. Precarious Work, Insecure Workers: Employment Relations in Transition. *Am. Sociol. Rev.* **2009**, *74*, 1–22. [CrossRef]
5. Jeszeck, C.A. Contingent Workforce: Size, Characteristics, Earnings, and Benefits. 2014. GAO-15-168R. Available online: https://www.gao.gov/assets/gao-15-168r.pdf (accessed on 1 October 2021).
6. Kalleberg, A.L. Job quality and precarious work: Clarifications, controversies, and challenges. *Work. Occup.* **2012**, *39*, 427–448. [CrossRef]
7. CDC Health Disparities and Inequalities Report-United States. MMWR; 22 November 2013. Available online: https://www.cdc.gov/mmwr/pdf/other/su6203.pdf (accessed on 1 October 2021).
8. Bureau of Labor Statistics. National Census of Fatal Occupational Injuries in 2015. *News Release*, 16 December 2016.
9. Quinlin, M.; Mayhew, C.; Bohle, P. The global expansion of precarious employment, work disorganization and consequences for occupational health: A review of recent research. *Int. J. Health Serv.* **2001**, *31*, 335–414. [CrossRef] [PubMed]
10. Ferrie, J.E.; Shipley, M.J.; Stansfeld, S.A.; Marmot, M.G. Effects of chronic job insecurity and change in job security on self reported health, minor psychiatric morbidity, physiological measures, and health related behaviours in british civil servants: The Whitehall II study. *J. Epidemiol. Community Health* **2002**, *56*, 450–454. [CrossRef] [PubMed]
11. Ferrie, J.E.; Westerlund, H.; Virtanen, M.; Vahtera, J.; Kivimäki, M. Flexible labor markets and employee health. *SJWEH Suppl.* **2008**, *6*, 98–110.
12. Miller, D.G.; Madsen, S.R. The development of an instrument to address the negative perception of hospitality jobs: A pilot study. *J. Hum. Resour. Hosp. Tour.* **2003**, *2*, 75–92. [CrossRef]
13. Butterworth, P.; Leach, L.; McManus, S.; Stansfeld, S. Common mental disorders, unemployment and psychosocial job quality: Is a poor job better than no job at all? *Psychol. Med.* **2013**, *43*, 1763–1772. [CrossRef]
14. Lewchuk, W.; Clarke, M.; de Wolff, A. Working without commitments: Precarious employment and health. *Work. Employ. Soc.* **2008**, *22*, 387–406. [CrossRef]
15. Nätti, J.; Kinnunen, U.; Mäkikangas, A.; Mauno, S. Type of employment relationship and mortality: Prospective study among Finnish employees in 1984–2000. *Eur. J. Public Health* **2009**, *19*, 150–156. [CrossRef]
16. Lippel, K.; Quinlan, M. Regulation of psychosocial risk factors at work: An international overview. *Saf. Sci.* **2010**, *49*, 543–546. [CrossRef]
17. Abbe, O.O.; Harvey, C.M.; Ikuma, L.H.; Aghazadeh, F. Modeling the relationship between occupational stressors, psychosocial/physical symptoms and injuries in the construction industry. *Int. J. Ind. Ergon.* **2011**, *41*, 106–117. [CrossRef]
18. Brown, L.P.; Rospenda, K.M.; Sokas, R.K.; Conroy, L.M.; Freels, S.; Swanson, N.G. Evaluating the Association of Workplace Psychosocial Stressors with Occupational Injury, Illness, and Assault. *J. Occup. Environ. Hyg.* **2011**, *8*, 31–37. [CrossRef] [PubMed]
19. Nakata, A.; Ikeda, T.; Takahashi, M.; Haratani, T.; Hojou, M.; Fujioka, Y.; Swanson, N.G.; Araki, S. Impact of psychosocial job stress on non-fatal occupational injuries in small and medium-sized manufacturing enterprises. *Am. J. Ind. Med.* **2006**, *49*, 658–669. [CrossRef] [PubMed]
20. Goldenhar, M.L.; Williams, L.J.; Swanson, N.G. Modeling relationships between job stressors and injury and near-miss outcomes for construction labourers. *Work Stress* **2003**, *17*, 218–240. [CrossRef]
21. Turner, N.; Hershcovis, M.S.; Reich, T.C.; Totterdell, P. Work–family interference, psychological distress, and workplace injuries. *J. Occup. Organ. Psychol.* **2014**, *87*, 715–732. [CrossRef]
22. Sobeih, T.; Salem, O.; Genaidy, A.; Abdelhamid, T.; Shell, R. Psychosocial Factors and Musculoskeletal Disorders in the Construction Industry. *J. Constr. Eng. Manag.* **2009**, *135*, 267–277. [CrossRef]
23. Lamontagne, A.D.; Smith, P.M.; Louie, A.M.; Quinlan, M.; Shoveller, J.; Ostry, A.S. Unwanted sexual advances at work: Variations by employment arrangement in a sample of working Australians. *Aust. N. Z. J. Public Health* **2009**, *33*, 173–179. [CrossRef]
24. Rogers, J.K.; Henson, K.D. Hey why don't you wear a shorter skirt?: Structural vulnerability and the organization of sexual harassment in temporary clerical employment. *Gend. Soc.* **1997**, *11*, 215–237. [CrossRef]
25. Howard, J. Nonstandard work arrangements and worker health and safety. *Am. J. Ind. Med.* **2016**, *60*, 1–10. [CrossRef]
26. Muntaner, C.; Solar, O.; Vanroelen, C.; Martínez, J.M.; Vergara, M.; Santana, V.; Castedo, A.; Kim, I.-H.; Benach, J.; Network, E. Unemployment, Informal Work, Precarious Employment, Child Labor, Slavery, and Health Inequalities: Pathways and Mechanisms. *Int. J. Health Serv.* **2010**, *40*, 281–295. [CrossRef] [PubMed]
27. Krieger, N. Workers are people too: Societal aspects of occupational health disparities-an ecosocial perspective. *Am. J. Ind. Med.* **2009**, *53*, 104–115. [CrossRef] [PubMed]
28. Centers for Disease Control and Prevention. National Insitites of Occupational Safety and Health. Future of Work. Available online: https://www.cdc.gov/niosh/topics/future-of-work/default.html (accessed on 8 October 2021).
29. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the Future of Work to Safeguard the Safety, Health, and Well-being of the Workforce: A Perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef] [PubMed]
30. Division of Population Health, National Center for Chronic Disease Prevention and Health Promotion. Workplace Health Model. Centers for Disease Control. 2016. Available online: http://www.cdc.gov/workplacehealthpromotion/model/index.html (accessed on 20 December 2020).

31. Lee, M.; Hudson, H.; Richards, R.; Chang, C.; Chosewood, L.; Schill, A. *Fundamentals of Total Worker Health Approaches: Essential Elements for Advancing Worker Safety, Health, and Well-Being*; DHHS (NIOSH) Publication No. 2017-112; Natinoal Institute for Occupational Safety and Health: Cincinnati, OH, USA, 2016.
32. Burton, J. *WHO Healthy Workplace Framework and Model: Background and Supporting Ligerature and Practice*; World Health Organization: Geneva, Switzerland, 2010.
33. Centers for Disease Control and Prevention. Worksite Health ScoreCard. Workplace Health Promotion. 23 July 2019. Available online: www.cdc.gov/workplacehealthpromotion/initiatives/healthscorecard/index.html (accessed on 30 August 2019).
34. Health Enhancement Research Organization. HERO Health and Well-Being Best Practices Scorecard. HERO Scorecard. 2019. Available online: https://hero-health.org/hero-scorecard/ (accessed on 30 August 2019).
35. Cuture of Health. Harvard School of Public Health. 2021. Available online: https://www.hsph.harvard.edu/ecpe/category/culture-of-health/ (accessed on 10 July 2021).
36. Lipscomb, H.J.; Loomis, D.; McDonald, M.A.; Argue, R.A.; Wing, S. A Conceptual Model of Work and Health Disparities in the United States. *Int. J. Health Serv.* **2006**, *36*, 25–50. [CrossRef] [PubMed]
37. Baron, S.L.; Beard, S.; Davis, L.K.; Delp, L.; Forst, L.; Kidd-Taylor, A.; Liebman, A.K.; Linnan, L.; Punnett, L.; Welch, L.S. Promoting integrated approaches to reducing health inequities among low-income workers: Applying a social ecological framework. *Am. J. Ind. Med.* **2013**, *57*, 539–556. [CrossRef]
38. O'Campo, P. Invited commentary: Advancing theory and methods for multilevel models of residential neighborhoods and health. *Am. J. Epidemiol.* **2003**, *157*, 9–13. [CrossRef]
39. Rothstein, R. *The Color of Law: A Forgotten History of How Our Government Segregated America*; Liveright Publishing: New York, NY, USA, 2017.
40. Logan, J.R.; Stults, B.J.; Farley, R. Segregation of minorities in the metropolis: Two decades of change. *Demography* **2004**, *41*, 1–22. [CrossRef]
41. Murray, L.R. Sick and Tired of Being Sick and Tired: Scientific Evidence, Methods, and Research Implications for Racial and Ethnic Disparities in Occupational Health. *Am. J. Public Health* **2003**, *93*, 221–226. [CrossRef]
42. Forst, L.; Friedman, L.; Chin, B.; Madigan, D. Spatial Clustering of Occupational Injuries in Communities. *Am. J. Public Health* **2015**, *105*, S526–S533. [CrossRef]
43. Benach, J.; Solar, O.; Vergara, M.; Vanroelen, C.; Santana, V.; Castedo, A.; Ramos, J.; Muntaner, C.; Network, E. Six Employment Conditions and Health Inequalities: A Descriptive Overview. *Int. J. Health Serv.* **2010**, *40*, 269–280. [CrossRef]
44. Braveman, P.; Egerter, S.; Williams, D.R. The Social Determinants of Health: Coming of Age. *Annu. Rev. Public Health* **2011**, *32*, 381–398. [CrossRef]
45. International Labour Organization. *Policy Brief: The World of Work and COVID-19*; United Nations: New York, NY, USA, 2020. Available online: https://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/documents/genericdocument/wcms_748428.pdf (accessed on 1 January 2021).
46. University of Illinois Chicago School of Public Health the Population Health Analytics, Metric and Evaluation (PHAME) Chicago Health Atlas. 2021. Available online: www.chicagohealthatlas.org/community-areas (accessed on 23 August 2021).
47. United States Census Bureau. *2014–2018 ACS 5-Year Estimates. 2014–2018 American Community Survey*; U.S. Census Bureau's American Community Survey Office: Washington, DC, USA, 2021.
48. Lawson, M. *A Systematic Analysis of Census and Labor Data to Create a Community Profile of Work*; University of Illinois Chicago: Chicago, IL, USA, 2017.
49. Farmer, P.; Montesanti, S.; Thurston, W. Mapping the role of structural and interpersonal violence in the lives of women: Implications for public health interventions and policy. *BMC Women's Health* **2015**, *15*, 100.
50. Farmer, P. An anthropology of structural violence. *Curr. Anthropol.* **2004**, *45*, 305–326. [CrossRef]
51. Hebert-Beirne, J.; Felner, J.; Kennelly, J.; Eldeirawi, K.; Mayer, A.; Alexander, S.; Castañeda, Y.D.; Castañeda, D.; Persky, V.W.; Chávez, N.; et al. Partner development praxis: The use of transformative communication spaces in a community-academic participatory action research effort in a Mexican ethnic enclave in Chicago. *Action Res.* **2017**, *16*, 414–436. [CrossRef]
52. Hatcher, R. *Cooperation Chicago: Building Chicago's Worker Cooperative Ecosystem (White Paper)*; Illinois Worker Cooperative Alliance and John Marshall Law School Business Enterprise Law Clinic: Chicago, IL, USA, 2018. Available online: http://geo.coop/story/cooperation-chicago (accessed on 10 January 2021).
53. Minkler, M.; Wallerstein, N. Introduction to Community Based Participatory Research. In *Community Based Participatory Research for Health*; Minkler, M., Wallerstein, N., Eds.; Jossey-Bass: San Francisco, CA, USA, 2003.
54. Israel, B.A.; Schulz, A.J.; Parker, E.A.; Becker, A.B. Review of community-based research: Assessing partnership approaches to im-prove public health. *Annu. Rev. Public Health* **1998**, *19*, 173–202. [CrossRef] [PubMed]
55. Cacari-Stone, L.; Wallerstein, N.; Garcia, A.P.; Minkler, M. The Promise of Community-Based Participatory Research for Health Equity: A Conceptual Model for Bridging Evidence with Policy. *Am. J. Public Health* **2014**, *104*, 1615–1623. [CrossRef]
56. Israel, B.A.; Schultz, A.; Parker, E.; Becker, A.; Allen, A.; Guzman, R. Critical Issues in Developing and Following CBPR Principles. In *Community-Based Participatory Research for Health: From Process to Outcomes*; Jossey-Bass: San Francisco, CA, USA, 2008; pp. 47–66.
57. Kamberelis, G.; Dimitriadis, G. Focus group research: Retrospect and prospect. In *Oxford Library of Psychology. The Oxford Handbook of Qualitative Research*; Leavy, P., Ed.; Oxford University Press: Oxford, UK, 2014; pp. 315–340.

58. Charmaz, K. *Constructing Grounded Theory*, 2nd ed.; Sage: Thousand Oaks, CA, USA, 2014.
59. Saldana, J. *The Coding Manual for Qualitative Researchers*, 2nd ed.; Sage: Thousand Oaks, CA, USA, 2013.
60. Birks, M.; Chapman, Y.; Francis, K. Memoing in qualitative research. *J. Res. Nurs.* **2008**, *13*, 68–75. [CrossRef]
61. Hebert-Beirne, J.; Hernandez, S.G.; Felner, J.; Schwiesow, J.; Mayer, A.; Rak, K.; Chávez, N.; Castañeda, Y.; Kennelly, J. Using Community-Driven, Participatory Qualitative Inquiry to Discern Nuanced Community Health Needs and Assets of Chicago's La Villita, a Mexican Immigrant Neighborhood. *J. Community Health* **2018**, *43*, 775–786. [CrossRef]
62. Creswell, J.W.; Miller, D.L. Determining Validity in Qualitative Inquiry. *Theory Practice* **2000**, *39*, 124–130. [CrossRef]
63. Ryan, G.W.; Bernard, H.R. Techniques to Identify Themes. *Field Methods* **2003**, *15*, 85–109. [CrossRef]
64. Lambert, S.J.; Henly, J.R.; Kim, J. Precarious Work Schedules as a Source of Economic Insecurity and Institutional Distrust. *RSF Russell Sage Found. J. Soc. Sci.* **2019**, *5*, 218–257. [CrossRef]
65. Kalleberg, A.L.; Vallas, S.P. Probing Precarious Work: Theory, Research, and Politics. In *Precarious Work (Research in the Sociology of Work)*; Kalleberg, A.L., Vallas, S.P., Kalleberg, A.L., Vallas, S.P., Eds.; Emerald Publishing Limited: Bingley, UK, 2017; Volume 31, pp. 1–30. [CrossRef]
66. Agurs-Collins, T.; Persky, S.; Paskett, E.D.; Barkin, S.L.; Meissner, H.I.; Nansel, T.; Arteaga, S.S.; Zhang, X.; Das, R.; Farhat, T. Designing and Assessing Multilevel Interventions to Improve Minority Health and Reduce Health Disparities. *Am. J. Public Health* **2019**, *109*, S86–S93. [CrossRef]
67. Chicago Department of Public Health COVID-19 Dashboard. Available online: https://www.chicago.gov/city/en/sites/covid-19/home/covid-dashboard.html (accessed on 20 August 2021).
68. Shreffler, J.; Huecker, M.; Petrey, J. The Impact of COVID-19 on Healthcare Worker Wellness: A Scoping Review. *West. J. Emerg. Med.* **2020**, *21*, 1059–1066. [CrossRef]
69. Agren, D. Understanding Mexican health worker COVID-19 deaths. *Lancet* **2020**, *396*, 807. [CrossRef]
70. Solar, O.; Irwin, A. *A Conceptual Framework for Action on the Social Determinants of Health*; Social Determinants of Health Discussion Paper 2 (Policy and Practice); World Health Organization: Geneva, Switzerland, 2010.
71. Fritz, H.; Cutchin, M.P. Changing neighborhoods and occupations: Experiences of older African-Americans in Detroit. *J. Occup. Sci.* **2017**, *24*, 140–151. [CrossRef] [PubMed]
72. Poulsen, M.N.; Roni, A.N.; Peter, J.W. The multifunctionality of urban farming: Perceived benefits for neighbourhood improvement. *Local Environ.* **2017**, *22*, 1411–1427. [CrossRef]
73. Susanto, T.; Widayati, N. Quality of life of elderly tobacco farmers in the perspective of agricultural nursing: A qualitative study. Working with Older People. *Work. Older People (Brighton Engl.)* **2018**, *22*, 166–177. [CrossRef]
74. Binet, A.; Zayas del Rio, G.; Arcaya, M.; Roderigues, G.; Gavin, V. 'It feels like money's just flying out the window': Financial security, stress and health in gentrifying neighborhoods. *Cities Health* **2021**, 1–16. [CrossRef]

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Workplace Integrated Safety and Health Program Uptake in Nursing Homes: Associations with Ownership

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Abstract: Workers in nursing homes are at high risk of occupational injury. Understanding whether—and which—nursing homes implement integrated policies to protect and promote worker health is crucial. We surveyed Directors of Nursing (DON) at nursing homes in three US states with the Workplace Integrated Safety and Health (WISH) assessment, a recently developed and validated instrument that assesses workplace policies, programs, and practices that affect worker safety, health, and wellbeing. We hypothesized that corporate and for-profit nursing homes would be less likely to report policies consistent with Total Worker Health (TWH) approaches. For each of the five validated WISH domains, we assessed the association between being in the lowest quartile of WISH score and ownership status using multivariable logistic regression. Our sample included 543 nursing homes, 83% which were corporate owned and 77% which were for-profit. On average, DONs reported a high implementation of TWH policies, as measured by the WISH. We did not find an association between either corporate ownership or for-profit status and WISH score for any WISH domain. Results were consistent across numerous sensitivity analyses. For-profit status and corporate ownership status do not identify nursing homes that may benefit from additional TWH approaches.

Keywords: nursing homes; occupational health; total worker health

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1. Introduction

The Total Worker Health (TWH) Initiative was launched by the National Institute for Occupational Health and Safety (NIOSH) in 2011 as a strategy to integrate occupational safety, health protection, and health promotion, with the ultimate goal to protect and promote worker wellbeing, health, and safety [1–3]. TWH shows promise in improving the health, safety, and wellbeing of workers [4,5]. Research on the relationship between TWH principles and worker and enterprise outcomes must consider the degree to which TWH policies and practices are implemented in specific workplaces.

The Workplace Integrated Safety and Health Assessment (WISH) is an organizational level measure of workplace policies, programs, and practices that affect worker safety, health and wellbeing [6]. The tool, informed by the Total Worker Health® framework, was developed to allow employers and researchers to assess how well the best practices for supporting work safety, health, and wellbeing are implemented and was recently validated using item response theory analysis [7]. There are five domains in the validated measure: leadership commitment; participation; policies, programs, and practices that foster supportive working conditions; comprehensive and collaborative strategies; and

adherence to federal and state regulations and ethical norms. Administration of the WISH will allow for the evaluation of various hypotheses regarding TWH policies and practices and associated outcomes; for example, do institutions with high scores on the Policies, Programs, and Practices domain have lower rates of worker injury? Previous work provides a comprehensive overview of the WISH, including the conceptual model describing the central role of working conditions in shaping health and safety outcomes and how each domain reflects these conditions [6].

The implementation of TWH principles may be especially important for workplaces with low-wage workers where other approaches to addressing wellbeing, such as individual-centered wellness programs, have been ineffective [8,9]. In this analysis, we focus on long-term care facilities (nursing homes) because their worker population has relatively low wages and high rates of non-fatal work-related injury (5.9 per 100 full-time workers in 2019) [10–12]. The nursing home industry disproportionately employs groups identified by NIOSH as at-risk for occupational health disparities [13,14]. Nursing home employees can face both physically demanding job tasks and stressful work environments, leading to increased risks of physical health problems, such as musculoskeletal disorders and cardiovascular disease, as well as mental health problems [15–18]. Therefore, health promotion is especially important in this population. Additionally, there are over 15,000 nursing facilities in the U.S. that are certified to provide care and receive payment from the Centers for Medicare and Medicaid Services (CMS), the primary payer for long-term care services in the U.S. [19].

Nursing home ownership influences the operational philosophy and priorities of nursing homes [20]. These differences may also be reflected in the nursing home's approach to its workforce, as measured by the WISH. However, the literature is conflicted regarding the relationship between the ownership status of U.S. nursing homes and quality of care, with some studies suggesting that for-profit or chain status may influence quality of care [21,22] and others suggesting that ownership and management structures may be more nuanced than a simple for-profit vs. not for-profit designation [23,24]. We were unable to find any published manuscripts that have investigated whether ownership type influences the implementation of TWH policies and practices.

The purpose of this study is to determine the degree to which nursing homes implement TWH approaches as measured by the WISH and determine whether their ownership type, for-profit and/or corporate, is associated with their scores, after controlling for other organizational characteristics. We hypothesize that, after adjusting for nursing home characteristics, (1) for-profit ownership will be associated with a lower uptake of THW approaches, as measured by the WISH, (2) corporate ownership will be associated with a lower uptake of THW approaches, as measured by the WISH. To our knowledge, this is the first comprehensive survey in nursing homes of the implementation of workplace policies, programs, and practices that can affect worker safety, health, and wellbeing.

2. Materials and Methods

Study Design. We conducted a cross-sectional survey of all operating nursing homes that were certified by CMS in California, Massachusetts, and Ohio. The survey took about 20 min to complete and covered a wide array of topics relating to the working environment of the nursing home. The survey was subject to cognitive testing to ensure face validity [7]. We merged these data with those available from the Certification and Survey Provider Enhanced Reporting system to match each nursing home that answered the survey to relevant organizational characteristics. The study was approved by the Institutional Review Board of the Harvard T.H. Chan School of Public Health (IRB 18-1245).

Setting and Participants. The survey was conducted in two waves between October 2018 and June 2019. All nursing homes that served adults, had at least 30 beds, were open, and were certified by CMS were included in the study. The self-administered survey was initially sent out electronically via email link to the Directors of Nursing (DON) of each facility. There were three electronic follow-ups with the final follow-up, sent as a paper survey to the DON. DONs were instructed to seek input or pass the survey

to an appropriate health and safety representative for their nursing home, if needed. Approximately 35% of the sample also received a follow-up reminder phone call (randomly selected). Upon completion of the survey, respondents were sent Amazon gift cards. The overall response rate for the survey was 23.8% (569/2389). In previous work, we did not find any relationship between organizational characteristics, quality ratings, or health inspection citations with whether a nursing home responded to the survey [25].

Variables. The WISH was measured using the survey. The WISH instrument includes closed-ended questions, each with one of two four-point ordinal response scales ((0) not at all, (1) somewhat, (2) mostly, (3) completely; (0) not at all, (1) some of the time, (2) most of the time, (3) all of the time). Policies, Programs, and Practices contains 10 items with a total score ranging from 0 to 33. The other domains each contain four items and total scores ranging from 0 to 12. Higher scores reflect greater implementation of TWH principles. All domains exhibited scores skewed toward higher (more favorable) scores, therefore, for statistical modeling, we dichotomized each domain as the bottom 25th percent vs. top 75th percent. This cut-point was based on the data distribution; in sensitivity analyses, we dichotomized each domain at approximately the 10th percentile (bottom 10% vs. top 90%) and at approximately the 33rd percentile (bottom one-third vs. top two-thirds). As a final sensitivity analysis, we compared those nursing homes scoring in the bottom 25th percent to those in the top 25th percent.

The key predictor was ownership status according to Medicare provider files. Medicare data on federally certified nursing homes come from state surveys in each facility, which must occur at least once every 15 months. Publicly available data from the provider files define ownership according to the following categories: For-Profit (Corporation, Individual, LLC, or Partnership), Government (city, city/county, county, federal, hospital district, or state), or Non-Profit (church-related, corporation, or other). Given that we did not have government facilities in our sample, and based on the distribution of the sample across the remaining categories, we defined ownership in two ways, as for-profit or not-for-profit and corporate vs. non-corporate. Models were run separately for each ownership variable. As a secondary analysis, we considered four-level ownership: (1) corporate, for-profit, (2) corporate, not-for-profit, (3) non-corporate, for-profit, (4) non-corporate, not-for-profit.

Covariates included the number of federally certified beds, occupancy rate, percent of residents who are Medicaid recipients, and staffing patterns (RN ratio, LPN ratio, and CNAs ratio) according to Centers for Medicare and Medicaid Services. Nursing home location was classified as rural vs. non-rural using the most recent (2010) Rural–Urban Commuting area codes [26]. Codes 1–3 indicate metropolitan areas; all other codes were considered rural. By including all of these covariates we are estimating the marginal association of ownership type with the WISH.

Additionally, we included indicator variables for each state (using one as a reference), since each state has differences in how nursing homes are regulated and differ in many other ways. As mentioned above, the survey was operated as two separate waves, so we also included an indicator for whether the survey was in the first or second wave.

Statistical Methods. We present descriptive statistics for each WISH domain. We assessed the correlation between domains scores using Spearman correlation. We used multivariable logistic regression models to assess the association between dichotomous WISH score and ownership, with errors clustered at the state level. We report the results using odds ratios and simultaneous 95% Confidence Intervals. We added covariates to the model in three stages. Model 1 included only the survey wave and state. Model 2 additionally adjusted for all covariates with the exception of staffing patterns. We were concerned that staffing patterns may be mediators—of the causal pathway between ownership and WISH scores—thus, we included staffing patterns in a final exploratory Model 3.

Our initial power calculations assumed that the WISH domains would be analyzed as continuous outcomes. We anticipated obtaining surveys from 200 for-profit and 200 not-for-profit nursing homes, which would provide >80% power to detect an effect size of approximately

0.3 standard deviations. Recalculating power, assuming a dichotomous outcome with approximately 25% prevalence, finds a detectable OR of approximately 1.75.

3. Results

We received surveys from 569 out of 2389 nursing homes. A detailed description of the survey methods and predictors of survey response is provided in a previous work, which did not find any statistically significant predictors of response [25]. Two surveys did not include sufficient detail to compute any WISH domain; an additional 24 nursing homes were missing at least one covariate. These nursing homes were excluded from the analysis, leaving 543 in the final analytic sample.

Descriptive statistics of the nursing home characteristics are presented in Table 1. Seventy-seven percent of the nursing homes had for-profit ownership and 83% were owned by corporations. The average number of beds was 101. Thirty-seven percent of nursing homes were in California, 22% in Massachusetts, and 41% in Ohio.

Table 1. Descriptive Statistics of Nursing Home Characteristics.

Variable	Mean (SD) or *n*	Median; Min–Max or %
Ownership		
corporate, for-profit	315	58%
corporate, not-for-profit	97	18%
non-corporate, for-profit	98	18%
non-corporate, not-for-profit	33	6%
Number of beds	101 (46)	99; 30–378
Percent Medicaid [1]	61% (21%)	66%; 0–100%
Percent occupied [1]	85% (12%)	89%; 23–100%
RN ratio	0.61 (0.31)	0.55; 0.04–2.54
LPN ratio	0.98 (0.36)	0.94; 0.11–3.93
CNAs ratio	2.29 (0.55)	2.25; 1.02–7.84
Location-rural	82	15%
State		
California	203	37%
Massachusetts	117	22%
Ohio	223	41%

[1] Values over 100% truncated to 100%.

3.1. Reported Implementation of TWH Approaches

The reported implementation of TWH approaches was high. Descriptive statistics for each WISH domain are shown in Table 2 and histograms are shown in Supplementary Figure S1A–E. The median score for the Policies, Programs, and Practices was 28 (maximum possible 33), with 12% of respondents at the maximum possible score. The median scores for the other four domains (maximum possible score 12) ranged from 9 to 12. The Adherence domain had the highest average score (10.7 out of 12), while the Participation domain had the lowest average score (8.8 out of 12). Each domain score was dichotomized at the 25th percentile, or the bottom of the IQR (e.g., adherence was categorized as <10 vs. 10, 11, 12). We chose to dichotomize the measure to see whether the hypothesized characteristics were associated with low performers. These low performers would be a high priority for interventions to improve the working environment. We tested a few different cut points (such as the 10th percentile) with similar results.

The correlation between WISH domains was moderate to high, ranging from 0.55 (Participation vs. Adherence) to 0.78 (Policies, Programs, and Practices vs. Comprehensive and Collaborative Strategies) (Supplementary Table S1). Of the 543 nursing homes included in this analysis, 268 (49%) were in the top 75% on all five domains; 39 (7%) were in the bottom quartile on all five domains.

Table 2. Descriptive Statistics of WISH Domains.

WISH Domain	Mean (SD)	Median	IQR
Adherence	10.7 (2.0)	12	10, 12
Comprehensive and Collaborative Strategies	9.4 (2.8)	10	8, 12
Leadership	9.5 (2.5)	10	8, 12
Participation	8.8 (2.7)	9	7, 11
Policies, Programs, and Practices	26.2 (6.0)	28	23, 31

3.2. Associations between Nursing Home Owership and TWH Approaches

Supplementary Figure S2A,B display the association between each continuous WISH domain score and ownership in boxplots (2A: not-for-profit vs. for-profit, 2B: non-corporate vs. corporate). For both ownership variables, the distribution of each continuous WISH domain score is similar between ownership categories.

The adjusted odds of being in the bottom quartile of each WISH domain (reporting the least implementation of TWH program elements) for nursing homes with for-profit vs. not-for-profit ownership are shown in Table 3. We observed no significant associations between for-profit ownership and any WISH domain. There were trends showing slightly increased odds of for-profit nursing homes in the bottom quartile of Leadership, with for-profit nursing homes associated with 1.35 times increased odds of being in the bottom Leadership quartile. There were also slightly decreased odds of being in the bottom quartile of Participation and Comprehensive and Collaborative Strategies, but these associations were modest and not statistically significant. The results were similar in unadjusted analyses, and in analyses that were additionally adjusted for staffing patterns (Supplementary Table S2).

Table 3. Adjusted association between for-profit nursing home ownership and being in the bottom 25% percentile of WISH domain.

Variable	Odds Ratio [1]	95% CI [2]	*p*-Value
Adherence	0.98	[0.54, 1.77]	0.9364
Comprehensive and Collaborative Strategies	0.71	[0.39, 1.29]	0.2612
Leadership	1.35	[0.73, 2.50]	0.3394
Participation	0.79	[0.47, 1.34]	0.3784
Policies, Programs, and Practices	0.96	[0.53, 1.73]	0.8858

[1] Odds ratio of being in bottom 25th percent for for-profit vs. not-for-profit nursing homes, adjusted for survey wave, state, number of beds, occupancy rate, percent of residents who are Medicaid recipients. [2] CI = Confidence Interval.

The adjusted odds of being in the bottom quartile of each WISH domain for nursing homes with corporate vs. non-corporate ownership are shown in Table 4. We observed no significant associations between for-profit ownership and any WISH domain. Results were similar in unadjusted analyses, and in analyses additionally adjusted for staffing patterns (Supplementary Table S3).

Sensitivity analyses investigating a combined four-level ownership status were largely in line with the primary analyses (Table 5). Compared to non-corporate, not-for-profit nursing homes, all other ownership categories were at slightly decreased odds of being in the bottom quartile for Participation and Comprehensive and Collaborative Strategies, and slightly increased odds of being in the bottom quartile for Leadership. As with the primary analyses, none of the associations were statistically significant.

Table 4. Association between corporate nursing home ownership and being in the bottom 25% percentile of WISH domain.

Variable	Odds Ratio [1]	95% CI [2]	*p*-Value
Adherence	1.23	[0.73, 2.06]	0.4412
Comprehensive and Collaborative Strategies	1.10	[0.65, 1.87]	0.7109
Leadership	1.26	[0.73, 2.16]	0.4037
Participation	0.73	[0.46, 1.16]	0.1887
Policies, Programs, and Practices	1.00	[0.6, 1.67]	0.9911

[1] Odds ratio of being in bottom 25th percent for corporate vs. non corporate nursing homes, adjusted for survey wave, state, number of beds, occupancy rate, percent of residents who are Medicaid recipients. [2] CI = Confidence Interval.

Table 5. Association between corporate nursing home ownership and being in the bottom 25% percentile of WISH domain.

Variable	Odds Ratio [1]	95% CI [2]	*p*-Value
Adherence			0.8879
corporate, for-profit	1.24	[0.47, 3.32]	
corporate, not-for-profit	1.33	[0.46, 3.81]	
non-corporate, for-profit	1.04	[0.35, 3.06]	
non-corporate, not-for-profit	Reference		
Comprehensive and Collaborative Strategies			0.5643
corporate, for-profit	0.64	[0.25, 1.60]	
corporate, not-for-profit	0.80	[0.29, 2.18]	
non-corporate, for-profit	0.50	[0.18, 1.41]	
non-corporate, not-for-profit	Reference		
Leadership			0.6633
corporate, for-profit	1.56	[0.55, 4.42]	
corporate, not-for-profit	1.13	[0.36, 3.52]	
non-corporate, for-profit	1.22	[0.39, 3.83]	
non-corporate, not-for-profit	Reference		
Participation			0.4935
corporate, for-profit	0.59	[0.26, 1.35]	
corporate, not-for-profit	0.73	[0.30, 1.78]	
non-corporate, for-profit	0.79	[0.32, 1.97]	
non-corporate, not-for-profit	Reference		
Policies, Programs, and Practices			0.9992
corporate, for-profit	0.97	[0.38, 2.49]	
corporate, not-for-profit	1.01	[0.36, 2.84]	
non-corporate, for-profit	0.96	[0.34, 2.72]	
non-corporate, not-for-profit	Reference		

[1] Odds ratio of being in bottom 25th percent of each WISH domain compared to non-corporate, not-for-profit nursing homes, adjusted for survey wave, state, number of beds, occupancy rate, percent of residents who are Medicaid recipients. [2] CI = Confidence Interval.

Results from the sensitivity analyses investigating different cut-points for dichotomizing each WISH domain were similar to the primary analyses; we found no statistically significant associations between any WISH domain and either ownership variable [Supplementary Tables S4 and S5]. Finally, sensitivity analyses comparing those homes scoring in the bottom 25th percentile to those in the top 25th percentile were similar to the primary analysis comparing the bottom 25th percentile to the top 75th percentile (Supplementary Tables S6 and S7).

4. Discussion

4.1. Summary

In our survey of 543 DONs in three states, we found that nursing homes report a high degree of implementation of TWH approaches as measured by WISH scores. The Adher-

ence domain, assessing "the degree to which the organization adheres to federal and state regulations, as well as ethical norms, that advance worker safety, health and well-being", had, on average, the highest score, while the Participation domain, assessing "whether at every level of an organization, including labor unions or other worker organizations if present, help plan and carry out efforts to protect and promote worker safety and health", had, on average, the lowest score.

4.2. Practical Implications

We hypothesized that nursing home ownership—for-profit vs. not-for-profit and corporate vs. non-corporate—would be associated with the implementation of TWH approaches. We did not find any statistically significant or clinically meaningful associations between either ownership definition and any WISH domain. While both for-profit and corporate-owned nursing homes had slightly increased odds of lower Leadership domain scores, they also had a slightly increased odds of having higher Participation domain scores. Thus, we did not observe a meaningful association between ownership status and implementing TWH approaches.

The topic of ownership in U.S. nursing homes, particularly whether it impacts quality of care, has a long and fraught history [23]. Many papers have compared quality based on board ownership structure and have generally found that for-profit nursing homes provide lower-quality care in several key domains. However, many of the studies suffer from methodological difficulties that make causal inference challenging [21]. Several mechanisms for this difference have been highlighted in the literature, such as the context, principal-agent issues arising from owner-managers, financial performance, and profit taking [22,27–29]. The comparison generally made in the U.S., between non-profit and for-profit nursing homes differs from many other countries, such as Sweden, where private nursing homes are often compared to public ones or England, where public nursing homes are compared to private for-profit and private not-for-profit nursing homes [30,31].

Additionally, the work environment as measured by the WISH does not appear to be associated with broad ownership classification as defined in this paper. Nearly 70% (in 2016) of U.S. nursing homes are for-profit; thus, most older adults are cared for in for-profit settings [32]. Comparing these for-profit settings to nonprofit settings may not be the most useful comparison, despite its prevalence in the literature, particularly considering the increasing complexity of the ownership structures of nursing homes. Previous work in nursing homes did use ownership as a shorthand for trying to measure differences in incentives and motivations among nursing home operators that might have downstream effects on the quality of care. However, researchers who hope to incorporate measures of the work environment beyond average staffing levels need to measure this separately, rather than assume that these differences between nursing homes match up with ownership.

One recent study used a 43-item tool to assess readiness for integration in six nursing homes owned by a single for-profit chain owner. This study found low variability in scores, which is unsurprising because chain ownership necessitates uniformity in programs, policies, and practice [33]. In our much larger study of over 500 nursing homes, we found relatively low variability in WISH domain scores. The bottom 25th percent represented anywhere from ~75% (Adherence, the bottom 25th percent included scores ranging from 0 to 9 out of 12) to ~50% (Participation, the bottom 25th percent included scores ranging from 0 to 6 out of 12) of the scale range. The WISH tool may, therefore, be important when identifying nursing homes with the poorest TWH policies. Identifying these homes and their areas of weakness is the first step in developing interventions to improve the work environment.

4.3. Theoretical Implications

The WISH domains were developed through a comprehensive approach that includes content review by subject matter experts, cognitive testing with respondents to ensure comprehension and response mapping, and item response theory analysis. Data-driven change was included as a sixth domain, but no reasonably fitting model could be identified

for the dimension in validation analysis, and thus it is not presented further [7]. Common among all domains was the observation of low information (i.e., poorer measurement precision) at the higher end of the scores. Thus, the items have limited utility when differentiating among the higher-scoring nursing homes. However, it has great utility when identifying the lower-scoring nursing homes that are priorities for intervention as we did in the present analysis. This finding is reflected in our sensitivity analyses, which showed similar results with respect to the association between ownership and WISH scores when we compared those nursing homes in the bottom quartile of WISH scores to the top three quartiles (Tables 2 and 3) vs. those in the bottom vs. top quartile (Supplementary Tables S6 and S7). Future studies should extend our analysis to examine the structural relationships between nursing home operations and WISH domains, as well as the effectiveness of interventions in producing improvements in WISH scores among nursing homes that are priorities for intervention. Such analyses should use other scoring approaches, such as modal a priori scores or fitting structural equation models that capture the granularity in the range in which the WISH tool has its greatest ability to differentiate among nursing homes, and thus should be sensitive to differences among nursing homes and/or changes following intervention.

4.4. Future Directions

While the majority of surveyed nursing homes reported a high uptake of TWH policies, organizations may be interested in how they can improve the implementation of these policies and practices. The Center for Work, Health, and Well-Being at the Harvard T.H. Chan School of Public Health designed a suite of resources including Implementation Guidelines, training, and technical assistance to support the implementation of TWH policies [34]. A pilot study in three small-to-medium (less than 750 employees) organizations found that these resources were acceptable to the participating companies and could feasibly be implemented [35]. Implementing TWH interventions may be especially challenging in low-wage, high-attrition industries, such as long-term care facilities or food service [36]. A recent study highlighted how these Implementation Guidelines were utilized to develop and implement an organizational intervention to improve worker health among low-wage food service workers [37]. This work found the Implementation Guidelines to be transferable across industries. Future work should investigate whether and how such an approach could be implemented to improve worker health in long-term care facilities.

4.5. Limitations

This study has several limitations. The sample only included nursing homes from three US states and excluded nursing homes with fewer than 30 beds. Generalizing these findings should be done with caution; the WISH domains should be evaluated in different geographic locations and settings. The response rate of 23.8% was lower than has been cited in prior work surveying DONs [38,39]. However, a prior analysis on this sample did not find significant associations between nursing home characteristics and response [25]. The study was initially designed to assess the WISH domains as continuous scores. Dichotomizing continuous outcomes is known to reduce statistical power; however, given the highly skewed nature of the domain scores, we felt this was necessary [40]. Sensitivity analyses investigating different cut-points for dichotomization were similar to the primary analysis. Additionally, we used a relatively simple description of the ownership of nursing homes. Current ownership structures have become more complicated over time, and our measures may not reflect the differences in incentives and motivations that result from more complicated structures. Finally, all surveys were self-administered and may be subject to desirability or optimism biases. The WISH tool was designed to be completed at the organizational level by employer representatives [6]. Unlike other tools, such as the Integrated Health & Safety Index (IHS Index) and the HERO Scorecard, it was not designed to use individual employee data [41,42]. Therefore, the WISH tool could be utilized in future studies to complement surveys directed to workers in order to identify discordances

between organizational policies, practices and programmers, and workers' perceptions of these.

5. Conclusions

In our survey of over 500 nursing homes in three US states, we found a high degree of nursing homes that reported implementing TWH approaches as measured by the WISH. We did not find associations between for-profit vs. not-for-profit or corporate vs. non-corporate, and WISH domain scores. Simply relying on ownership status is not sufficient for researchers and policy makers seeking to identify nursing homes that may benefit from the additional implementation of TWH approaches.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph182111313/s1, Figure S1. Distribution of WISH domain scores. Figure S2. Distribution of WISH domain scores by ownership status. Table S1: Spearman Correlation Coefficients between WISH Domains. Table S2: Associations between for-profit nursing home ownership and being in the bottom 25% percentile of WISH domain. Table S3: Associations between corporate nursing home ownership and being in the bottom 25% percentile of WISH domain. Table S4: Associations between for-profit nursing home ownership and each WISH domain: sensitivity analysis for WISH cut-points. Table S5: Associations between corporate nursing home ownership and each WISH domain: sensitivity analysis for WISH cut-points. Table S6: Associations between for-profit nursing home ownership and each WISH domain: sensitivity analysis comparing top to bottom quartile. Table S7: Associations between corporate nursing home ownership and each WISH domain: sensitivity analysis comparing top to bottom quartile. Results.

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Data Availability Statement: Data available on request due to privacy restrictions. The data presented in this study are available on request from the corresponding author. The data are not publicly available to reduce the risk of identification of the subjects who are often the only person with their job title at an individual nursing home.

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References

1. Schill, A.L.; Chosewood, L.C. The NIOSH total worker health™ program: An overview. *J. Occup. Environ. Med.* **2013**, *55*, S8–S11. [CrossRef]
2. Schill, A.L.; Chosewood, L.C. Total Worker Health®: More implications for the occupational health nurse. *Workplace Health Saf.* **2016**, *64*, 4–5. [CrossRef]
3. Goetzel, R. *NIOSH 2012. Research Compendium: The NIOSH Total Worker Health Program: Seminal Research Papers 2012*; Department of Health and Human Services: Washington, DC, USA, 2012; p. 10214.
4. Anger, W.K.; Elliot, D.L.; Bodner, T.; Olson, R.; Rohlman, D.S.; Truxillo, D.M.; Kuehl, K.S.; Hammer, L.B.; Montgomery, D. Effectiveness of total worker health interventions. *J. Occup. Health Psychol.* **2015**, *20*, 226. [CrossRef]
5. Grant, M.P.; Okechukwu, C.A.; Hopcia, K.; Sorensen, G.; Dennerlein, J.T. An inspection tool and process to identify modifiable aspects of acute care hospital patient care units to prevent work-related musculoskeletal disorders. *Workplace Health Saf.* **2018**, *66*, 144–158. [CrossRef]
6. Sorensen, G.; Sparer, E.; Williams, J.A.R.; Gundersen, D.; Boden, L.I.; Dennerlein, J.T.; Hashimoto, D.; Katz, J.N.; McLellan, D.L.; Okechukwu, C.A.; et al. Measuring Best Practices for Workplace Safety, Health, and Well-Being: The Workplace Integrated Safety and Health Assessment. *J. Occup. Environ. Med.* **2018**, *60*, 430–439. [CrossRef]
7. Lopez Gomez, M.A.; Gundersen, D.A.; Boden, L.I.; Sorensen, G.; Katz, J.N.; Collins, J.E.; Wagner, G.; Vriniotis, M.G.; Williams, J.A. Validation of the Workplace Integrated Safety and Health (WISH) assessment in a sample of nursing homes using Item Response Theory (IRT) methods. *BMJ Open* **2021**, *11*, e045656. [CrossRef]
8. Sorensen, G.; Barbeau, E.; Hunt, M.K.; Emmons, K. Reducing social disparities in tobacco use: A social-contextual model for reducing tobacco use among blue-collar workers. *Am. J. Public Health* **2004**, *94*, 230–239. [CrossRef]
9. Baid, D.; Hayles, E.; Finkelstein, E.A. Return on Investment of Workplace Wellness Programs for Chronic Disease Prevention: A Systematic Review. *Am. J. Prev. Med.* **2021**, *61*, 256–266. [CrossRef]
10. Stone, R.; Wiener, J.M. *Who Will Care for Us?: Addressing the Long-Term Care Workforce Crisis*; US Department of Health and Human Services: Washington, DC, USA, 2001.
11. U.S. Bureau of Labor Statistics. Injuries, Illnesses, and Fatalities. Available online: https://www.bls.gov/web/osh/summ1_00.htm (accessed on 19 August 2021).
12. Zuckerbraun, S.E.A. Wages, Fringe Benefits, and Turnover for Direct Care Workers Working for Long-Term Care Providers in Oregon. Available online: https://www.oregon.gov/dhs/aboutdhs/dhsbudget/20152017%20Budget/Oregon%20Final%20Direct%20Care%20Wage%20Report%20to%20DHS.pdf (accessed on 20 August 2021).
13. Baron, S.L.; Steege, A.L.; Marsh, S.M.; Menendez, C.C.; Myers, J.R.; Centers for Disease, C. Prevention, Nonfatal work-related injuries and illnesses-United States, 2010. *MMWR Suppl.* **2013**, *62*, 35–40.
14. Steege, A.L.; Baron, S.L.; Marsh, S.M.; Menendez, C.C.; Myers, J.R. Examining occupational health and safety disparities using national data: A cause for continuing concern. *Am. J. Ind. Med.* **2014**, *57*, 527–538. [CrossRef]
15. Lapane, K.L.; Hughes, C.M. Considering the employee point of view: Perceptions of job satisfaction and stress among nursing staff in nursing homes. *J. Am. Med. Dir. Assoc.* **2007**, *8*, 8–13. [CrossRef]
16. Miranda, H.; Gore, R.J.; Boyer, J.; Nobrega, S.; Punnett, L. Health behaviors and overweight in nursing home employees: Contribution of workplace stressors and implications for worksite health promotion. *Sci. World J.* **2015**, *2015*. [CrossRef] [PubMed]
17. Zhang, Y.; Flum, M.; Nobrega, S.; Blais, L.; Qamili, S.; Punnett, L. Work organization and health issues in long-term care centers: Comparison of perceptions between caregivers and management. *J. Gerontol. Nurs.* **2011**, *37*, 32–40. [CrossRef]
18. Zhang, Y.; Punnett, L.; Mawn, B.; Gore, R. Working conditions and mental health of nursing staff in nursing homes. *Issues Ment. Health Nurs.* **2016**, *37*, 485–492. [CrossRef] [PubMed]
19. Total Number of Certified Nursing Facilities. Available online: https://www.kff.org/other/state-indicator/number-of-nursing-facilities (accessed on 19 August 2021).
20. Harrington, C.; Hauser, C.; Olney, B.; Rosenau, P.V. Ownership, financing, and management strategies of the ten largest for-profit nursing home chains in the United States. *Int. J. Health Serv.* **2011**, *41*, 725–746. [CrossRef]
21. Hillmer, M.P.; Wodchis, W.P.; Gill, S.S.; Anderson, G.M.; Rochon, P.A. Nursing home profit status and quality of care: Is there any evidence of an association? *Med. Care Res. Rev.* **2005**, *62*, 139–166. [CrossRef]
22. Weech-Maldonado, R.; Laberge, A.; Pradhan, R.; Johnson, C.E.; Yang, Z.; Hyer, K. Nursing home financial performance: The role of ownership and chain affiliation. *Health Care Manag. Rev.* **2012**, *37*, 235–245. [CrossRef]
23. Stevenson, D.G.; Bramson, J.S.; Grabowski, D.C. Nursing home ownership trends and their impacts on quality of care: A study using detailed ownership data from Texas. *J. Aging Soc. Policy* **2013**, *25*, 30–47. [CrossRef] [PubMed]
24. Ronald, L.A.; McGregor, M.J.; Harrington, C.; Pollock, A.; Lexchin, J. Observational evidence of for-profit delivery and inferior nursing home care: When is there enough evidence for policy change? *PLoS Med.* **2016**, *13*, e1001995. [CrossRef]
25. Williams, J.A.R.; Vriniotis, M.G.; Gundersen, D.A.; Boden, L.I.; Collins, J.E.; Katz, J.N.; Wagner, G.R.; Sorensen, G. How to ask: Surveying nursing directors of nursing homes. *Health Sci. Rep.* **2021**, *4*, e304. [CrossRef]
26. Rural-Urban Commuting Area Codes. Available online: https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes/ (accessed on 20 August 2021).

27. O'Neill, C.; Harrington, C.; Kitchener, M.; Saliba, D. Quality of care in nursing homes: An analysis of relationships among profit, quality, and ownership. *Med. Care* **2003**, *41*, 1318–1330. [CrossRef]
28. Huang, S.S.; Bowblis, J.R. The principal–agent problem and owner-managers: A n instrumental variables application to nursing home quality. *Health Econ.* **2018**, *27*, 1653–1669. [CrossRef] [PubMed]
29. Decker, F.H. Nursing home performance in resident care in the United States: Is it only a matter of for-profit versus not-for-profit? *Health Econ. Policy Law* **2008**, *3*, 115–140. [CrossRef] [PubMed]
30. Winblad, U.; Blomqvist, P.; Karlsson, A. Do public nursing home care providers deliver higher quality than private providers? Evidence from Sweden. *BMC Health Serv. Res.* **2017**, *17*, 1–12. [CrossRef] [PubMed]
31. Barron, D.N.; West, E. The quasi-market for adult residential care in the UK: Do for-profit, not-for-profit or public sector residential care and nursing homes provide better quality care? *Soc. Sci. Med.* **2017**, *179*, 137–146. [CrossRef]
32. National Center for Health Statistics. Nursing Home Care. Available online: https://www.cdc.gov/nchs/fastats/nursing-home-care.htm (accessed on 20 August 2021).
33. Faghri, P.D.; Kotejoshyer, R.; Cherniack, M.; Reeves, D.; Punnett, L. Assessment of a Worksite Health Promotion Readiness Checklist. *J. Occup. Environ. Med.* **2010**, *52*, 893–899. [CrossRef]
34. McLellan, D.; Moore, W.; Nagler, E.; Sorensen, G. *Implementing an Integrated Approach Weaving Worker Health, Safety, and Well-being into the Fabric of Your Organization*; Harvard Center for Work, Health and Wellbeing: Boston, MA, USA, 2017; pp. 1–141.
35. Pronk, N.P.; McLellan, D.L.; Dennerlein, J.T.; Anderson, P.; Karapanos, M.; Nagler, E.; Schmidt, D.; Spoonheim, J.; Wallace, L.M.; Sorensen, G. Building Capacity for Integrated Occupational Safety, Health, and Well-Being Initiatives Using Guidelines for Total Worker Health® Approaches. *J. Occup. Environ. Med.* **2021**, *63*, 411–421. [CrossRef] [PubMed]
36. Alamgir, H.; Swinkels, H.; Yu, S.; Yassi, A. Occupational injury among cooks and food service workers in the healthcare sector. *Am. J. Ind. Med.* **2007**, *50*, 528–535. [CrossRef] [PubMed]
37. Nagler, E.M.; Stelson, E.A.; Karapanos, M.; Burke, L.; Wallace, L.M.; Peters, S.E.; Nielsen, K.; Sorensen, G. Using Total Worker Health® Implementation Guidelines to Design an Organizational Intervention for Low-Wage Food Service Workers: The Workplace Organizational Health Study. *Int. J. Environ. Res. Public Health* **2021**, *18*, 9383. [CrossRef]
38. Castle, N.G.; Wagner, L.M.; Ferguson, J.C.; Handler, S.M. Safety culture of nursing homes: Opinions of top managers. *Health Care Manag. Rev.* **2011**, *36*, 175–187. [CrossRef]
39. Clark, M.A.; Roman, A.; Rogers, M.L.; Tyler, D.A.; Mor, V. Surveying multiple health professional team members within institutional settings: An example from the nursing home industry. *Eval. Health Prof.* **2014**, *37*, 287–313. [CrossRef] [PubMed]
40. Altman, D.G.; Royston, P. The cost of dichotomising continuous variables. *BMJ* **2006**, *332*, 1080. [CrossRef] [PubMed]
41. Loeppke, R.R.; Hohn, T.; Baase, C.; Bunn, W.B.; Burton, W.N.; Eisenberg, B.S.; Ennis, T.; Fabius, R.; Hawkins, R.J.; Hudson, T.W. Integrating health and safety in the workplace: How closely aligning health and safety strategies can yield measurable benefits. *J. Occup. Environ. Med.* **2015**, *57*, 585–597. [CrossRef] [PubMed]
42. Rosenbaum, E.; Grossmeier, J.; Imboden, M.; Noeldner, S. *The HERO Health and Well-Being Best Practices Scorecard in Collaboration with Mercer (HERO Scorecard)*; SAGE Publications Sage: Los Angeles, CA, USA, 2020.

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Commentary

Health Equity and a Paradigm Shift in Occupational Safety and Health

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Abstract: Despite significant improvements in occupational safety and health (OSH) over the past 50 years, there remain persistent inequities in the burden of injuries and illnesses. In this commentary, the authors assert that addressing these inequities, along with challenges associated with the fundamental reorganization of work, will require a more holistic approach that accounts for the social contexts within which occupational injuries and illnesses occur. A biopsychosocial approach explores the dynamic, multidirectional interactions between biological phenomena, psychological factors, and social contexts, and can be a tool for both deeper understanding of the social determinants of health and advancing health equity. This commentary suggests that reducing inequities will require OSH to adopt the biopsychosocial paradigm. Practices in at least three key areas will need to adopt this shift. Research that explicitly examines occupational health inequities should do more to elucidate the effects of social arrangements and the interaction of work with other social determinants on work-related risks, exposures, and outcomes. OSH studies regardless of focus should incorporate inclusive methods for recruitment, data collection, and analysis to reflect societal diversity and account for differing experiences of social conditions. OSH researchers should work across disciplines to integrate work into the broader health equity research agenda.

Keywords: occupational safety and health; health equity; social determinants of health; work; biopsychosocial model; inclusive research methods

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1. Introduction

Increased levels of disease and poverty among workers during the industrial revolution led Rudolf Virchow and others to establish the field of social medicine, which explores how social and economic conditions affect health, disease, and the practice of medicine [1]. However, the field of occupational safety and health (OSH) has evolved over the past half-century from its historic roots in social medicine into a largely technical field that focuses on identifying and eliminating physical, chemical, biological, and ergonomic hazards found in the workplace [2,3]. Rooted in the biomedical model of health [4], OSH generally utilizes a reductionist approach to isolate and address single, proximate factors that "cause" an injury or illness. This model has led to significant improvements in worker health over the past 50 years [5]. Nevertheless, persistent inequities in the burden of occupational injuries and illnesses, as well as challenges associated with the fundamental reorganization of the world of work [6], highlight the need to expand the current paradigm to account for the social contexts within which occupational injuries and illnesses occur [7–9]. Consideration of the role that social institutions and norms play in the inequitable distribution of work-related risks and benefits across society, and resultant issues of health equity, are central to this shift in OSH from a biomedical to a biopsychosocial approach [4]. A biopsychosocial approach takes a more holistic view by exploring the dynamic, multidirectional interactions between biological phenomena, psychological factors, and social relationships and contexts, which constitute processes of human development over the life course.

While the biomedical model circumscribes most OSH research, it is important to recognize that the field has increasingly embraced research on health inequities, including a growing commitment over the past two decades from the National Institute for Occupational Safety and Health (NIOSH) to conduct and support health equity-focused research. For example, over the past five years the NIOSH Occupational Health Equity Program has worked to expand these research efforts and promote a biopsychosocial approach across the field. This article discusses a paradigm shift to a biopsychosocial approach and then describes in detail how this shift may impact three key areas of OSH: research that explicitly examines occupational health inequities, incorporation of inclusive methods across OSH research, and integration of work into health equity research.

2. A Paradigm Shift to Advance Health Equity

Central to the current approach to OSH is the biomedical model of medicine, which focuses on identifying a specific physical cause for illness or injury and eliminating it [4]. The field of epidemiology in general and the tools of OSH epidemiology and surveillance have become increasingly tied to this epistemology. This approach has contributed to significant declines in work-related illness and injury over the past 50 years [5]. There is growing recognition, however, of the need for a more holistic and nuanced perspective on work and its impact on population health [10–12]. The declines in worker illnesses and injuries have not been distributed evenly across worker populations. Factors such as growing social inequality (along the lines of race/ethnicity, gender, and other social axes), restructuring of employer-employee relationships, and subcontracting practices that externalize risk highlight the need to account for the impact of the wider social context on work-related health outcomes [13]. These challenges lead us toward a biopsychosocial approach (viewing health within a social context) in OSH.

The concept of social determinants of health (SDOH), or how the structuring of society impacts the health and well-being of individuals and populations, can be useful towards understanding the biopsychosocial model of health. Social structures are dynamic and are continually shaped and reshaped by the distribution of power, money, and resources embedded in the social, political, and economic organization of society [14,15]. Work itself is a social determinant that affects the distribution of injuries, illnesses, health and well-being in society [10]. Work is currently listed as contributing to two (employment stability and social and community context) of the five key domains of SDOH within the Healthy People 2030 framework [16]. Many social determinants shape the inequitable distribution of work-related health risks and benefits [12]. Social determinants of health also often interact and overlap with one another in ways that can further privilege or disadvantage individual workers [17].

Social structures influence more than just the distribution of health and safety exposures, risks, and outcomes. They also contribute to exclusionary research, prevention, and mitigation practices which are often inadvertently tailored to the normative group [18]. As a result, those most in need of benefiting from preventive interventions are often least likely to receive them [19,20]. Public health interventions that do not account for these structural limitations can actually aggravate inequities as they often disproportionally help members of socially privileged groups [21].

3. Work, Health Inequities, and Society

Not all workers have the same risk of experiencing a work-related injury or illness, even when they have the same job. The way societies configure social and economic institutions creates the social conditions that influence workers' exposures to occupational hazards (differential exposure) and their abilities to cope with risks or adverse consequences of an occupational injury or illness (differential susceptibility) [22]. Occupational health inequities are avoidable differences in work-related injury and illness incidence, morbidity and mortality that are closely linked with social, economic, and environmental disadvantage resulting from social arrangements [23]. Perhaps the three most salient social

determinants of worker health are structures of social groups, industries, and jobs. Workers from certain groups, such as racialized/ethnic minorities and immigrants, are sorted into and overrepresented in dangerous occupations [24,25], receive differential treatment on the job [26], and have limited access to worker protection resources and benefits [27,28]. Industry structures can favor the health and well-being of some workers over others through, for example, the competitive bidding process and practice of externalizing costs, risks, and liability from large corporations to smaller ones through the use of sub-contracting arrangements [13,29]. Similarly, non-standard work arrangements, shift work, and considerations of autonomy at work are just some of the ways jobs are structured that also impact the distribution of work-related benefits and risks [30–32]. Furthermore, work's influence on health and illness goes beyond the specific conditions at work. Indeed, the structure of one's job or career exerts a significant influence over other aspects of life that contribute or detract from an individual's health and that of their family such as income, social status, housing, access to healthcare, and leisure time. While work is a social determinant that contributes to inequities, it can also be a principal mechanism for securing fundamental needs and increasing health equity and well-being [10,33–35].

4. Towards the Integration of a Biopsychosocial Approach to OSH Research

A biopsychosocial approach to OSH explicitly takes into account the role that social arrangements play in the inequitable distribution of work-related risks and benefits and can be a tool for both deeper understanding of the social determinants of health and advancing health equity [3]. The integration of a health equity perspective into OSH research requires organizational changes to:

- Promote research focused on identifying, understanding and ameliorating OSH-related inequities that are closely linked with social, economic, and environmental disadvantage;
- Integrate inclusive research practices across the OSH field so that the knowledge base reflects societal diversity and accounts for differing experiences of social conditions; and
- Develop a better understanding of how work-related constructs contribute to the inequitable distribution of illness, injury, mortality, and wellbeing in society and how the world of work could be leveraged to improve community health.

4.1. Research Focused on Occupational Health Inequities

Traditional fields of study used in OSH, such as industrial hygiene, often utilize studies that test very specific exposure/disease associations via risk assessment tools and worksite analysis to evaluate potential physical, chemical, and biological risks. Epidemiologic research that focuses on health inequities allows us to distinguish the most salient determinants, industries, and worker populations for understanding inequities. While these studies are key for documenting population-level occupational health inequities, the analysis is often limited to a single or limited set of variables. Yet, since the social position of any individual is a complex, interwoven set of identities based on asymmetrical power relationships along social axes such as race/ethnicity, sex/gender, nativity, and class [36,37], there is a need for research on relationships and interactions between these factors, as well as more contextualized analyses. Increasing research that aims to understand the social and structural factors that influence OSH risks, exposures, and outcomes, and the relationships between these factors, is essential.

Workers from groups that are socially marginalized are often disproportionately exposed to structural disadvantages related to other social determinants of OSH. For example, immigrants and racialized/ethnic minorities are overrepresented in contingent work arrangements [38] and foreign-born workers are overrepresented in small construction firms and receive less training and less overall safety communication than those employed by large companies [27]. These overlapping structural vulnerabilities [17] result in what Gravel and Dubé have termed "cumulative precarity," meaning social and structural factors

interact to create risks greater than the sum of the risk from each individual factor [39]. Overlapping structural vulnerabilities, and the ways they create cumulative precarity, need to be systematically investigated to bring a more complete picture of how occupational health inequities operate [40].

In addition to identifying which social factors, individually or in combination, contribute to occupational health inequities, research is also needed to characterize how structural disadvantages materialize at the worksite and in the lives of workers. For example, in 2019, foreign-born individuals made up two-thirds of occupational fatalities among Latinos in the United States despite the fact that immigrants represent only about one third of the Latino population in the United States [41]. However, few studies explore factors related to the immigrant experience that may lead to increased work-related fatalities. One such study examines how the assignment of an "undocumented" status results in a complex web of economic and social consequences that places workers at increased risk for occupational injury or illness and limits their ability to address the risks they face at work [42]. Developing an understanding of what contributes to the distribution of risks across different worker groups, industries, and occupations (not solely in terms of individual worker characteristics, but rather a deep inquiry into the social and structural conditions that shape workers' lives) is essential to creating effective strategies to reduce these inequities.

Intervention research needs to engage an equity lens. Efforts to address occupational health inequities generally attempt to integrate workers from disadvantaged groups into existing institutional practices and paradigms that focus on the individual worker within the context of the immediate workplace [8,43]. These efforts tend to emphasize improving workers' safety knowledge and promoting behavioral modifications with workers, an approach that has limited success [44]. A small but growing literature documents efforts to culturally tailor interventions [28]. While these efforts often acknowledge social constraints that may contribute to increased risk, they generally focus on integrating creative and inclusive teaching methods. Safety knowledge and behavior modification often remain the focus of the intervention. Unfortunately, much of the work to address occupational health inequities often relies on simplistic, individualistic and uncritical models of culture that reinforce the predominant worldview that the workers' 'otherness' is both the cause of inequalities and the target for interventions [45]. For example, commonplace descriptions of immigrant and racialized/ethnic minority workers as "hard-to-reach" suggests that it is something about "them" (i.e., language, culture, mistrust of institutions, and other factors) that limits the services they receive from OSH organizations. Framing the issue in this way hides the fact that safety and health institutions have evolved to better meet the needs of workers from the cultural majority or normative group more than those from other social groups. A first step in acknowledging and addressing these institutional limitations would be to change the conceptualization of these workers from "hard to reach" to "hardly reached"—in other words, asking not what makes these workers "hard to reach", but rather asking what organizations need to do to develop the institutional capacity to more effectively work with an increasingly multicultural and diverse workforce [46].

4.2. Integrate Inclusive Research Practices across OSH

While not all OSH research needs to have a primary focus on health inequities, all research should account for the diversity in the workforce and the influence that exclusionary social structures have on work-related risks, exposures, and outcomes as well as on OSH research design itself. Currently, concerns over health inequities are largely the domain of individual standard bearers or specific programs within larger institutions. Integrating equity more thoroughly, through inclusive OSH research and interventions, will require converting individual concerns into a core institutional value and implementing practices that better address the realities of a diverse workforce. In short, this will require a shift in organizational culture from individual concern for health equity to institutionalized practice [47]. This transition not only addresses ethical concerns related to inclusion, but

will make for better science, as designs and interpretations will take into better account real-world contexts and represent a broader range of worker experiences.

As mentioned above, the exclusionary social structures that operate within society at large also operate within OSH organizations [3]. As a result, the assumptions, practices and approaches that guide OSH research have, often inadvertently, evolved to more effectively serve the needs of workers from some social groups more than others [18,21]. Identifying and correcting these exclusionary assumptions, practices and approaches is essential to ensuring that OSH research is responsive to the diversity within the workforce and effectively accounts for the social context within which research and practice related to worker safety and health take place [48]. Identifying and enumerating all of the potential ways that social context may contribute to exclusionary research practices is a daunting task. To simplify, we have identified three key areas that may be a good place to begin.

4.2.1. Structural Invisibility

As the old adage goes, "you can't fix what you don't see" [49]. Structural invisibility results from society's privileging and paying attention to the experiences of some social groups over others [50]. One way this privileging occurs is through data collection and analysis. The principal way that OSH institutions "see" reality is through data. The limitations of OSH surveillance systems to collect demographic and other data relevant to the experiences of historically underrepresented groups such as racialized/ethnic minorities and immigrants is well documented [10,51,52]. Data on social factors that potentially contribute to the inequitable distribution of work-related benefits and risks are often not collected, analyzed or published, thus rendering occupational health inequities and the social conditions that shape them invisible to researchers and institutions. Some research practices that contribute to structural invisibility include: lack or superficial treatment of socioeconomic variables by data collection instruments [53]; not accurately collecting socioeconomic data [52]; exclusionary recruitment practices and underrepresentation of workers from minority groups in study samples [54]; and an absence of or inadequate data analysis plan to identify potential occupational health inequities [55,56].

Common analytical perspectives and practices developed within the dominant social structure reflect the myopic and reductionist approach of the biomedical model which "asks only biological questions about what are in fact biosocial phenomena" [14] (p. 1686). For example, standard practices in epidemiology such as interpreting race as an individual demographic characteristic rather than a social construct or statistically adjusting for race instead of investigating the root causes of racial inequalities can reinforce ideas of biologic determinism and reify them in the scientific literature [55,56]. The result is a decontextualization of occupational injuries and illnesses that hides the social drivers of the inequities which further, albeit erroneously, reinforces the biomedical paradigm. It also has real world consequences as the scientific results impact the scope and focus of future research as well as decisions on intervention resource allocation, thus perpetuating the inequities that have been rendered invisible. For example, statistically controlling for sex in analysis of data on urinary tract infections (UTI) implies that women's higher rate of UTI is entirely attributable to anatomical difference [57]. The result is that social factors that may be contributing to these disparities, such as reduced access to restroom facilities for female employees relative to males, are made invisible. The real-world consequence is that the potential solution of increasing access to restroom facilities for female employees is overlooked. More sophisticated data collection and analytical approaches, rooted in the biopsychosocial paradigm, are required to create a fuller, more accurate picture in which the range of worker experiences can be visible.

4.2.2. Institutionalized Exclusion

Central to the biomedical model is the scientific method, which is based on the belief that replicable experimentation results in objective, generalizable knowledge of biological processes which can be used to identify and eliminate injury and illness. Alternately, a

biopsychosocial approach recognizes that scientific inquiry itself is socially constructed and its evolution has been circumscribed by the same exclusionary social structures (race, class, gender, nativity, and other factors) that result in occupational health inequities [9,58]. "Studying up" or turning the analytical gaze back on scientific inquiry and research practices allows us to identify how exclusionary social structures are often codified in research practices, instruments, and scientific models resulting in an inherent bias in favor of the normative group [59].

There is a long history of male bias in scientific modeling and data production [60]. For example, toxicology defines the standard human as a 70 kg male (definition has now been updated to 80 kg male), treating females simply as smaller males. This scientific practice clearly demonstrates a bias towards the normative group in US society (men) and as a result, toxicological research may not account for important biological differences between males and females. Similarly, personal protective equipment (PPE) has been designed based on anthropometric measurements taken from military recruits in the United States during the 1950s to 1970s, a sample that was largely male and white [61]. The result is a decrease in the ability to achieve good fits for PPE for women, people of color, and individuals with body sizes or shapes that do not conform to those of military recruits [62]. Bias in scientific models is not only carried over from legacies of the past but continues to be introduced today. For example, anecdotal evidence suggests that modeling and development of work-related exoskeletons are developed to fit the male form which can lead to poor comfort and low acceptance by women [63]; similar concerns have been raised around the integration of bias in the development of artificial intelligence [64]. Identifying exclusionary scientific research practices, instruments, and scientific models and finding ways to correct them is an essential, yet often overlooked, element of addressing occupational health inequities and ensuring that the benefits of OSH research are shared equally, by all.

4.2.3. Unexamined Assumptions

Scientists may not be objective observers but rather actors that occupy social positions within society that influence how they perceive the world and their research [65]. Research is circumscribed by the social context within which it develops and is impacted by the cultural norms and biases of the scientists themselves [18]. These biases and norms may underlie all aspects of research studies, from what questions get asked and the methods used to answer them, to the interpretations of results and how a given study is presented to and received by research and practice communities [66–68]. Failure to recognize the impact of these social arrangements on research poses epistemological barriers that potentially affect the interpretation of data and construction of knowledge [69]. However, this is easier said than done. The perspectives and assumptions of the normative group are frequently perceived as commonsensical and universal rather than culturally bound, especially by members of that group [70]. These perspectives are socially sanctioned, normalized and empowered through institutions such as media, laws, education systems, and institutional practices, and often permeate research without attention or reflection [71]. Accounting for assumptions that result from one's social position and disciplinary conventions is essential to conducting inclusive research [72]. Just as individual worker's social positions are complex, dynamic, and interwoven sets of identities based on asymmetrical power relationships along social axes that balance privilege and exclusion, so too are the social positions and identities of researchers [37]. As a researcher, understanding one's position within this complex social web and how that position circumscribes one's perspective of the world and one's approach to public health requires an interactive process of education, reflection and action [36,73].

Conceptual approaches and reflexive practices, such as cultural humility, help researchers recognize that they bring culturally bound assumptions to their work which need to be identified and made explicit [74–76]. Involving researchers and study partners from diverse social and disciplinary backgrounds and fostering a culture of inclusion that openly discusses these differences and their potential impacts on the research is essential to

identifying and addressing unexamined assumptions within the research [77]. Reflecting on the positionality of those involved in the project is an essential step to engage in these discussions. For example, the authors have been able to draw on their intersectional identities belonging to non-normative groups such as women, LGBTQ people, black people, multiracial people, people from working-class family backgrounds, and people with family experiences as refugees and immigrants, to provide insights for this commentary into how society excludes the experiences of some individuals along multiple social axes. The authors' experiences of privilege associated with their education levels, employment with the federal government, and identities as white, male, heterosexual, upper-class family background and native-born US citizens have influenced their awareness and perceptions of the dynamics of exclusion and privilege. This mix of personal experiences, together with their professional training and work experiences outlined in their biographies, contextualize the perspectives outlined in this paper.

Another way to make unexamined assumptions of the research team explicit is to incorporate practices and methods that can help identify assumptions in research designs and data collection instruments, and analysis, such as cognitive testing, when developing data collection instruments [78,79]. This is even true when using well-established, validated instruments [80]. Box 1 contains an example that highlights the importance of accounting for the assumptions of the research team. More robust approaches to identify and address the unexamined assumptions of researchers are needed to truly ensure research projects are inclusive of the workforce diversity and that the data collected accurately reflects the experience of all of the respondents.

Box 1. Not All Perspectives are Created Equal.

The following example comes from a larger study [81] of tuberculosis (TB) among Latino immigrant workers and has been simplified to highlight some of the key concepts in this section such as unexamined assumptions and socially endorsed perspectives. It should not be taken as a scientific reporting of the results of the individual interviews but rather as an example of how exclusionary practices can manifest themselves in practice.

During a formative investigation of tuberculosis (TB) among Latino immigrant workers, participants were asked if the results of their TB test were positive, to which many answered "yes". When asked if they were taking their medicine several answered "no". According to the researchers' understandings of the questions as they had written them, these results would have been interpreted as indicating that these workers had test results that indicated the presence of TB, that they required medication, and that they were noncompliant with their treatment.

However, to account for any possible unexamined assumptions, a modified cognitive testing protocol was integrated into the interview. This additional step asked the respondents to explain to the researchers how they understood the key concepts in the interview. A common answer was that a "positive TB test result" was good news that meant they were not sick and therefore did not need medicine.

While different, both the researchers' and the respondents' understanding of "positive test result" are reasonable, yet they are not treated equally by public health institutions and society in general. Had the respondents' interpretations not been uncovered during cognitive testing, the researchers' initial interpretations of these workers having TB and being noncompliant with treatment would have held as a result of the investigation. Had these findings been published they would have become reified in the scientific literature, further reinforcing the researchers' perspective. The erroneous findings would not only have misrepresented the lives of these workers, but the results would potentially have influenced the focus and funding of future research and interventions on topics that were not addressing the real needs of this community.

4.3. The World of Work and Health Inequities

Socioecological models have long recognized that the impact of employment on health goes beyond conditions at work. Indeed, as described above, one's job exerts a significant influence over other aspects of life that contribute to or detract from an individual's health and that of their family [35,82,83]. However, the classification of exposures and outcomes as work-related or not often separates occupational health research and practice from the rest of public health and work-related variables are largely absent from health equity

research [3,22]. Despite these limitations, there is a small but growing body of literature that explores work as a causal pathway of health inequities. For example, recent analyses show that higher education does not confer the same benefit of access to safe and higher quality jobs, with demonstrable inequities in late life cognitive function [84] and all-cause mortality [85]. In other words, education's protective effects through occupation (i.e., higher education leading to better jobs and better health) differ by race and gender. Greater attention to the relationship between work and health by population health researchers is essential to improving our understanding of work as a social determinant of health inequities and its potential to mitigate them [34].

Since work has a significant impact on the ability to secure the basic needs that provide the foundation for health and well-being, it directly and indirectly intersects with and influences many of the other social determinants of health. Therefore, the world of work has powerful potential to be leveraged to address health inequities in general, not only those classified as "occupational." At the societal level, labor policies and workforce development initiatives that improve the quality of jobs and increase access to "decent work" can be analyzed and understood through a public health lens [86]. Further research is needed to fully explicate the promise of public health impacts beyond the workplace of labor- and work-focused policies and interventions, such as job security, wage and hour laws, paid sick leave, and other factors [87]. At the organizational level, issues related to work design, such as contract, wage, hour, and benefit structures, can improve worker health and well-being on and off the job [88]. Innovative practices around, for example, safety culture, work stress, and work-life balance are already implemented by organizations. The biopsychosocial approach extends the way organizations consider the costs and benefits of these strategies, as the impacts likely interact with non-work factors to amplify results. Indeed, there is a growing body of literature that elaborates the conceptual rationale and explores the business case for expanding the breadth of workplace wellness programs to include a social determinants perspective [89]. The Total Worker Health® framework is an effort to operationalize the broader conceptualization of the relationship between work and health so that it can be implemented and studied [90]. Conversely, the inclusion of work and social factors related to occupation in broader public health and health equity research and practice is vital to understanding and taking advantage of the intersection of work with other aspects of individuals' and communities' lives. Work's potential as an intervention site to provide access to resources and improve social determinants of health is a powerful, yet underutilized tool, in addressing health inequities [33].

5. Conclusions

Health equity is a central element of a larger paradigm shift to a biopsychosocial approach to OSH. This shift requires a change in organizational culture that makes health equity an institutionalized element of practice aligned with organizational values rather than the domain of individual concern. While this shift does not require all research to focus on health equity, it does require all research to engage in inclusive methods that address concerns around structural invisibility, institutionalized exclusion and unexamined assumptions. How quickly and successfully OSH organizations adapt to this paradigm shift will largely depend on the institutional support given to this transition. Within the biomedical model that has dominated OSH over the past 50 years, research on the technical aspects of OSH has been privileged over research that explores its social aspects [3,22,91]. As a result, the social sciences are underrepresented in work on occupational safety and health and the field has developed a limited ability to account for the historical and social context that circumscribe the injury experience and contribute to elevated rates of injuries among workers from certain groups.

Integration of social scientists into occupational safety and health is essential to improving the depth, breadth and quality of research and interventions that address occupational health inequities. It is also a prerequisite for developing the institutional capacity to embrace a paradigm shift to the biopsychosocial approach. Successful integration of social

scientists will require organizations to increase their internal capacity, expand external interest and foreground the social perspective. Perhaps the most commonsensical and effective approach to building institutional capacity in the social sciences will be to prioritize directly hiring professionals from underrepresented fields such as medical anthropology, health communications, sociology, social epidemiology, and translation research. Our own team for this paper represents some of the leaders in occupational health equity at the National Institute for Occupational Safety and Health, a federal government institution that is steeped in the normative culture of the United States and has extensive global reach and influence. Our training comes from diverse fields of anthropology, population health, and epidemiology and our experience covers surveillance, quantitative and qualitative methods, health communication, translation and intervention research, and public health programs and partnerships. Our work at NIOSH has cut across organizational lines as we have worked to promote health equity within our divisions and are moving as an Institute towards embracing the sorts of cultural shifts in norms, values, and practices described herein.

However, direct hires alone are not enough. Generating interest in OSH among nontraditional academic departments and professional organizations will be essential to improving occupational health equity research. It is easy to see how specific concerns around occupational health equity, such as gender inequity in exoskeleton design, racial bias in artificial intelligence, discrimination and workplace stress, alternative work arrangements and substance abuse, could be of interest to researchers in gender and ethnic studies, communications, anthropology and sociology, among others. In addition, an expanded framing of the relationship among work, health and inequity through sociocultural, biopsychosocial, and social determinants lenses not only makes OSH relevant to a larger number of academic fields but also leverages the awareness of these relationships that was built during the COVID-19 pandemic. Indeed, making explicit the implicit connections between public health, OSH, and the social sciences more broadly will go a long way in bridging the gap between OSH and the social sciences and improving our understanding of the social dimensions of worker health and well-being. Finally, ensuring social science perspectives influence the organizational direction, strategic plans, and budget decisions of OSH organizations is essential to promoting health equity research. Foregrounding a social perspective in OSH organizations will require the participation of social scientists in internal leadership positions as well as external influencers through their service on such bodies as advisory boards and grant review committees. The question left to these organizations is: How can we best leverage this moment to institutionalize a biopsychosocial approach to OSH?

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References

1. Brown, T.M.; Fee, E. Rudolf Carl Virchow: Medical scientist, social reformer and role model. *Am. J. Public Health* **2006**, *96*, 2104–2105. [CrossRef] [PubMed]
2. Abrams, H.K. A short history of occupational health. *J. Public Health Policy* **2001**, *22*, 34–80. [CrossRef]

3. Flynn, M.A. Im/migration, Work and Health: Anthropology and the Occupational Health of Labor Im/migrants. *Anthropol. Work Rev.* **2018**, *39*, 116–123. [CrossRef]
4. Engel, G.L. The need for a new medical model: A challenge for biomedicine. *Science* **1977**, *196*, 129–136. [CrossRef]
5. Occupational Safety and Health Administration [OSHA]. Commonly Used Statistics. Available online: www.osha.gov/oshstats/commonstats.html (accessed on 11 June 2021).
6. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.A.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065. [CrossRef] [PubMed]
7. Farmer, P. Social Medicine and the Challenge of Biosocial Research. In *Innovative Structures in Basic Research: Ringberg-Symposium*; Opolka, U., Schoop, H., Eds.; Max-Planck-Gesellschaft: Munich, Germany, 2000; pp. 55–73.
8. Saxton, D.I.; Stuesse, A. Workers' Decompensation: Engaged Research with Injured Im/migrant Workers. *Anthropol. Work Rev.* **2018**, *39*, 65–78. [CrossRef]
9. Stonington, S.; Holmes, S.M. Social medicine in the twenty-first century. *PLoS Med.* **2006**, *3*, e445. [CrossRef]
10. Ahonen, E.Q.; Fujishiro, K.; Cunningham, T.; Flynn, M.A. Work as an inclusive part of population health inequities research and prevention. *Am. J. Public Health* **2018**, *108*, 306–311. [CrossRef]
11. Schulte, P.; Vainio, H. Well-being at work–overview and perspective. *Scand. J. Work Environ. Health* **2010**, *1*, 422–429. [CrossRef] [PubMed]
12. WHO Commission on Social Determinants of Health, World Health Organization. *Closing the Gap in a Generation: Health Equity through Action on the Social Determinants of Health: Commission on Social Determinants of Health Final Report*; World Health Organization: Geneva, Switzerland, 2008; p. 33.
13. Weil, D. *The Fissured Workplace: Why Work Became So Bad for So Many and What Can Be Done to Improve It*; Harvard University Press: Cambridge, MA, USA, 2017; p. 424.
14. Farmer, P.; Nizeye, B.; Stulac, S.; Keshavjee, S. Structural Violence and Clinical Medicine. *PLoS Med.* **2006**, *3*, 1686–1691. [CrossRef]
15. World Health Organization. Social Determinants of Health. 2014. Available online: http://www.who.int/social_determinants/en/ (accessed on 27 September 2021).
16. Centers for Disease Control and Prevention. About Social Determinants of Health (SDOH). Available online: https://www.cdc.gov/socialdeterminants/about.html (accessed on 15 May 2021).
17. National Institute for Occupational Safety and Health and American Society of Safety Engineers (NIOSH/ASSE). *Overlapping Vulnerabilities: The Occupational Safety and Health of Young Workers in Small Construction Firms*; NIOSH Publication No. 2015-178; U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, DHHS: Cincinnati, OH, USA, 2015.
18. Ford, C.L.; Airhihenbuwa, C.O. The public health critical race methodology: Praxis for antiracism research. *Soc. Sci. Med.* **2010**, *71*, 1390–1398. [CrossRef]
19. Victora, C.G.; Vaughan, J.P.; Barros, F.C.; Silva, A.C.; Tomasi, E. Explaining trends in inequities: Evidence from Brazilian child health studies. *Lancet* **2000**, *356*, 1093–1098. [CrossRef]
20. Hart, J.T. The inverse care law. *Lancet* **1971**, *297*, 405–412. [CrossRef]
21. White, M.; Adams, J.; Heywood, P. How and why do interventions that increase health overall widen inequalities within populations. *Soc. Inequal. Public Health* **2009**, *65*, 82.
22. Peckham, T.K.; Baker, M.G.; Camp, J.E.; Kaufman, J.D.; Seixas, N.S. Creating a future for occupational health. *Ann. Work Expo. Health* **2017**, *61*, 3–15. [PubMed]
23. National Institute for Occupational Safety and Health. Occupational Health Equity. Available online: https://www.cdc.gov/niosh/programs/ohe/default.html (accessed on 21 June 2021).
24. Orrenius, P.M.; Zavodny, M. Do immigrants work in riskier jobs? *Demography* **2009**, *46*, 535–551. [CrossRef]
25. Steege, A.L.; Baron, S.L.; Marsh, S.M.; Menéndez, C.C.; Myers, J.R. Examining occupational health and safety disparities using national data: A cause for continuing concern. *Am. J. Ind. Med.* **2014**, *57*, 527–538. [CrossRef] [PubMed]
26. Okechukwu, C.A.; Souza, K.; Davis, K.D.; de Castro, A.B. Discrimination, harassment, abuse, and bullying in the workplace: Contribution of workplace injustice to occupational health disparities. *Am. J. Ind. Med.* **2014**, *57*, 573–586. [CrossRef]
27. Cunningham, T.R.; Guerin, R.J.; Keller, B.M.; Flynn, M.A.; Salgado, C.; Hudson, D. Differences in safety training among smaller and larger construction firms with non-native workers: Evidence of overlapping vulnerabilities. *Saf. Sci.* **2018**, *103*, 62–69. [CrossRef]
28. O'Connor, T.; Flynn, M.A.; Weinstock, D.; Zanoni, J. Education and training for underserved populations. In Proceedings of the Eliminating Health and Safety Disparities at Work Conference, Chicago, IL, USA, 14 September 2011; Available online: http://www.aoecdata.org/conferences/healthdisparities/index.html (accessed on 20 September 2021).
29. Paap, K. *Working Construction: Why White Working-Class Men Put Themselves and the Labor Movement in Harm's Way*; Cornell University Press: Ithica, NY, USA, 2006; p. 272.
30. Facey, M.E.; Eakin, J.M. Contingent work and ill-health: Conceptualizing the links. *Soc. Theory Health* **2010**, *8*, 326–349. [CrossRef]
31. Foley, M. Factors underlying observed injury rate differences between temporary workers and permanent peers. *Am. J. Ind. Med.* **2017**, *60*, 841–851. [CrossRef] [PubMed]

32. Howard, J. Nonstandard work arrangements and worker health and safety. *Am. J. Ind. Med.* **2017**, *60*, 1–10. [CrossRef]
33. Flynn, M.A.; Wickramage, K. Leveraging the Domain of Work to Improve Migrant Health. *Int. J. Environ. Res. Public Health* **2017**, *14*, 1248. [CrossRef]
34. Fujishiro, K.; Ahonen, E.Q.; de Porras, D.G.; Chen, I.C.; Benavides, F.G. Sociopolitical values and social institutions: Studying work and health equity through the lens of political economy. *SSM-Popul. Health* **2021**, *14*, 100787. [CrossRef] [PubMed]
35. Schulte, P.A.; Guerin, R.J.; Schill, A.L.; Bhattacharya, A.; Cunningham, T.R.; Pandalai, S.P.; Eggerth, D.E.; Stephenson, C.M. Considerations for incorporating "well-being" in public policy for workers and workplaces. *Am. J. Public Health* **2015**, *2015 105*, e31–e44. [CrossRef]
36. Collins, P.H. *Intersectionality as Critical Social Theory*; Duke University Press: Durham, NC, USA, 2019; p. 376.
37. Crenshaw, K. Mapping the margins: Intersectionality, identity politics, and violence against women of color. *Stan. L Rev.* **1990**, *43*, 1241. [CrossRef]
38. Quinlan, M.; Bohle, P. Contingent work and occupational safety. In *The Psychology of Workplace Safety*; Barling, J., Frone, M.R., Eds.; American Psychological Association: Washington, DC, USA, 2004; pp. 81–105.
39. Gravel, S.; Dubé, J. Occupational health and safety for workers in precarious job situations: Combating inequalities in the workplace. *E-J. Int. Comp. Labour Stud.* **2016**, *5*, 11–39.
40. Ceballos, D.M.; Côté, D.; Bakhiyi, B.; Flynn, M.A.; Zayed, J.; Gravel, S.; Herrick, R.F.; Labrechè, F. Overlapping vulnerabilities in workers of the electronics recycling industry formal sector: A commentary. *Am. J. Ind. Med.* **2020**, *63*, 955–962. [CrossRef]
41. Bureau of Labor Statistics. Fatal work injuries to Hispanic or Latino Workers. Census of Fatial Occupational Injuries, 2020. Available online: https://www.bls.gov/charts/census-of-fatal-occupational-injuries/fatal-work-injuries-to-hispanic-or-latino-workers.htm (accessed on 2 June 2021).
42. Flynn, M.A.; Eggerth, D.E.; Jacobson, C.J. Undocumented status as a social determinant of occupational health: The workers' perspective. *Am. J. Ind. Med.* **2015**, *58*, 1127–1137. [CrossRef]
43. Ahonen, E.Q. Occupational Health Challenges for Immigrant Workers. In *Oxford Research Encyclopedia of Global Public Health*; Oxford University Press: Oxford, UK, 2019.
44. Caffaro, F.; Cremasco, M.M.; Bagagiolo, G.; Vigoroso, L.; Cavallo, E. Effectiveness of occupational safety and health training for migrant farmworkers: A scoping review. *Public Health* **2018**, *160*, 10–17. [CrossRef]
45. Premji, S. Discourse on culture in research on immigrant and migrant workers' health. *Am. J. Ind. Med.* **2019**, *62*, 460–470. [CrossRef]
46. Flynn, M.A.; Eggerth, D.E.; Keller, B.M.; Check, P. Reaching "hard to reach" workers: Evaluating approaches to disseminate worker safety information via the Mexican consular network. *J. Occup. Environ. Hyg.* **2021**, *18*, 180–191. [CrossRef]
47. Dean, H.D.; Roberts, G.W.; Bouye, K.E.; Green, Y.; McDonald, M. Sustaining a focus on health equity at the centers for disease control and prevention through organizational structures and functions. *J. Public Health Manag. Pract.* **2016**, *22*, S60–S67. [CrossRef]
48. Flynn, M.A.; Castellanos, E.; Flores-Andrade, A. Safety across cultures: Understanding the challenges. *Profl. Saf.* **2018**, *63*, 28–32.
49. Carter, P.L.; Skiba, R.; Arredondo, M.I.; Pollock, M. You can't fix what you don't look at: Acknowledging race in addressing racial discipline disparities. *Urban Educ.* **2017**, *52*, 207–235. [CrossRef]
50. Lever, J.; Milbourne, P. The Structural Invisibility of Outsiders: The Role of Migrant Labour in the Meat-Processing Industry. *Sociology* **2017**, *51*, 306–322. [CrossRef] [PubMed]
51. National Academies of Sciences, Engineering, and Medicine. *A Smarter National Surveillance System for Occupational Safety and Health in the 21st Century*; National Academies Press: Washington, DC, USA, 2018; p. 318.
52. Souza, K.; Steege, A.L.; Baron, S.L. Surveillance of occupational health disparities: Challenges and opportunities. *Am. J. Ind. Med.* **2010**, *53*, 84–94. [CrossRef] [PubMed]
53. Rodriguez-Lainz, A.; McDonald, M.; Fonseca-Ford, M.; Penman-Aguilar, A.; Waterman, S.H.; Truman, B.I.; Cetron, M.S.; Richards, C.L. Collection of data on race, ethnicity, language, and nativity by US public health surveillance and monitoring systems: Gaps and opportunities. *Public Health Rep.* **2018**, *133*, 45–54. [CrossRef] [PubMed]
54. Schenker, M.B. A global perspective on migration and occupational health. *Am. J. Ind. Med.* **2010**, *53*, 329–337. [CrossRef] [PubMed]
55. Jones, C.P. Invited commentary: "race," racism, and the practice of epidemiology. *Am. J. Epidemiol.* **2001**, *154*, 299–304. [CrossRef]
56. Kaufman, J.S.; Cooper, R.S.; McGee, D.L. Socioeconomic status and health in blacks and whites: The problem of residual confounding and the resiliency of race. *Epidemiology* **1997**, *8*, 621–628. [CrossRef]
57. Fujishiro, K. *Occupational Health Disparities: What Are They? How Should We Think about Them? Presented at the Division of Field Studies and Engineering Health Occupational Epidemiology Seminar Series*; National Institute for Occupational Safety and Health: Cincinnati, OH, USA, 2021.
58. Press, S.J.; Tanur, J.M. *The Subjectivity of Scientists and the Bayesian Approach*; John Wiley & Sons: New York, NY, USA, 2001; p. 288.
59. Nader, Laura. Up the Anthropologist: Perspectives Gained from 'Studying Up'. In *Reinventing Anthropology*; Hymes, D., Ed.; Random House: New York, NY, USA, 1972; pp. 284–311.

60. Perez, C.C. *Invisible Women: Exposing Data Bias in a World Designed for Men*; Abrams Press: New York, NY, USA, 2019; p. 272.
61. Spahr, J.; Kau, T.; Hsiao, H.; Zwiener, J. Anthropometric differences among Hispanic occupational groups. In Proceedings of the 2003 National Occupational Injury Research Symposium (NOIRS), Pittsburgh, PA, USA, 28–30 October 2003.
62. Hsiao, H.; Friess, M.; Bradtmiller, B.; Rohlf, F.J. Development of sizing structure for fall arrest harness design. *Ergonomics* **2009**, *52*, 1128–1143. [CrossRef]
63. Robertson, L.D.; Syron, L.; Flynn, M.A.; Teske, T.; Hsiao, H.; Lu, J.; Lowe, B.D. Exoskeletons and Occupational Health Equity. NIOSH Science Blog. Available online: http://blogs.cdc.gov/niosh-science-blog/2020/12/14/exoskeletons-health-equity/ (accessed on 14 May 2021).
64. Zou, J.; Schiebinger, L. AI can be sexist and racist-it's time to make it fair. *Nature* **2018**, *559*, 324–326. [CrossRef]
65. Harding, S.G. *The Science Question in Feminism*; Cornell University Press: Ithica, NY, USA, 1986; p. 263.
66. Airhihenbuwa, C.O.; Liburd, L. Eliminating health disparities in the African American population: The interface of culture, gender, and power. *Health Educ. Behav.* **2006**, *33*, 488–501. [CrossRef]
67. Carnethon, M.R.; Kershaw, K.N.; Kandula, N.R. Disparities research, disparities researchers, and health equity. *JAMA* **2020**, *323*, 211–212. [CrossRef] [PubMed]
68. Marcus, G.E. *Ethnography through Thick and Thin*; Princeton University Press: Princeton, NJ, USA, 1998.
69. Gershon, I. Reflexivity in Others' Contexts: An Introduction. *Ethnos: J. Anthropol.* **2006**, *71*, 445–452. [CrossRef]
70. Hall, E.T. *The Silent Language*; Anchor Books: New York, NY, USA, 1959.
71. Rodseth, L. Hegemonic Concepts of Culture: The Checkered History of Dark Anthropology. *Am. Anthropol.* **2018**, *120*, 398–411. [CrossRef]
72. Airhihenbuwa, C.O. SOPHE Presidential Address: On being comfortable with being uncomfortable: Centering an Africanist vision in our gateway to global health. *Health Educ. Behav.* **2007**, *34*, 31–42. [CrossRef] [PubMed]
73. Chang, E.S.; Simon, M.; Dong, X. Integrating cultural humility into health care professional education and training. *Adv. Health Sci. Educ.* **2012**, *17*, 269–278. [CrossRef]
74. Chiarenza, A. Developments in the concept of cultural competence. In *Inequalities in Health Care for Migrants and Ethnic Minorities*; Ingleby, D., Chiarenza, A., Devillé, W., Kotsioni, I., Eds.; Garant Publishers: Antwerp, Belgium, 2012; pp. 66–81.
75. Foronda, C. A theory of cultural humility. *J. Transcult. Nurs.* **2020**, *31*, 7–12. [CrossRef]
76. Isaacson, M. Clarifying concepts: Cultural humility or competency. *J. Prof. Nurs.* **2014**, *30*, 251–258. [CrossRef] [PubMed]
77. Flynn, M.A.; Eggerth, D.E. Occupational Health Research with Immigrant Workers. In *Migration and Health: A Research Methods Handbook*; Schenker, M.B., Castañeda, X., Rodriguez-Lainz, A., Eds.; University of California Press: Oakland, CA, USA, 2014; pp. 377–395.
78. Fujishiro, K.; Gong, F.; Baron, S.; Jacobson, C.J., Jr.; DeLaney, S.; Flynn, M.; Eggerth, D.E. Translating questionnaire items for a multi-lingual worker population: The iterative process of translation and cognitive interviews with English-, Spanish-, and Chinese-speaking workers. *Am. J. Ind. Med.* **2010**, *53*, 194–203. [CrossRef] [PubMed]
79. Teresi, J.A.; Stewart, A.L.; Morales, L.S.; Stahl, S.M. Measurement in a multi-ethnic society: Overview to the special issue. *Med. Care* **2006**, *44* (Suppl. 3), S3. [CrossRef] [PubMed]
80. Flynn, M.A.; Eggerth, D.E.; Jacobson, C.J.; Lyon, S.M. Heart Attacks, Bloody Noses, and Other "Emotional Problems": Cultural and Conceptual Issues with the Spanish Translation of Self-Report Emotional Health Items. *Fam. Community Health* **2021**, *44*, 1–9. [CrossRef]
81. Eggerth, D.E.; Keller, B.M.; Flynn, M.A. Exploring workplace TB interventions with foreign-born Latino workers. *Am. J. Ind. Med.* **2018**, *61*, 649–657. [CrossRef] [PubMed]
82. Bambra, C. *Work, Worklessness, and the Political Economy of Health*; Oxford University Press: Oxford, UK, 2011; pp. 130–162.
83. Lipscomb, H.J.; Loomis, D.; McDonald, M.A.; Argue, R.A.; Wing, S. A conceptual model of work and health disparities in the United States. *Int. J. Health Serv.* **2006**, *36*, 25–50. [CrossRef]
84. Fujishiro, K.; MacDonald, L.A.; Crowe, M.; McClure, L.A.; Howard, V.J.; Wadley, V.G. The role of occupation in explaining cognitive functioning in later life: Education and occupational complexity in a US national sample of black and white men and women. *J. Gerontol Ser. B* **2019**, *74*, 1189–1199. [CrossRef]
85. Fujishiro, K.; MacDonald, L.A.; Howard, V.J. Job complexity and hazardous working conditions: How do they explain educational gradient in mortality? *J. Occup. Health Psychol.* **2020**, *25*, 176. [CrossRef]
86. International Labor Organization (ILO). Decent Work for Migrants and Refugees. Geneva. Available online: http://www.ilo.org/wcmsp5/groups/public/---dgreports/--dcomm/documents/publication/wcms_524995.pdf (accessed on 12 June 2021).
87. Pratap, P.; Dickson, A.; Love, M.; Zanoni, J.; Donato, C.; Flynn, M.A.; Schulte, P.A. Public Health Impacts of Underemployment and Unemployment in the United States: Exploring Perceptions, Gaps and Opportunities. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10021. [CrossRef]
88. National Institute for Occupational Safety and Health. Healthy Work Design and Well-Being Program. Available online: https://www.cdc.gov/niosh/programs/hwd/default.html (accessed on 14 December 2021).
89. Sherman, B.W.; Stiehl, E. Health management in commercially insured populations: It is time to include social determinants of health. *J. Occup. Environ. Med.* **2018**, *60*, 688–692. [CrossRef]

90. NIOSH. *Fundamentals of Total Worker Health Approaches: Essential Elements for Advancing Worker Safety, Health, and Well-Being*; Lee, M.P., Hudson, H., Richards, R., Chang, C.C., Chosewood, L.C., Schill, A.L., Eds.; DHHS (NIOSH) Publication No. 2017-112; Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health: Atlanta, GA, USA, 2016.
91. Felknor, S.A.; Streit, J.M.; McDaniel, M.; Schulte, P.A.; Chosewood, L.C.; Delclos, G.L. How Will the Future of Work Shape OSH Research and Practice? A Workshop Summary. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5696. [CrossRef] [PubMed]

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Article

Leveraging an Implementation Science Framework to Measure the Impact of Efforts to Scale Out a *Total Worker Health*® Intervention to Employers

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Abstract: The role of dissemination and implementation (D&I) science is critical to the translation of *Total Worker Health*® into practice and to the success of interventions in addressing current and future implications for worker safety, health, and well-being. D&I frameworks can guide researchers to design *Total Worker Health* ("TWH") delivery approaches that use flexible implementation strategies to implement the core components of programs for employers with varying contextual factors, including small/mid/large-sized businesses and different industry types. To date, there have been very few examples of applying implementation frameworks for the translation and delivery of interventions into organizational settings that require adoption and implementation at the business level to benefit the working individuals. We present a TWH case study, Health Links™, to illustrate an approach to applying an existing implementation framework, RE-AIM, to plan, design, build, and then evaluate TWH implementation strategies. Our case study also highlights key concepts for scaling-out TWH evidence-based interventions where they are implemented in new workplace settings, new delivery systems, or both. Our example provides strong support of key implementation planning constructs including early and consistent stakeholder engagement, tailored messaging and marketing, flexibility, and adaptations in implementation strategies to maximize adoption, implementation, and maintenance among participating businesses.

Keywords: Total Worker Health; dissemination and implementation; RE-AIM; small business; consulting; safety and health

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1. Introduction

As chronic health conditions and disease rates continue to rise, attention has turned to the role employers play in supporting evidence-based interventions to improve worker health, safety, and well-being. *Total Worker Health*® ("TWH") is a transdisciplinary approach

for integrating workplace health promotion with occupational health and safety protection strategies promulgated by the National Institute for Safety and Health (NIOSH 2020). The approach represents key work and non-work domains of worker well-being including workplace policies and culture, work experience, safety climate, and health status [1]. Over the past decade, NIOSH and TWH researchers have developed frameworks and tools, such as the research-to-practice (r2p) approach, to help employers translate TWH into practice across a range of organizational settings [2]. r2p has focused on translating interventions to workplaces; however, it does not necessarily focus on the systematic study of these processes, as is customarily undertaken by D&I researchers [3]. The state of science of moving TWH research into practice has begun to shift to the application of dissemination and implementation (D&I) methods to improve translation [3–6]. The advances and rapid changes across the workplace, work, and workforce require special attention to the identification of the barriers and facilitators to adoption and implementation of TWH interventions [3].

This paper will present a case study, Health Links™, a TWH intervention aimed at improving the adoption and implementation of TWH in organizations across a range of industries, specifically targeting small- and mid-sized enterprises. In our approach for Health Links, we selected the RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) framework for designing and evaluating the program implementation because its flexibility and adaptability have been demonstrated across a range of settings [7].

1.1. TWH Intervention Background

TWH has its origin in the principles of organizational behavior change theory and the socio-ecological model used to identify key factors that influence worker health [8,9]. Conceptual models developed by the Centers of Excellence for *Total Worker Health*®, the Centers for Disease Control and Prevention (CDC), and the World Health Organization (WHO) present different approaches for program planning and implementation for workplace interventions. However, all underscore similar components of organizational support, leadership commitment, and employee involvement to inform the intervention components delivered and the ways that these components are delivered [10,11]. Businesses are increasingly seeking solutions for employee health, safety, and well-being that are evidence-based and can be operationalized in ways that are both practical and scalable [12,13].

The piece of "how" an intervention is delivered is defined as an "implementation strategy" in the field of D&I science [14]. Implementation strategies should be tailored to the local sociopolitical context [14]. In the case of TWH, it is common to identify organizations as a target setting for intervening to improve worker health, safety, and well-being and consider the unique needs these groups face [3,15]. Accordingly, implementation strategies are the methods by which certain core components are deployed to fit the varying priorities and needs of a business and its employees. The major categories of implementation strategies include stakeholder engagement, technical support for programs, the identification of business "champions", and financial support for programs, among other strategies [16,17].

In support of this notion that we need to take a more comprehensive approach to identify the feasibility, quality, and scalability of TWH interventions, Bradley et al., published a summary from the December 2015 National Institutes of Health (NIH) Pathways to Prevention workshop "Total Worker Health-What's Work Got to Do With It?" Bradley and coauthors recommended further D&I research to identify key factors that facilitate the "scaling out" of TWH and other evidence-based interventions across large networks of businesses/service systems [5]. In particular, scaling out includes implementing interventions in wide networks of businesses as well as organizations of different sizes and in different industry types. To address these calls for empirical data to inform how we scale out TWH with attention to the organizational context of businesses, D&I theories, models, and frameworks are foundational [18].

1.2. Application of D&I to TWH

D&I research has evolved over the past three decades to overcome pervasive challenges in translating evidence-based research into practice, including slow translation of evidence into practice, inequitable translation with low-resource settings being less likely to adopt evidence-based programs, and limited attention to key contextual factors that will facilitate or impede translation [7,19]. The D&I research literature includes theories, models, and frameworks that were empirically developed to accelerate the translation of evidence-based programs into practice [20]. Many of the theories and frameworks, including Roger's Diffusion of Innovation and community-based participatory research (CBPR), have methodologically-rich literature indicating that shared-power and partnership with organizations and workers impact the ability of public health interventions to improve health behaviors [21,22]. As they relate to TWH, D&I frameworks provide opportunities to understand the modifiable organizational factors linked to the successful and sustainable translation of TWH. By targeting those factors with better implementation approaches and strategies for delivering TWH, D&I research holds promise to help more employers adopt and sustain TWH, thus leading to a greater impact on the health, safety, and well-being of working populations. Implementation frameworks can be broad and flexible in nature, spanning levels of the socio-ecological model [23]. The selection process involves considering key questions about the study, scope, timeframe, and availability of measures, and what level of the socio-ecological model is to be targeted [23].

The distinctions between D&I theories, models, and frameworks have been discussed in detail elsewhere and are beyond the scope of this paper [18,24–26]. In brief, they may be considered as process models that guide the steps of working with stakeholders to explore, plan, and implement an intervention; evaluation frameworks to assess implementation outcomes; and determinant theories/frameworks of constructs that predict implementation outcomes. Specifically, D&I frameworks can guide researchers to design TWH delivery approaches that use flexible implementation strategies to implement the core components of programs for employers with varying contextual factors, including small/mid/large-sized businesses and different industry types. While our case study will illustrate the application of these principles using the RE-AIM framework, we will return to the consideration of other models in the Discussion.

1.3. RE-AIM and Occupational Safety and Health

More than a hundred D&I theories, models, and frameworks exist and there are resources to search these to identify the appropriate guides for different implementation phases, such as planning, evaluation, or sustainment [27]. A smaller number of models or frameworks are useful across both the implementation planning and evaluation phases [3,7,24,28]. RE-AIM has been used for implementation planning and evaluation efforts for more than 20 years in a variety of settings. RE-AIM has evolved to include an iterative process for use in intervention planning, during implementation, as well as for program evaluation [29–33]. The Practical Robust Implementation and Sustainability Model (PRISM) further expands upon RE-AIM to allow for the conceptualization and specification of contextual factors [34,35].

The application of implementation frameworks to provide guidance on selecting implementation strategies to fit organizational contexts has been widely embraced in the design and delivery of interventions by clinical and community organizations [24,36] However, to date, despite their promise [3], there have been few examples of applying implementation frameworks for the translation and delivery of interventions into organizational settings that require adoption and implementation at the business level to benefit working individuals [4,15,37–40]. Specifically in relation to occupational safety and health translational research, it was noted that consideration of the unique and contextual challenges to achieving success in a workplace setting is critical in addition to finding a common language of D&I terminology [15].

As TWH researchers and practitioners design and implement workplace programs, we propose starting with two key questions regarding the influences of an employer's

and their teams' decisions to deliver TWH in their workplace, or not. The first question is related to the characteristics of employers and their perspectives of TWH: "How do you apply implementation frameworks to successfully engage employers in TWH?" The second question is related to the organizational capacity for workplaces to both implement and sustain TWH: "How do you design TWH interventions to scale out successfully?" This paper offers a TWH case study to illustrate an approach to applying an existing implementation framework, RE-AIM, to plan, design, build, and then evaluate TWH implementation strategies with attention to these two questions.

1.4. Purpose

Our goal in this manuscript is to elevate the importance of using D&I frameworks to guide the implementation of TWH, through a case example of how we have used recent recommendations for the use of RE-AIM [7] to inform the planning/design and the evaluation of TWH interventions. Because RE-AIM has been more typically used in clinical and community settings, we highlight certain RE-AIM domains that warrant minor translation for the business organization context. Our case study describes a TWH intervention implemented at the organization-level and also highlights key concepts for "scaling-out" TWH evidence-based interventions where they are implemented in new workplace settings, new delivery systems, or both [41].

2. Application of RE-AIM to TWH Intervention Science

Applying RE-AIM to TWH Interventions

We selected the RE-AIM model because of its pragmatic use in planning and evaluation across multiple levels including community and organizations. It is broad yet flexible, allowing researchers to apply different dimensions of the framework based on the needs of the study [32]. While RE-AIM has been largely used in clinical settings to test and scale interventions directed at improving patient care, it has also been used in workplace-based interventions. For example, researchers evaluated a walking at work program in terms of the increasing of employee physical activity. In this study, they were able to use RE-AIM to measure the number of workplaces that participated in the program and, by evaluating its implementation, they found a range of activities delivered [42]. The adaptability of the framework lends itself to tailoring the evaluation process based on available resources/funding, and the scope of the project. RE-AIM principles may be applied across the discovery, planning, implementation, and evaluation stages of a project. This type of ongoing process review helps identify points where the delivery of a TWH intervention could be corrected, even in the slightest of ways, to promote the efficient implementation of the program, and to promote its long-term maintenance. Critiques of the use of the RE-AIM framework include limited information about how levels of the model interact; limited consensus on what constitutes adequate reach, adoption, and implementation; and the challenges involved in associating arbitrary time intervals [31]. These can be especially apparent when working in complex systems such as organizations [31].

The five dimensions of RE-AIM include Reach (the number and representativeness of participants), Effectiveness (the impact of the intervention on outcomes of interest), Adoption (the number and representativeness of settings and agents willing to implement a program), Implementation (the fidelity to the key components of the intervention), and Maintenance (the degree to which the program becomes institutionalized). To adapt to the unique needs of workplace adopters, we focused the five dimensions of RE-AIM so that they can be applied to the organizational-level settings of businesses. Table 1 specifically outlines the steps for TWH implementation mapped to the RE-AIM domains.

Table 1. Implementation outcome measures by RE-AIM component applied to organizational-level TWH interventions.

RE-AIM Outcome Dimension	Definition	Business Planning	Outcome Metrics for Organizational/Business Setting	Steps for Implementation	Evaluation Considerations
Adoption level 1—organizations contemplating participation after initial contact	The number of businesses and the number of delivery agents that are willing to consider participation	*Marketing* (Target audience, competitive analysis, positioning, pricing, messaging.)	• The number of businesses that receive information about the TWH intervention through implementation strategies including communication, marketing, direct outreach, and stakeholder engagement.	• Build relationships with stakeholders and partners across multiple levels of implementation ecosystem. • Solicit stakeholder feedback on implementation strategies. • Allow for new ideas, modifications, and revisions from users.	• Defining the target number (denominator) and representativeness of organizations. • Not pragmatic to go back historically and estimate.
Adoption level 2—organizations sign up to deliver TWH	The number of businesses and the number of intervention agents (people who deliver TWH) who are willing to initiate program.	*Distribution, sales strategy* (Moving the product from conception to end user.)	• Setting level—The number of businesses that enroll or sign-up in the TWH intervention. Enrollment rate by groups (business size, industry, geographical location), company supports for TWH. • Agent level—Percent of employees that participate. Characteristics of employees participating vs. nonparticipating employees.	• Identify decision makers and the core values/mission of organization. • Identifying existing practices, including expertise of delivery agents, to implement TWH programs. • Provide data and information (success stories, testimonial) on effectiveness of program.	• Can be defined as the number that are willing to initiate or implement programs compared to the number offered and why.

Table 1. *Cont.*

RE-AIM Outcome Dimension	Definition	Business Planning	Outcome Metrics for Organizational/Business Setting	Steps for Implementation	Evaluation Considerations
Implementation Fidelity Adaptations	The extent to which the intervention or program happened as intended in the business.	*Product testing* (Product review, product changes, costs.)	• The number of organizations that complete the TWH intervention components. • The adaptions to program deliver (who delivers it, changes to materials, customizations) • The cost of staff time to complete assessment and advising to improve TWH.	• Use a participatory process with stakeholders to identify barriers and facilitators to implementation. • Tailor implementation strategies to level of experience of target audience. • Develop and refine evaluations questions related to needs, process, effectiveness, and associated outcomes. • Develop logic model to describe relationships between inputs, outputs, and implementation outcomes.	• Characterize adaptations, type of adaptation, and why it was made at both the intervention level and the organizational level. • Calculate the cost of the implementation effort at different levels (intervention and organization).
Maintenance	The extent to which TWH becomes institutionalized within the organization's operation or becomes a routine practice and policy.	*Sustainability* (Loyal customer base, revenue neutral, and profitability.)	• The number of businesses that still have implemented intervention (TWH) at $\geq$6 months post intervention. • TWH is aligned and included in organization's mission and/or business model.	• Build TWH into existing infrastructure. • Conduct check-ins with businesses that encourage TWH progress. • Focus on environmental or policy changes.	• Measure long-term effects of program by TWH outcome. • Information that is available on long-term institutional efforts.

In the case of planning and implementing TWH interventions, adoption is defined in two ways: (1) the percent of businesses that agree to participate (setting level), and (2) the percent of staff that agree to participate (staff level). For workplace/organizational interventions, the setting and staff levels can be matched because the delivery agent representing the business is required to be the deciding factor in adoption. For example, we would measure adoption at the setting level by the number of businesses that adopt the TWH intervention equal to the staff level, which would be represented by an individual or team of people that are responsible for executing the changes in each organization. In another case, the setting-level and staff-level proportions could be different. For example, if there is an intervention targeting the adoption of a TWH training for managers to support employee mental health, the setting level would be the number of businesses that are willing to offer the training. The staff level would be the number of managers that participate in the training. There is an important distinction because TWH interventions often target multiple levels within an organization. Reach refers to the absolute number of employees that participate in TWH efforts (policies, programs, and supports) within a business. We discuss the considerations of how reach is defined and measured using RE-AIM below.

For RE-AIM, three important objectives of designing the implementation strategies/approaches and evaluating programs are: (1) to identify the key characteristics of adopters/end-users at both the setting and staff levels (target audience); (2) to determine the intervention perspectives of those adopters/end-users (i.e., priorities, facilitators/needs/resources, and barriers), (3) to understand the external incentives/penalties related to reach, adoption and implementation, and (4) to determine the likelihood of assessing the implementation and sustainability infrastructure—factors that will contribute to TWH implementation continuing after the external program facilitation/support has ended. For example, in this case study described below, our TWH intervention, Health Links™, provided external support for businesses to initially implement TWH, after which time employers could either sustain or terminate TWH delivery. The process for collecting multiple data points can involve qualitative and quantitative methods.

We also identified an opportunity to map RE-AIM constructs to the essential parts of the creation of a business plan. It turns out that there are many similarities that are relevant to how TWH interventions should gather information and design strategies that target employers as the primary "consumer" of TWH. The primary purpose of a business plan is to determine the concept and identify marketing and operational strategies for selling the product. This process involves understanding the needs and motivations of users, or in the case of RE-AIM, understanding how to reach and engage adopters. One could argue that in the TWH context, D&I is a public health product or service, and that business principles of product development, marketing, distribution, and finance can be translated for intervention design and implementation strategy (Brownson 2017). These business plan sections are also outlined in Table 1 and described in the case study below.

3. The Health Links® Case Study

The Health Links program was developed and launched in 2013. It was designed applying RE-AIM in concert with theories of health behavior and organizational change as an intervention to maximize participation in TWH among employers as a means for improving worker health, safety, and well-being. The program has three main intervention components: (1) an assessment tool that helps an organization self-evaluate across six benchmarks (Organizational Supports, Workplace Assessment, Health Policies and Programs, Safety Policies and Programs, Engagement, and Evaluation), (2) one-on-one advising sessions that assist organizations in goal setting for TWH improvements in areas of greatest need, and (3) access to TWH evidence-based resources including implementation aides developed by NIOSH and other Centers of Excellence for TWH. When the program launched, our first goal was to first establish its effectiveness before scaling it to reach many employers, specifically small businesses. To achieve that, we tested its effectiveness through a pilot study in Pueblo, Colorado [37]. After establishing effectiveness, we conducted a

process of stakeholder engagement to identify implementation strategies for delivering an intervention that would appeal and function across diverse workplace settings, was adaptable to meet unique business needs, and that could be implemented by a variety of people in an organization.

3.1. Implementation Design

The multi-level TWH conceptual approach for the Health Links program applies organizational behavior change and dissemination theories. According to the socio-ecological model, individual behavior change is based on influences across self, relationship, community (in this case, including organization), and society [9]. We aimed to reach individuals responsible for TWH within organizations in order to influence workplace conditions that in-turn influence organizational actions that would protect and promote worker health and safety.

The Health Links intervention followed a D&I process model approach that can be illustrated in four phases, as shown in Figure 1: exploration, preparation, implementation, and sustainment. We initially identified our program adopters, explored their priorities/needs related to the contextual factors that predict RE-AIM outcomes, planned the implementation armed with this stakeholder input, and then implemented the program [18,43]. We convened a multidisciplinary team of communication specialists, public health practice professionals, and occupational safety and health experts to guide our implementation process. First, we wrote a business plan for Health Links, to assess the landscape of workplace health promotion and health protection programs, identify the stakeholders who would serve as program adopters and implementers, state outcomes and performance objectives, select and design implementation strategies, and develop a communication and marketing plan, including a dissemination arm that was charged with identifying channel partners to conduct outreach in communities of business. We next conducted focus groups and key informant interviews with business leaders, small business owners, employees, chambers of commerce, insurers, brokers, offices of economic development, marketing and advertising consultants, public health officials, experts in occupational health and safety, occupational medicine, health promotion practitioners, and other stakeholders. The goal was to consider multi-stakeholder perspectives to ensure the most relevant intervention components were incorporated into our program. The major themes that were identified from the focus groups and interviews determined that the intervention must: (1) be based on best available evidence, (2) accommodate the needs of many different types of businesses and workforces, (3) be feasible for small businesses to access and adopt, meaning inexpensive and not resource/time intensive, (4) be scalable to large numbers of businesses, (5) apply basic principles of organizational change management, and (6) generate metrics so that the program could be evaluated in five domains of the RE-AIM model: reach, efficacy, adoption, implementation, and maintenance of the intervention [32].

Through stakeholder input, we established the Health Links program's core intervention package, including: (1) the online Healthy Workplace Assessment to benchmark existing TWH policies and practices and identify strengths and opportunities for improvement in an organization, (2) one-on-one advising to provide assistance and coaching for TWH goal setting by the organization, and (3) certification to recognize achievement in TWH in three levels (Certified Healthy Workplace, Partner, and Leader). The Health Links Healthy Workplace Assessment™ was developed by adopting measures from the CDC Healthy Workplace Scorecard, the WHO Healthy Workplace Framework, and the TWH framework to measure policies, programs, and workplace strategies across six benchmarks: Organizational Supports, Workplace Assessment, Health Policies and Programs, Safety, Engagement, and Evaluation.

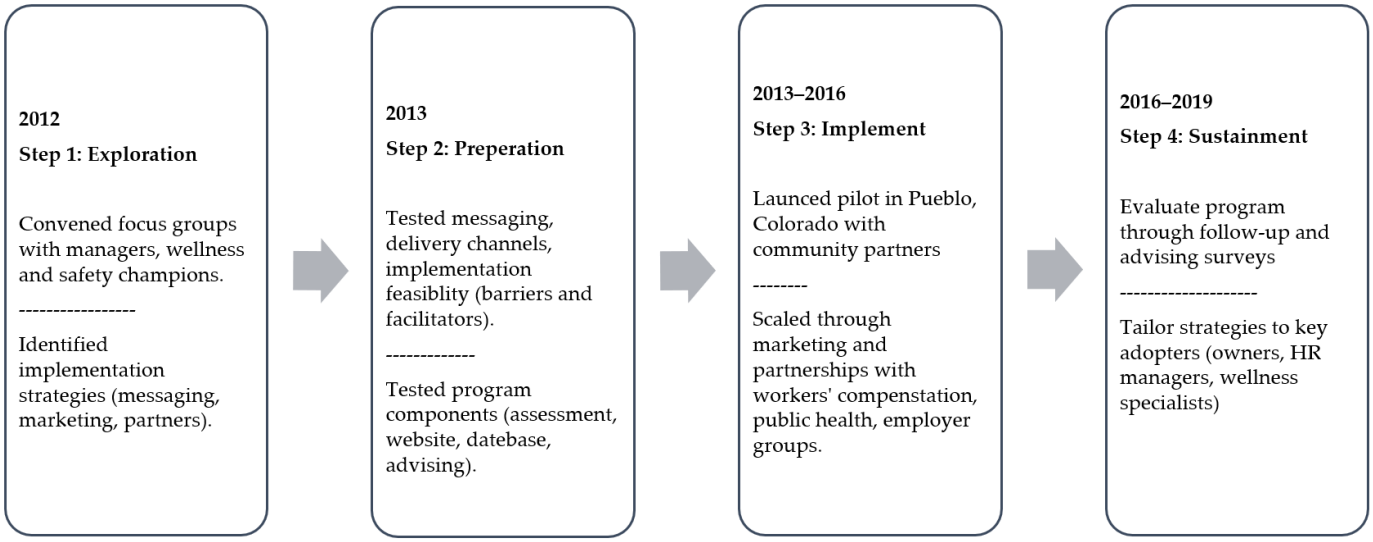


Figure 1. Timeline of Health Links implementation steps.

Advising was determined to be particularly important in the provision of ongoing consultation to organizations and their TWH delivery agents to identify goals and evidence-based strategies and resources to use [38]. During the advising process, representatives from organizations met with Health Links advisors to review the results of the organization's Healthy Workplace Assessment and participate in on-site and virtual (live telephonic or video) sessions. During these sessions, the advisor worked with the designated representatives from the organization to identify strengths and barriers to improving TWH and created action plans that set three SMART (specific, measurable, actionable, relevant, and timely) goals, each with action steps for putting evidence-based strategies in place. Principles from theories of motivational interviewing were incorporated to serve as a technique for addressing the unique needs of the organization and their workers.

3.2. Implementation Strategies

We used RE-AIM principles with stakeholders during the exploration and planning stages to formulate implementation strategies that would target the key priorities, address facilitators and barriers that relate to the characteristics and perspectives of end-user organizations and workers, and develop an implementation and sustainability infrastructure. The process maps to the expert recommendations for implementing change (ERIC) steps for planning implementation strategies, which also demonstrates how using RE-AIM in conjuncture with other D&I frameworks is beneficial [44]. The steps below describe the key ERIC concepts for pre-implementation, active implementation, and sustainment built on (1) gathering information to identify needs and barriers, (2) selecting and tailoring strategies that are modeled to scale up, and (3) building buy-in from partners and stakeholders.

3.3. Message Development

Our primary audience for communications about the Health Links intervention were delivery agents of TWH. These individuals were identified as representatives responsible for employee health, safety, and well-being in organizations. The communication challenge is that this audience is diverse, including business owners, managers, human resource professionals, health and safety professionals, and volunteer employee committees designated to run wellness committees. We developed messaging and program content aimed at encouraging employers (by way of individuals or groups) to take the necessary action to sign up and participate in Health Links. Feedback gathered from the focus groups and pilot informed the content presented on the website [45] and optimized the user experience. Another communication challenge was that we needed to educate our audience about TWH as well as provide information on how to participate. We developed messaging

that provided basic information on the benefits of TWH, including improving employee health, safety, and productivity; reducing absenteeism and presenteeism; and being an employer of choice. The final messaging concisely communicated how to join the program. The final website included basic information on the TWH approach, easy steps to begin, examples of the assessment, success stories that showcased Health Links businesses, and a simple call to action to "Get Started". The website also includes a resource center, a training and events page, and a dashboard where businesses can view their organizational assessment, report card, and schedule advice, and can download action plans and access resources and modules that provide deeper dives into each benchmark and links to specific topic areas including family-friendly workplaces, stress management, leadership support, and employee engagement [45]. Figure 1 illustrates the core implementation strategies including direct outreach to businesses and indirect dissemination through partners.

3.4. Dissemination

To establish our approach to dissemination, we applied concepts from RE-AIM and business planning as outlined in Table 1. Dissemination strategies are a subset of implementation strategies that particularly attend to the natural communication channels of end-users and developing networks of individuals—TWH champions who share our priorities for implementation [20]. Commonly, these TWH champions are representatives who already have health and safety responsibilities within organizations. They were quick to understand the TWH concept and to value the importance of promoting employee health. For implementation, we define these individuals as the delivery agents. They are the ones that are responsible for adopting and implementing Health Links as a program that benefits the organization and, by way of workplace policies and programs, individual employees. In addition, partners including chambers of commerce, small business and economic development centers, public health agencies, and insurance groups in healthcare and workers' compensation, were identified as our secondary target audience. These groups were previously identified as "intermediaries" and were specifically found to be effective when working to engage small businesses [15,46]. These groups served as our dissemination partners and were considered key in program adoption. Engaging dissemination partners involved relationship building with program directors, community outreach and relations staff, and health educators that had an agenda for delivering public health programming to employers. Chambers of commerce were identified by stakeholders as a trusted source of information, serving as a business network, a local organization, whose goal is to further the interests of businesses. They also represent members from different trades and industries, which was a helpful way of broadening representation across businesses. Local public health agencies were eager to partner with Health Links as a vehicle to deliver workplace-based programs for health promotion addressing tobacco cessation, disease prevention and management, and breastfeeding accommodations. We worked with partners to develop co-branded communication materials including newsletters, event promotions, and training flyers. Ways in which we adapted these delivery methods to increase adoption and scale the program are described below. By disseminating through business groups and trade associations, we aimed to engage healthcare, education, municipal, construction, and service industries.

To communicate the success of the program to stakeholders, we targeted the contextual influence of an employer's perspective on the intervention [7,34,47]. We invited participating businesses to share success stories through interviews and online blogs that highlighted how they were implementing TWH and how their participation in Health Links as an intervention had influenced positive change in their organization. We collected video and written testimonials to share personal stories and successes about Health Links to inspire businesses to act and join Health Links. We found that communication among the participants was also important to provide evidence of the intervention's effectiveness to employees and decision-makers. Developing the communication tools for businesses to share their TWH successes was, therefore, identified as an important implementation

strategy that we promoted in recruitment, during participation, and during retention efforts. These tools included a short press release, sample social media posts, and certification badges that could be shared through the business's communications and on their websites.

3.5. Adaptation

Over the course of seven years, we evaluated and then adapted the implementation blueprint for Health with the goal of enhancing employer adoption and honing our implementation strategies to optimize its scale out. This approach of conducting process and intermediary outcome evaluations is analogous to what others have undertaken when applying RE-AIM during program implementation [29]. Two significant changes included updating the Healthy Workplace Assessment and transitioning advising from in-person community advisors to a virtual model. During the initial four years, we offered two versions of the Assessment based on levels of organizational readiness. One version was for organizations that met the criteria for Healthy Workplace Certification. The other version was for those that were aspiring to reach, but not yet meeting, qualifying criteria. After learning that the two pathways were creating confusion for users, we created a single version of the assessment with updated questions and an improved user journey. In revising the survey tool, we designed a stepped process for each section and explanatory text for each question. We verified responses through advising to track and evaluate how businesses were implementing new TWH policies and programs annually [38].

In 2016, we conducted a pilot in Oregon in partnership with a state-based workers' compensation insurer to test Health Links in a new market. We implemented advising through Zoom to test a virtual model as a next step for scaling the program nationally and to offer greater reach to employers where there were no local Health Links community advisors. The pilot resulted in the decision to offer virtual advising exclusively as part of the program's expansion. Community advisors brought face-to-face connection to businesses and a local, personal touch, and were able to apply direct outreach methods for dissemination and recruitment, as indicated in Figure 2. However, the tradeoff was that managing a team of 12 remote advisors required a full-time staff person, ongoing training, financial and contract support to compensate them, and a continuous effort to retain current and recruit new advisors. The actual program cost per participating business was compared to the expense of hiring a full-time in-house advisor with the responsibility of providing double the number of advising sessions.

We also adapted our communication strategies based on input from our stakeholders and dissemination partners. We modified messaging and marketing to be able to co-brand program materials as well as speak directly to specific audiences. For example, when partnering with trade associations such as the Colorado Motor Carriers Association, we co-wrote a letter to members with their president that included basic information on the program and TWH and how it would benefit truck drivers. We also learned to leverage the reach of existing public health efforts in the region. When partnering with the state health department to engage small employers, we incorporated information about the benefits of businesses promoting the National Diabetes Prevention Program in Health Links outreach. Importantly, when we were delivering Health Links in different regions of the state, we aligned with the community health goals and held Health Links trainings based on the local needs of employers. These examples illustrate a successful way to raise awareness about TWH and promote Health Links as a valuable program while establishing relationships with local partners.

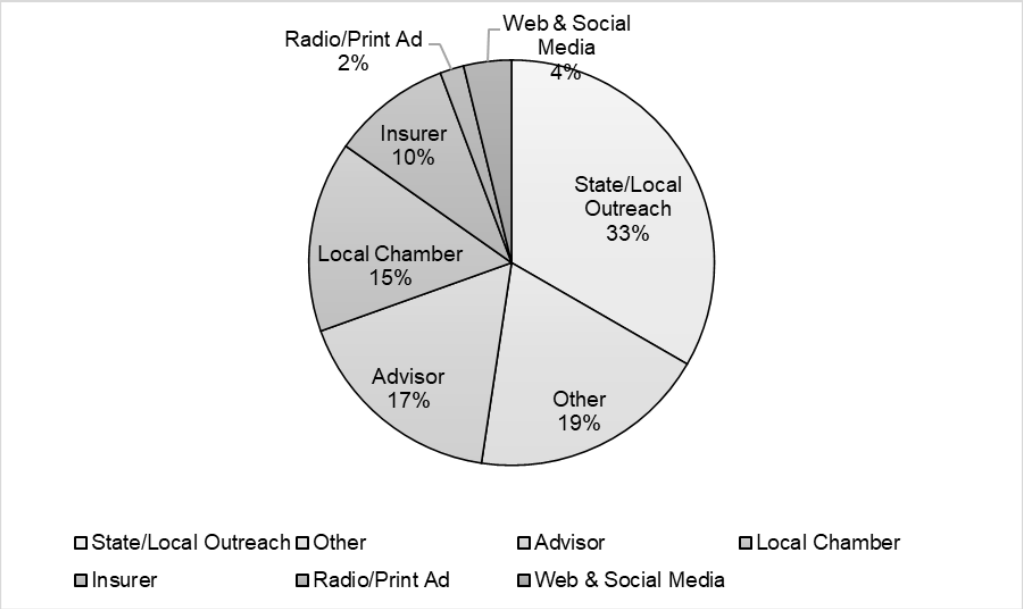


Figure 2. Primary sources of dissemination indicated by Health Links enrolled users. "How did you hear about Health Links?".

After making these mid-course adjustments, we observed better uptake demonstrated by expanded adoption among employers. We were able to scale the delivery of the TWH intervention because our implementation strategies appealed to a broader range of organizations. The types of adaptations that we needed to make to implement the program were both proactive (planned-in-advance) and reactive (agile adjustments to address unanticipated barriers). These types of adaptations can be categorized under RE-AIM as changes to who delivered the program (target audiences and distribution strategy) and implementation strategies to scale the program including tailored messaging, improved functionality of the web portal to deliver core intervention components, and promoting the program more broadly.

3.6. Scaling Out

We saw an opportunity to expand Health Link's adoption by employers after three years. Participants of the first generation of Health Links (2013–2016) provided feedback in the form of 6-month follow up surveys, giving evaluations of advising sessions and partner meetings. They identified advising sessions and organization recognition as the two most valuable components of the program. Respondents of the advising survey (N = 170) rated advising on a 5-point scale as helpful (4.62) and reported that they were confident to start or improve their wellness and safety program (4.52). Participants representing Health Links-certified businesses shared in a focus group (N = 12) that they viewed the Health Links brand as having a favorable reputation, found it to be a credible evidence-based program, and did not find cost to be a barrier to participation. However, some participants felt the website was hard to navigate, reporting that it took too many steps online to begin participating. Therefore, we re-tooled parts of the intervention and addressed some implementation barriers in the next generation of Health Links in 2016, using these program evaluation data to (1) enhance the online user experience, (2) create a plan structure for participation that allowed businesses to select the level of access and number of advising sessions, and (3) increase the reference and overall terminology to TWH in our messaging.

In the next generation of Health Links, we improved the user experience for a more focused primary audience: decision-makers in organizations including executives, managers, human resource professionals, and health and safety professionals. The messaging spoke to these still very diverse audiences by identifying common roles, values, and motivations.

It presented a vision of TWH as the umbrella for delivering occupational health and safety and sharing the alignment with our program's mission. We found it important to walk a fine line by showing that Health Links is practical as well as evidence based. We used language that reflected our academic underpinnings, while staying approachable and adaptable to organizations that ranged in industry and size. The visual components of the delivering Health Links were also important to portraying the look and feel of TWH. We selected images of diverse workers—individuals in their work environments that differed in age, race, ethnicity, and geographical location. The branding for Health Links overall was fresh, fun, and modern.

4. Evaluation Methods

We developed methods to evaluate Health Links' three domains of RE-AIM: adoption, implementation, and maintenance.

To estimate adoption, we measured the number of businesses that enrolled in Health Links. We were able to estimate the proportion of those that committed versus those that were in the precontemplation phase of adoption by measuring the number of businesses that expressed interest by way of a consult and/or registration. In the planning phases of the intervention, we identified primary barriers to participation through formative research and continued this evaluation process by direct business outreach conducted through phone calls and emails with primary contacts. We deployed adaptation strategies throughout the intervention to address the barriers to enhance participation as described below. We collected and tracked data from implementation strategies for marketing the program including trainings, email and print marketing, social media, and direct outreach through community advisors and program staff. To understand the how and why of adoption, we included a question on the user registration page to ask "how did you hear about us?" in order to understand what methods were most successful in reaching user groups. The counts for reach were based on multiple touch points that represented a single individual or multiple delivery agents from the same organization receiving the information. For our denominator, we used county-level data to estimate the number of businesses in our target market for those counties where we were disseminating program information and had positioned channel partners. There were no exclusion criteria for participating in Health Links to consider. We also recorded reasons why participating businesses decided not to participate in a subset of pilot businesses.

To measure implementation, we first developed a logic model to identify and describe the relationships between inputs, activities, outputs, and implementation outcomes (Figure 3). We administered a 6-month follow up survey to obtain feedback on how businesses were implementing TWH and to gauge the extent to which primary contacts from the businesses were following through on the goals they set in the Health Links advising sessions. Our program staff also tracked the businesses that had higher versus lower levels of program use by assessment completion rates, advising rates, and program attrition. We did not collect cost information from organizations and, therefore, were not able to calculate the implementation cost for each business. This is an important area for future work. We did attempt to deliver a low time burden intervention, based on our initial stakeholder input.

To estimate maintenance, we continued to contact participating organizations after dropout. Through surveys and business relations, we debriefed with business representatives to identify what they liked best and least about the program and which aspects they were interested in continuing and modifying. For dropout businesses, we employed follow-up emails and phone calls to qualitatively understand reasons for not continuing to utilize the intervention. We also used indicators of program-level maintenance including retention rates, re-enrollment lapses, and changes to participation levels. Because Health Links is an ongoing service, as opposed to a research study with an end date, a number of these evaluation practices are embedded in the program as quality assessment and quality

improvement practices. These measures map directly to the Maintenance planning tools promoted by the RE-AIM framework (RE-AIM Measures and Checklist 2019).

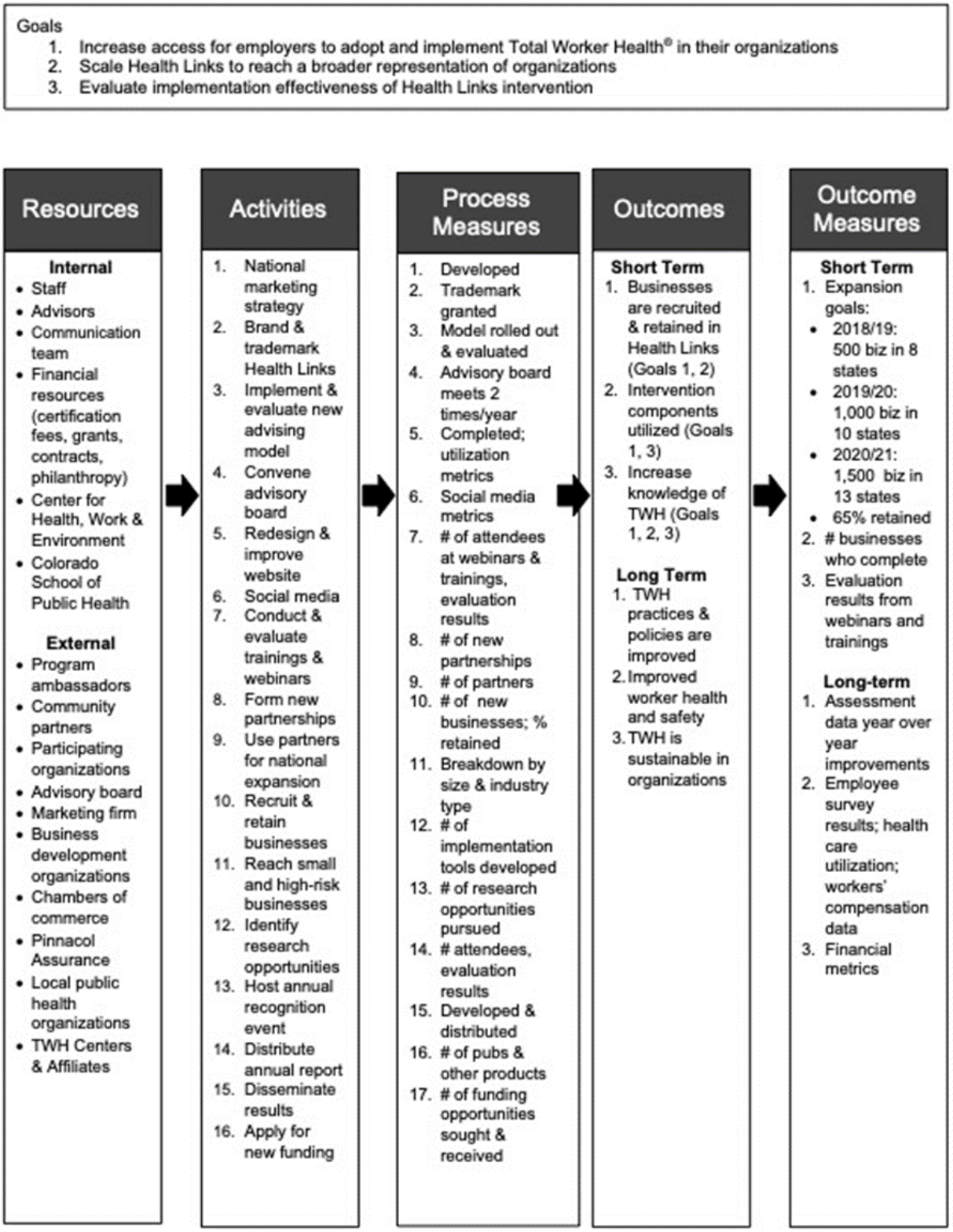


Figure 3. Logic model for Health Links' intervention implementation design.

5. Discussion

Our experience in applying RE-AIM as the implementation framework for Health Links led to a few major conclusions. First, the approach to guiding the process of translating TWH evidence into practice and evaluating implementation outcomes was iterative and continuous. If research on a TWH intervention shows efficacy, investigators must be prepared to make a major transition in translating a promising TWH product or service into an ongoing, sustainable intervention. The Health Links case study illustrates the relevance of selecting an implementation framework for planning, delivering, and evaluating TWH interventions and the merits of how implementation frameworks can inform the program logics for converting promising research into ongoing practice.

Establishing relationships with partners and stakeholders to identify the complex set of factors that impact TWH adoption and implementation proved crucial. By measuring adoption and maintenance, we determined that employers who are interested and motivated to participate will continue to participate in a TWH intervention, especially if it is practical, evidence based, and returns value for the time and cost invested by the organization. Priming action of these organizations requires the identification of both the individuals responsible for employee health and safety and the decision makers who consider TWH a medium-to-top priority. Many organizational staff are not familiar with TWH, so it proved to be necessary to educate target organizations and present the case for why TWH holds promise for improving their approach to health and safety. In effect, we learned that the application of principles from community participatory-based research should be integrated into TWH intervention frameworks.

The EPIS (Exploration, Preparation, Implementation, Sustainment) framework that we used in our timeline (Figure 1) highlights the importance of engaging stakeholders from multiple levels to inform and influence system-driven implementation efforts [48]. This notion parallels business and product development models that stress the importance of market research to engage users and consumers in the process of informing what is desirable and functional. Identifying barriers and facilitators was critical to planning how to reach employers and increase program adoption. Gathering feedback from decision makers in organizations to understand motivations for TWH also aids in planning and delivering effective interventions. Operationalizing TWH into any business setting may require the breaking down of silos due to the nature of how employee health and safety is implemented. It involves coordination across management, HR, communications, marketing, and health and safety.

Crafting an implementation strategy that is 'tailored to context' is extremely important. Businesses, similarly to people, have periods when they are more receptive to new initiatives and new behaviors. Businesses operate on many different calendars, with different production/service peak times, times when they decide upon new workplace health and safety initiatives and allocate resources (time and budget). As such, there are times when organizations will be more receptive to a TWH intervention. In some cases, the acknowledgement that TWH may not be a top priority informs the delivery of the program itself. For example, some organizations we worked with had signing up for Health Links on their list but waited to right before the holidays to enroll while others decided to act during slower business periods. Tracking enrollment and reenrollment trends helped us pinpoint adjustments for our outreach and dissemination activities. Re-prompting organizations to implement Health Links, especially during the organization's 'down time' periods, is a useful strategy for recruitment.

Consistent with D&I research, it is important to craft the intervention to fit into a 'blanket' implementation strategy of tailoring to the context of the adopting organization [19]. In making the transition from research to practice, investigators must be prepared to adapt the intervention based on ongoing evaluation and be agile in deriving creative solutions. Our example supports previous proposals for D&I science to consider adaptations that go beyond cultural elements [49,50]. Health Links required modification to implementation strategies to fit different employer characteristics, organizational contexts, and even

community- and industry-based settings. Akin to continuous quality improvement practices, having a continuous process of asking key questions to identify what organizations and decision makers valued about TWH and Health Links has proven to be formative. Understanding the level of TWH knowledge and expertise in an organization and building relationships with participating businesses and intermediaries all served as important ways to improve program adoption and implementation. We gained real-time feedback from stakeholders to test our implementation approaches by surveying our established network of businesses.

Frequent and disciplined evaluation practices provide important lessons about the role of communication. Marketing TWH to employers required a mix of state and local outreach, staff outreach, and training and supporting local advisors to conduct recruitment. For Health Links, the three most influential partners in implementation were chambers of commerce, local public health agencies, and workers' compensation insurers. These groups should be considered as effective channels for sharing TWH information and implementing programs, depending on the target of the intervention. We also learned that certain content appealed to different audiences within organizations. Some businesses and individuals were more interested in Healthy Workplace Certification and recognition, while others reported more value in the advising sessions. The range of motivations required a strategy for implementation that can appeal to a wide range of individuals representing different roles including ownership, management, human resources, and health and safety.

Our experience illustrates why TWH interventions require the efforts of a multidisciplinary team that is prepared to integrate its knowledge to create a product or service that can integrate with business systems. In the Health Links example, forming a program team with expertise in program planning, health communication, marketing, sales, statistics, psychology, health promotion, occupational health and safety, and business development allowed for diverse viewpoints on program components and dissemination methods. This is also consistent with recommendations for using implementation frameworks that stress continuous cycles of establishing and maintaining stakeholder engagement, exploration to determine implementation factors, selecting and tailoring implementation strategy(s), and then repeating the cycle with attention to sustainability considerations [43,51].

For the Health Links intervention, RE-AIM proved to be an adequate implementation framework for designing and evaluating an intervention in accordance with the RE-AIM domains of Adoption, Implementation, and Maintenance, and for conducting repeated domain-specific evaluations to guide continuous process improvement. We experienced several limitations to identifying and measuring RE-AIM dimensions. Specifically for Reach, we do not have outcome measures on individual workers who benefited from businesses adopting and implementing Health Links. However, from the perspective of occupational safety and health purveyors of TWH, we submit for consideration that one might also define the number or percentage of businesses who benefitted from our outreach sufficiently recruit businesses as our Reach to workplaces—even though it is more conventional in RE-AIM to define this term as Adoption. This point raises a debate for D&I and occupational safety and health around how to define and measure reach in the application of RE-AIM to organizational-level interventions that have the primary purpose of changing workplace behaviors. Measuring the percentage of businesses that agree to adopt TWH can also be challenge for wide-reaching TWH interventions because while we may know the numerator of adopting organizations, it is not always feasible to estimate a denominator of businesses that had heard about, and thus had the opportunity to adopt, the intervention, when using multiple marketing channels to disseminate an intervention at the organizational level. Furthermore, because businesses learned about Health Links in different ways, we may have or may not have been able to connect that encounter to participation.

Additionally, there are contextual factors that influence the way Health Links is implemented by organizations. As described in the case study, these factors included the different types of adopters, who vary in their motivations, roles, and influence within

the organization. These attributes, among others, likely impact the level of engagement. We know there are many other internal and external influences that cannot always all be measured, which may limit generalizability.

While this paper focused on RE-AIM, we acknowledge that there are many other D&I theories, models, and frameworks that could be used at a business setting for TWH interventions [3]. One of the benefits of using the RE-AIM framework is measuring the mediating relationships between implementation strategies and implementation outcomes and the ability to track and adapt over time. There have been models developed to look at this specifically. The Practical, Robust, Implementation, and Sustainability Model (PRISM) expands upon RE-AIM and contains constructs to understand the contextual factors that exist between the intervention characteristics and the ecosystem where implementation occurs [34]. We were able to track some of this, in part, by collecting information on barriers and facilitators to adoption and implementation through Health Links advising, focus groups, and interviews. PRISM also provides a way to enhance maintenance at the work setting level by building in pieces of the intervention to organizational infrastructure such as job requirements, audits, and institutionalization. This type of real-time evaluation and program improvement process is the future of research-to-practice. New D&I models have promise, especially in TWH intervention research that involves multiple and complex implementation targets across work settings.

Future research for TWH implementation science will need to address gaps in how TWH is adapted and operationalized in the real-world where businesses are constantly facing changing demands. This will require that translation activities start at the earliest stages of development and continually assess barriers and facilitators to adoption and maintenance over time [15]. The ideal scenario for evaluating the implementation of any TWH intervention would be to apply a systems approach to assess how organizations and individuals responsible for TWH deliver and tailor it, and why. Glasgow et al. argue that a program cannot be successful if it is effective solely at the individual level because it must be able to be adopted and implemented consistently in a variety of settings and by a variety of agents [7,30]. More research is needed to fully understand organizational factors and the measurement of organizational-level impact as a result of TWH in practice. Formative research including focus groups and stakeholder engagement can assist in identifying the primary and secondary audiences for TWH interventions. Marketing research methods can also help assess the demand for TWH among business communities and determine the existing competition. These are all important aspects of D&I for ensuring that TWH programs are differentiated for maximizing reach and adoption. There are also business models such as Rogers' Diffusion of Innovation and Segmentation, Targeting and Positioning (STP) [22,52] that provide similar approaches for conceptualizing dissemination and implementation through the lends of marketing and product development. More coordination between business institutions and TWH may be beneficial to develop blended models for implementation science in business settings.

6. Conclusions

In conclusion, as TWH research expands to consider applied implementation science, the RE-AIM framework provides a strong model to inform the planning and evaluation of TWH interventions. Through Health Links, we demonstrated the importance of flexibility in the application of implementation frameworks to accommodate adaptation in design and objectives, in general, and for TWH interventions specifically.

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References

1. Chari, R.; Chang, C.-C.; Sauter, S.L.; Sayers, E.L.P.; Cerully, J.L.; Schulte, P.; Schill, A.L.; Uscher-Pines, L. Expanding the Paradigm of Occupational Safety and Health. *J. Occup. Environ. Med.* **2018**, *60*, 589–593. [CrossRef]
2. NIOSH. r2p. Available online: https://www.cdc.gov/niosh/r2p/default.html (accessed on 1 September 2021).
3. Guerin, R.J.; Harden, S.M.; Rabin, B.A.; Rohlman, D.S.; Cunningham, T.R.; TePoel, M.R.; Parish, M.; Glasgow, R.E. Dissemination and Implementation Science Approaches for Occupational Safety and Health Research: Implications for Advancing Total Worker Health. *Int. J. Environ. Res. Public Health* **2021**, *18*, 11050. [CrossRef]
4. Anger, W.K.; Elliot, D.L.; Bodner, T.; Olson, R.; Rohlman, D.S.; Truxillo, D.M.; Kuehl, K.S.; Hammer, L.B.; Montgomery, D. Effectiveness of Total Worker Health interventions. *J. Occup. Health Psychol.* **2015**, *20*, 226–247. [CrossRef]
5. Bradley, C.J.; Grossman, D.C.; Hubbard, R.A.; Ortega, A.N.; Curry, S.J. Integrated interventions for improving Total Worker Health: A panel report from the National Institutes of Health Pathways to Prevention Workshop: Total Worker Health—What's Work Got to Do with It? *Ann. Intern. Med.* **2016**, *165*, 279–283. [CrossRef]
6. Tamers, S.L.; Chosewood, L.C.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.-C. *Total Worker Health*® 2014–2018: The Novel Approach to Worker Safety, Health, and Well-Being Evolves. *Int. J. Environ. Res. Public Health* **2019**, *16*, 321. [CrossRef]
7. Glasgow, R.E.; Harden, S.M.; Gaglio, B.; Rabin, B.; Smith, M.L.; Porter, G.C.; Ory, M.G.; Estabrooks, P.A. RE-AIM Planning and Evaluation Framework: Adapting to New Science and Practice With a 20-Year Review. *Front. Public Health* **2019**, *7*, 64. [CrossRef]
8. Burton, J.; World Health Organization. *WHO Healthy Workplace Framework and Model: Background and Supporting Literature and Practices*; World Health Organization: Geneva, Switzerland, 2010; Available online: https://apps.who.int/iris/bitstream/handle/10665/113144/9789241500241_eng.pdf?sequence=1&isAllowed=y (accessed on 1 September 2021).
9. Centers for Disease Control and Prevention. The Socio-Ecological Model: A Framework for Prevention. Available online: https://www.cdc.gov/violenceprevention/publichealthissue/social-ecologicalmodel.html (accessed on 10 July 2019).
10. Harris, J.R.; Hannon, P.A.; Beresford, S.A.; Linnan, L.A.; McLellan, D.L. Health promotion in smaller workplaces in the United States. *Annu. Rev. Public Health* **2014**, *35*, 327–342. [CrossRef]
11. Schwatka, N.V.; Tenney, L.; Dally, M.J.; Scott, J.; Brown, C.E.; Weitzenkamp, D.; Shore, E.; Newman, L.S. Small Business Total Worker Health: A Conceptual and Methodological Approach to Facilitating Organizational Change. *Occup. Health Sci.* **2018**, *2*, 25–41. [CrossRef]
12. Dugan, A.G.; Punnett, L. Dissemination and Implementation Research for Occupational Safety and Health. *Occup. Health Sci.* **2017**, *1*, 29–45. [CrossRef]
13. Hudson, H.L.; Nigam, J.A.S. Future directions and opportunities for Total Worker Health®. *Total Worker Health* **2019**, 295–309. [CrossRef]
14. Frieden, T.R. Six Components Necessary for Effective Public Health Program Implementation. *Am. J. Public Health* **2014**, *104*, 17–22. [CrossRef]
15. Cunningham, T.; Jacklitsch, B.; Richards, R. Intermediary Perspectives on Total Worker Health in Small Businesses. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10398. [CrossRef]
16. Kirchner, J.E.; Waltz, T.J.; Powell, B.J.; Smith, J.L.; Proctor, E.K. Implementation strategies. In *Dissemination and Implementation Research in Health: Translating Science to Practice*; Oxford University Press: Oxford, UK, 2017; Volume 2, pp. 245–266.
17. Mazzucca, S.; Tabak, R.G.; Pilar, M.; Ramsey, A.T.; Baumann, A.A.; Kryzer, E.; Lewis, E.M.; Padek, M.; Powell, B.J.; Brownson, R.C. Variation in Research Designs Used to Test the Effectiveness of Dissemination and Implementation Strategies: A Review. *Front. Public Health* **2018**, *6*, 32. [CrossRef]
18. Nilsen, P.; Bernhardsson, S. Context matters in implementation science: A scoping review of determinant frameworks that describe contextual determinants for implementation outcomes. *BMC Health Serv. Res.* **2019**, *19*, 189. [CrossRef]
19. Balas, E.; Boren, S. Managing Clinical Knowledge for Health Care Improvement. *Yearb. Med. Inform.* **2000**, *9*, 65–70. [CrossRef]
20. Brownson, R.C.; Colditz, G.A.; Proctor, E.K. Dissemination and Implementation Research in Health Translating Science to Practice. In *Dissemination and Implementation Research in Health: Translating Science to Practice*; Oxford University Press (OUP): Oxford, UK, 2012.
21. Cook, W.K. Integrating research and action: A systematic review of community-based participatory research to address health disparities in environmental and occupational health in the USA. *J. Epidemiol. Community Health* **2008**, *62*, 668–676. [CrossRef]
22. Lundblad, J.P. A review and critique of Rogers' diffusion of innovation theory as it applies to organizations. *Organ. Dev. J.* **2003**, *21*, 50.

23. Tabak, R.G.; Chambers, D.A.; Hook, M.; Brownson, R.C. The conceptual basis for dissemination and implementation research. In *Dissemination and Implementation Research in Health: Translating Science to Practice*; Oxford University Press, Inc.: New York, NY, USA, 2018; pp. 73–88.
24. Damschroder, L.J.; Aron, D.C.; Keith, R.E.; Kirsh, S.R.; Alexander, J.A.; Lowery, J.C. Fostering implementation of health services research findings into practice: A consolidated framework for advancing implementation science. *Implement. Sci.* **2009**, *4*, 50. [CrossRef]
25. Damschroder, L.J. Clarity out of chaos: Use of theory in implementation research. *Psychiatry Res.* **2019**, *283*, 112461. [CrossRef]
26. Nilsen, P. Making sense of implementation theories, models and frameworks. *Implement. Sci.* **2015**, *10*, 53. [CrossRef]
27. Dissemination and Implementation Models in Health Research and Practice. Available online: www.dissemination-implementation.org (accessed on 12 December 2021).
28. Nilsen, P.; Birken, S. *Handbook on Implementation Science*; Edward Elgar Publishing: Cheltenham, UK, 2020. [CrossRef]
29. Glasgow, R.E.; Battaglia, C.; McCreight, M.; Ayele, R.A.; Rabin, B.A. Making Implementation Science More Rapid: Use of the RE-AIM Framework for Mid-Course Adaptations Across Five Health Services Research Projects in the Veterans Health Administration. *Front. Public Health* **2020**, *8*, 194. [CrossRef] [PubMed]
30. Glasgow, R.E.; Lichtenstein, E.; Marcus, A.C. Why Don't We See More Translation of Health Promotion Research to Practice? Rethinking the Efficacy-to-Effectiveness Transition. *Am. J. Public Health* **2003**, *93*, 1261–1267. [CrossRef]
31. Glasgow, R.E.; Klesges, L.; Dzewaltowski, D.; Estabrooks, P.A.; Vogt, T.M. Evaluating the impact of health promotion programs: Using the RE-AIM framework to form summary measures for decision making involving complex issues. *Health Educ. Res.* **2006**, *21*, 688–694. [CrossRef] [PubMed]
32. Glasgow, R.E.; Vogt, T.M.; Boles, S.M. Evaluating the public health impact of health promotion interventions: The RE-AIM framework. *Am. J. Public Health* **1999**, *89*, 1322–1327. [CrossRef]
33. Harden, S.M.; Smith, M.L.; Ory, M.G.; Smith-Ray, R.L.; Estabrooks, P.A.; Glasgow, R.E. RE-AIM in Clinical, Community, and Corporate Settings: Perspectives, Strategies, and Recommendations to Enhance Public Health Impact. *Front. Public Health* **2018**, *6*, 71. [CrossRef]
34. Feldstein, A.C.; Glasgow, R.E. A practical, robust implementation and sustainability model (PRISM) for integrating research findings into practice. *Joint. Comm. J. Qual. Patient Saf.* **2008**, *34*, 228–243. [CrossRef]
35. McCreight, M.S.; Rabin, B.A.; Glasgow, R.E.; Ayele, R.A.; Leonard, C.A.; Gilmartin, H.M.; Frank, J.W.; Hess, P.L.; Burke, R.E.; Battaglia, C.T. Using the Practical, Robust Implementation and Sustainability Model (PRISM) to qualitatively assess multilevel contextual factors to help plan, implement, evaluate, and disseminate health services programs. *Transl. Behav. Med.* **2019**, *9*, 1002–1011. [CrossRef]
36. Gaglio, B.; Shoup, J.A.; Glasgow, R.E. The RE-AIM Framework: A Systematic Review of Use Over Time. *Am. J. Public Health* **2013**, *103*, e38–e46. [CrossRef]
37. Tenney, L.; Fan, W.; Dally, M.; Scott, J.; Haan, M.; Rivera, K.; Newman, M.; Newman, L.S. Health Links™ Assessment of Total Worker Health® Practices as Indicators of Organizational Behavior in Small Business. *J. Occup. Environ. Med.* **2019**, *61*, 623–634. [CrossRef]
38. Tenney, L.; Dexter, L.; Shapiro, D.C.; Dally, M.; Brown, C.E.; Schwatka, N.V.; Huebschmann, A.G.; McMillen, J.; Newman, L.S. Impact of Advising on Total Worker Health Implementation. *J. Occup. Environ. Med.* **2021**, *63*, 657–664. [CrossRef]
39. Schwatka, N.V.; Dally, M.; Tenney, L.; Shore, E.; Brown, C.E.; Newman, L.S. Total Worker Health Leadership and Business Strategies Are Related to Safety and Health Climates in Small Business. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2142. [CrossRef] [PubMed]
40. Schwatka, N.V.; Dally, M.; Shore, E.; Dexter, L.; Tenney, L.; Brown, C.E.; Newman, L.S. Profiles of total worker health® in United States small businesses. *BMC Public Health* **2021**, *21*, 1010. [CrossRef]
41. Aarons, G.A.; Sklar, M.; Mustanski, B.; Benbow, N.; Brown, C.H. "Scaling-out" evidence-based interventions to new populations or new health care delivery systems. *Implement. Sci.* **2017**, *12*, 111. [CrossRef] [PubMed]
42. Adams, E.J.; Chalkley, A.E.; Esliger, D.W.; Sherar, L.B. Evaluation of the implementation of a whole-workplace walking programme using the RE-AIM framework. *BMC Public Health* **2017**, *17*, 466. [CrossRef] [PubMed]
43. Moullin, J.C.; Dickson, K.S.; Stadnick, N.A.; Albers, B.; Nilsen, P.; Broder-Fingert, S.; Mukasa, B.; Aarons, G.A. Ten recommendations for using implementation frameworks in research and practice. *Implement. Sci. Commun.* **2020**, *1*, 42. [CrossRef]
44. Waltz, T.J.; Powell, B.J.; Chinman, M.J.; Smith, J.L.; Matthieu, M.M.; Proctor, E.K.; Damschroder, L.J.; E Kirchner, J. Expert recommendations for implementing change (ERIC): Protocol for a mixed methods study. *Implement. Sci.* **2014**, *9*, 39. [CrossRef]
45. Health Links. 2019. Available online: https://www.healthlinkscertified.org (accessed on 15 March 2020).
46. Cunningham, T.R.; Sinclair, R.; Schulte, P. Better understanding the small business construct to advance research on delivering workplace health and safety. *Small Enterp. Res.* **2014**, *21*, 148–160. [CrossRef]
47. Dearing, J.W. Applying Diffusion of Innovation Theory to Intervention Development. *Res. Soc. Work. Pr.* **2009**, *19*, 503–518. [CrossRef]
48. Moullin, J.C.; Dickson, K.S.; Stadnick, N.A.; Rabin, B.; Aarons, G.A. Systematic review of the Exploration, Preparation, Implementation, Sustainment (EPIS) framework. *Implement. Sci.* **2019**, *14*, 1–16. [CrossRef]
49. Baumann, A.A.; Cabassa, L.J.; Stirman, S.W. Adaptation in dissemination and implementation science. In *Dissemination and Implementation Research in Health: Translating Science to Practice*; Oxford University Press: Oxford, UK, 2017; Volume 2, pp. 286–300.

50. Stirman, S.W.; Baumann, A.A.; Miller, C.J. The FRAME: An expanded framework for reporting adaptations and modifications to evidence-based interventions. *Implement. Sci.* **2019**, *14*, 1–10. [CrossRef]
51. Kilbourne, A.; Neumann, M.; Pincus, H.A.; Bauer, M.; Stall, R. Implementing evidence-based interventions in health care: Application of the replicating effective programs framework. *Implement. Sci.* **2007**, *2*, 1–10. [CrossRef]
52. Romppanen, J.M. Segmentation, Targeting & Positioning (STP). 2021. Available online: https://www.researchgate.net/profile/Jan-Romppanen/publication/348923039_Segmentation_Targeting_Positioning_STP/links/607768762fb9097c0ce54a58/Segmentation-Targeting-Positioning-STP.pdf (accessed on 1 September 2021).

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Editorial

Promising Occupational Safety, Health, and Well-Being Approaches to Explore the Future of Work in the USA: An Editorial

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1. Introduction

The future of work continues to undergo profound and fundamental changes in response to shifting social, technological, economic, environmental, and political contexts. These shifts have led to further developments in the workplace and work, with implications for the safety, health, and well-being of the workforce [1]. As a result, experts have called for innovative and responsive occupational safety and health (OSH) approaches to better understand burgeoning future of work issues, help harness presented opportunities, and address exhibited challenges [2–5]. One such approach is the *Total Worker Health*® (TWH) framework [6,7], which recognizes work as a social determinant of health and prioritizes the principles of healthy work design [8] to protect and promote worker well-being both on- and off-the-job. Such holistic OSH strategies can improve our capacity to confront anticipated and unanticipated hazards and exposures likely to meet tomorrow's workforce, thereby advancing worker well-being, overall. Consequently, workers and employers will be more likely to thrive and productively contribute to their communities and the Nation.

2. Objective of the Special Issue

The collection of articles, reviews, and commentaries from the USA presented in this special issue [9] add to the worker safety, health, and well-being literature by focusing on existing or expected future of workplace and work factors, their implications for the future workforce, and expanded OSH strategies and methods to address them.

3. The Papers

A total of 29 papers that underwent the IJERPH peer review process were accepted for publication in this special issue, based on scientific quality and methodological soundness. These papers cover a far-reaching range of workplace settings; work functions; worker populations; OSH risks, hazards, and exposures; safety, health, and well-being issues and outcomes; research methods, strategies, interventions, and practical applications; and tools, metrics, guidelines, and other resources. In this editorial, the guest editors offer an introduction to each, organized by type (research, review, and other), as ordered on the corresponding IJERPH special issue webpage [9].

3.1. Research

Continuing to build the evolving future of work evidence base and its OSH strategies is essential. Featured research papers focus specifically on either the TWH approach or the development or application of healthy work design strategies to address a variety of

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future of work topics, offering insights to OSH and related professionals and practitioners to help inform their own research and practice efforts. In this section, papers are organized into five interrelated sub-sections: social context and factors, leadership, small businesses, organizational design, and mixed methods and qualitative methods approaches.

3.1.1. Social Context and Factors

The social context—networks and support derived from a variety of sources including through work—and social factors that may increase vulnerability are critical well-being contributors, providing an avenue for potential OSH opportunities, especially important for higher risk sectors and during times of crises.

To begin, Namazi et al. [10] and Kotejoshyer et al. [11] separately discuss aspects of the development, implementation, and evaluation of a TWH peer health mentoring program designed to address safety, health, and well-being for newly hired correctional officers (CO), a worker population at increased risk of issues such as cumulative stress and resultant outcomes. Though overall CO physical and mental health decline during the study, participating mentors note several social benefits of the program, such as opportunities to learn more about themselves and form meaningful relationships with co-worker mentees.

Horan et al. [12] also offer a peer mental health support intervention, in this instance for first responders, a worker population that suffers from a high burden of chronic stress and mental health distress from critical incidents. While findings suggest a floor effect for self-efficacy, the authors conclude that trust, attention to the social context, and other collaborative safety and health solutions will be vital in light of future of work changes.

Haas et al. [13] advocate for more strategic planning after examining emergency response calls from fire departments during the COVID-19 pandemic. The authors find higher social vulnerability based on household composition, minority/language, and housing/transportation increase the risk of first responders' exposure to SARS-CoV-2 (the virus that causes COVID-19), and are significantly associated with response calls that require emergency treatment and transport.

3.1.2. Leadership

Employers, and upper and middle management play a pivotal role in the lives of workers. Healthy leadership is therefore essential not only for the well-being of the workforce but also for that of organizations.

Cavallari et al. [14] pilot test HearWell, a TWH intervention created to preserve hearing among highway maintainers. The participatory research approach identifies a need for a comprehensive safety leadership training for managers to be included within existing program elements, emphasizing the importance of healthy leadership within hearing conservation interventions.

Relatedly, Rohlman et al. [15] evaluate a TWH on-line training for supervisors of young agricultural workers, considered at greater risk of injury compared to young workers in other industries. Post-training, the authors observe that supervisors have a greater understanding of the risks to young workers and are more likely to engage in communication behaviors to protect their safety and health.

Collins and colleagues [16] survey directors of nursing at nursing homes, using the Workplace Integrated Safety and Health (WISH) instrument to assess TWH polices, programs, and practices related to leadership commitment, participation, supportive working conditions, comprehensive and collaborative strategies, and adherence to federal and state regulations and ethical norms. Findings reveal high implementation of TWH approaches, though the authors are unable to distinguish certain types of nursing homes that might benefit from additional TWH efforts.

Nagler et. al. [17] use the TWH Implementation Guidelines to evaluate the TWH approach for low-wage food service workers. Site-level managers, different levels of leadership, and frontline workers from a large multinational company are involved in the development and implementation of this intervention designed to address high levels of

injury and turnover. Results support the TWH Implementation Guidelines as a useful and likely transferable resource for other industries and similar interventions.

3.1.3. Small Businesses

Unlike many larger organizations, small businesses are often faced with limited resources, making it more challenging to comprehensively meet changing workforce needs, and reinforcing evidence that a one size approach does not fit all.

Macy et al. [18] focus on the state of Kentucky to examine trends in organizations offering workplace health promotion and OSH programs and identify potential program-related gaps and disparities. Though more employers report making such programs available compared to previous years, larger workplaces remain more likely to offer them as opposed to smaller ones.

Similarly, Cunningham et al. [19] apply the NIOSH Small Business Intervention Diffusion Model to conduct community-based activities in two metropolitan communities, assessing perceptions of a TWH approach in small businesses. The authors observe that intermediary organizations such as local health departments and workers compensation insurers find value in providing TWH assistance to small employers, but several safety and health intervention challenges remain, especially inadequate resources.

Brown and colleagues [20] examine whether employees in small businesses receiving a TWH leadership development intervention prior to the COVID-19 pandemic are able to maintain pre-COVID-19 pandemic perceptions of safety and health climates and well-being. Though employees view their workplaces as supportive of their safety and health, other factors continue contributing to a decline in worker well-being during the COVID-19 pandemic.

3.1.4. Organizational Design

The overall context in which work is performed determines the hours, shifts, load, control, flexibility, and arrangements that significantly contribute to worker safety, health, and well-being outcomes. These facets of organizational design have not only been increasingly spotlighted in the future of work but have also experienced accelerated changes since the COVID-19 pandemic.

Ray and Pana-Cryan [21] analyze data from the 2002–2018 General Social Survey—Quality of Worklife and conclude that working at home increases the likelihood of job stress and job satisfaction; taking time off decreases the likelihood of job stress and days with activity limitations, and increases the likelihood of job satisfaction; and adopting a more flexible schedule decreases the likelihood of job stress and increases the likelihood of job satisfaction.

Hernandez et al. [22] examine how frequencies of high workload and recovery activities from work and non-work are associated with same day well-being measures. The authors find that more frequent engagement in high workload activities is associated with lower well-being (i.e., higher stress), while greater recovery activity frequency is associated with higher well-being (i.e., lower stress and higher positive affect).

Davis and Rohlman [23] investigate motor vehicle crash data and county-level characteristics and determine that winter weather that produces hazardous driving conditions also plays a role in crashes during commute hours. The authors suggest adopting policies for flexible work start and stop times, or remote work, to help workers avoid associated risks.

And, Tumlin et al. [24] investigate equine-assisted programs that address human health issues and rely on a predominantly volunteer workforce (not often represented in OSH) with non-traditional schedules, to assess protections for worker well-being in environments characterized in part by dust exposure. The authors identify factors needed to refine the scalability of future air contaminant monitoring and provide frameworks for education, workplace design, and prevention of exposure to dust.

3.1.5. Mixed Methods and Qualitative Methods Approaches

While most studies in this special issue take a quantitative methods approach, mixed methods and qualitative methods are particularly useful in elucidating the complex and novel concerns workers face that can help in the development of innovative OSH strategies.

For example, Hebert-Beirne et al. [25] use a mixed methods community health assessment in high social and economic hardship neighborhoods with a high proportion of individuals engaged in precarious work. Based on themes extracted from focus group data, the authors advocate for resident worker voices to be heard and the imperativeness of their participation in all efforts that impact them to better ascertain nuanced issues and establish a culture of healthy work.

Hudson et al. [26] explore how the Hierarchy of Controls Applied to NIOSH Total Worker Health (TWH HoC) are implemented, focusing specifically on work-related issues of fatigue, stress, sedentary work, and tobacco control. Key determinants identified include organizational culture, implementation climate, and readiness for implementation. The authors emphasize the need to better understand the extent to which OSH guidance like the TWH HoC is used to help prepare for future opportunities and challenges.

Fukumura and colleagues [27] collect worker perspectives on incorporating artificial intelligence (AI) in office settings using a qualitative study design. Based on their findings, the authors note that acceptability of AI in the workplace is complex, that divergent worker-level needs must be addressed, and that AI acceptance is dependent upon whether advantages outweigh challenges. These will remain paramount considerations as new and emerging technologies are more widely applied across workplaces, particularly as employers consider adopting hybrid or remote flexible work options.

Pratap et al. [28] perform an environmental scan of unemployment and underemployment via a literature review and key informant interviews. The authors highlight the pivotal role that employment (and lack thereof) plays in the work and home lives of individuals and the need to prioritize integrated workforce health and well-being approaches into labor and economic development agendas to reduce health inequities.

Peters et al. [29] share outcomes from a literature review, workshop, interviews with experts, and cognitive testing conducted to develop a measure that assesses "thriving" at work. The measure is defined as "the state of positive mental, physical, and social functioning in which workers' experiences of their work and working conditions enable them to thrive in their overall lives, contributing to their ability to achieve their full potential in their work, home, and community".

An additional article by Peters and other colleagues [30] uses focus groups and key informant interviews as part of a larger study that develops and evaluates a TWH intervention to examine work's role in fatigue, stress, back pain, and poor dietary habits among professional bus drivers. Primary themes of the study include lack of trust between drivers and supervisors, scheduling of shifts and routes, and difficulty performing positive health behaviors.

Using a case study as an example, Tenney et al. [31] discuss the role of dissemination and implementation (D&I) science as a critical piece in the translation of research into practice to flexibly implement core TWH intervention components. The authors highlight one D&I framework in particular: Reach, Effectiveness, Adoption, Implementation, and Maintenance (RE-AIM), useful across TWH implementation phases and for employers with varying contextual factors, such as business size and industry type.

3.2. Reviews

Featured review papers focus on several key future of work topical areas, offering readers comprehensive background and guidance to enhance the role of OSH as the world of work unfolds.

To help inform policymakers and employers, Ng et al. [32] examine pre-COVID-19 pandemic and COVID-19 pandemic trends for three topics (work arrangements, compensation and benefits, and the organization of work) to explore their effects on the future of

work. The authors find that the COVID-19 pandemic has both accelerated and disrupted various trends, including exacerbating work-related inequities.

Pishgar and colleagues [33] use the Risk Evolution, Detection, Evaluation, and Control of Accidents (REDECA) framework across five occupational sectors to review the literature and evaluate AI's use in detecting hazards, incidents, and harmful work conditions. The authors call for additional exploration of AI's expanded use to enhance worker well-being.

Horan and another set of co-authors [34] contend that sound recommendations for the future of work need to account for the overall context of the specific industry in question. Using the hospitality industry as an example, the authors describe the advantages of the industry context perspective; examine present trends and the extent to which the OSH literature incorporates an industry focus; and provide informed solutions for researchers and practitioners to better understand and address developing OSH issues.

Given the unknowns brought on by workplace, work, and workforce developments and the increasing implementation of TWH approaches, Rogers and Schill [35] review TWH ethical constructs and competencies and examine codes of ethics for workers in OSH, health promotion, and education. Using an ethical decision-making case study, the authors analyze crucial issues for TWH and propose a transdisciplinary framework that supports both elements of an ethical workplace culture and a core set of practical ethical competencies.

Streit et al. [36] demonstrate the need to employ innovative methods and approaches to monitor and prepare for the emergence of safety and health issues and trends. The authors review strategic foresight—a promising methodological tool that can enhance OSH capacity to anticipate, and perhaps even shape, the future of work—and present a working foresight framework tailored for OSH, with recommendations for research and practice.

3.3. Other

In this third and final section of the special issue, featured "other" papers consist of commentaries that provide poignant considerations when exploring current and emerging future of work issues and the expanded approaches used to address them.

Guerin et al. [37] examine D&I science for TWH researchers and practitioners, offering an overview of the literature; a plain language explanation of key concepts; a TWH research-to-practice case study example; and a discussion of future opportunities to increase worker safety, health, and well-being through D&I science.

Flynn et al. [38] discuss existing and persistent OSH inequities, calling for more holistic OSH approaches that account for the social contexts within which work-related injuries and illnesses occur, especially given COVID-19 pandemic impacts. The authors cover several areas to advance health equity, including a biopsychosocial paradigm tool that explores the dynamic, multidirectional interactions between biological phenomena, psychological factors, and social contexts.

4. Conclusions

A culture of safer and healthier work will require preparation, vigilance, and a willingness to continuously adapt. As the future of work evolves, so will complex factors that influence worker safety, health, and well-being outcomes and needed OSH research, strategies, interventions, methods, and tools. The papers featured in this special issue offer readers an opportunity to explore a range of issues that currently exist and ones that may emerge, as well as healthy work design and well-being strategies that can be used to address them. These may not only inspire new research on the future of work, but also inform practice, policy, and capacity-building activities. Next step efforts will especially benefit from healthy leadership, active worker participation, customized and responsive interventions, and proactive and collaborative partnerships. Ideally, employers, workers, governments, academic institutions, industry, not-for-profit businesses, labor unions, community organizations, and international establishments will pull together to successfully navigate the future of work and the future practice of OSH.

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References

1. Tamers, S.L.; Streit, J.; Pana-Cryan, R.; Ray, T.; Syron, L.; Flynn, M.; Castillo, D.; Roth, G.; Geraci, C.; Guerin, R.; et al. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *Am. J. Ind. Med.* **2020**, *63*, 1065–1084. [CrossRef] [PubMed]
2. Schulte, P.; Delclos, G.; Felknor, S.; Chosewood, L. Toward an expanded focus for occupational safety and health: A commentary. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4946. [CrossRef] [PubMed]
3. Felknor, S.; Streit, J.; McDaniel, M.; Schulte, P.; Chosewood, L.; Delclos, G.; on behalf of the Workshop Presenters and Participants. How will the future of work shape OSH research and practice? A workshop summary. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5696. [CrossRef] [PubMed]
4. Schulte, P.; Streit, J.; Sheriff, F.; Delclos, G.; Felknor, S.; Tamers, S.L.; Fendinger, S.; Grosch, J.; Sala, R. Potential scenarios and hazards in the work of the future: A systematic review of the peer-reviewed and gray literatures. *Ann. Work. Expo. Health* **2020**, *64*, 786–816. [CrossRef]
5. National Institute for Occupational Safety and Health (NIOSH). Future of Work Initiative. Available online: https://www.cdc.gov/niosh/topics/future-of-work/default.html (accessed on 12 October 2021).
6. National Institute for Occupational Safety and Health. Total Worker Health Program. Available online: https://www.cdc.gov/NIOSH/twh/ (accessed on 12 October 2021).
7. Tamers, S.L.; Chosewood, L.C.; Childress, A.; Hudson, H.; Nigam, J.; Chang, C.C. Total Worker Health((R)) 2014(–)2018: The Novel Approach to Worker Safety, Health, and Well-Being Evolves. *Int. J. Environ. Res. Public Health* **2019**, *16*, 321. [CrossRef]
8. National Institute for Occupational Safety and Health. Healthy Work Design and Well-Being Program. Available online: https://www.cdc.gov/niosh/programs/hwd/default.html (accessed on 12 October 2021).
9. International Journal of Environmental Research and Public Health Special Issue. Worker Safety, Health, and Well-Being in the USA. Available online: https://www.mdpi.com/journal/ijerph/special_issues/worker_health (accessed on 12 October 2021).
10. Namazi, S.; Kotejoshyer, R.; Farr, D.; Henning, R.A.; Tubbs, D.C.; Dugan, A.G.; El Ghaziri, M.; Cherniack, M. Development and Implementation of a Total Worker Health®Mentoring Program in a Correctional Workforce. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8712. [CrossRef]
11. Kotejoshyer, R.; Gilmer, D.O.; Namazi, S.; Farr, D.; Henning, R.A.; Cherniack, M. Impact of a Total Worker Health®Mentoring Program in a Correctional Workforce. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8436. [CrossRef] [PubMed]
12. Horan, K.A.; Marks, M.; Ruiz, J.; Bowers, C.; Cunningham, A. Here for My Peer: The Future of First Responder Mental Health. *Int. J. Environ. Res. Public Health* **2021**, *18*, 11097. [CrossRef]
13. Haas, E.J.; Furek, A.; Casey, M.; Yoon, K.N.; Moore, S.M. Applying the Social Vulnerability Index as a Leading Indicator to Protect Fire-Based Emergency Medical Service Responders' Health. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8049. [CrossRef]
14. Cavallari, J.M.; Suleiman, A.O.; Garza, J.L.; Namazi, S.; Dugan, A.G.; Henning, R.A.; Punnett, L. Evaluation of the HearWell Pilot Program: A Participatory Total Worker Health®Approach to Hearing Conservation. *Int. J. Environ. Res. Public Health* **2021**, *18*, 9529. [CrossRef] [PubMed]
15. Rohlman, D.S.; TePoel, M.; Campo, S. Evaluation of an Online Training for Supervisors of Young Agricultural Workers. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10395. [CrossRef] [PubMed]
16. Collins, J.E.; Boden, L.I.; Gundersen, D.A.; Katz, J.N.; Wagner, G.R.; Sorensen, G.; Williams, J.A.R. Workplace Integrated Safety and Health Program Uptake in Nursing Homes: Associations with Ownership. *Int. J. Environ. Res. Public Health* **2021**, *18*, 11313. [CrossRef] [PubMed]

17. Nagler, E.M.; Stelson, E.A.; Karapanos, M.; Burke, L.; Wallace, L.M.; Peters, S.E.; Nielsen, K.; Sorensen, G. Using Total Worker Health®Implementation Guidelines to Design an Organizational Intervention for Low-Wage Food Service Workers: The Workplace Organizational Health Study. *Int. J. Environ. Res. Public Health* **2021**, *18*, 9383. [CrossRef]
18. Macy, G.; Basham, J.; Watkins, C.; Golla, V. Workplace Health in Kentucky: A Statewide Comparison. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5473. [CrossRef] [PubMed]
19. Cunningham, T.; Jacklitsch, B.; Richards, R. Intermediary Perspectives on Total Worker Health in Small Businesses. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10398. [CrossRef]
20. Brown, C.E.; Dexter, L.; Schwatka, N.V.; Dally, M.; Tenney, L.; Shore, E.; Newman, L.S. Total Worker Health®and Small Business Employee Perceptions of Health Climate, Safety Climate, and Well-Being during COVID-19. *Int. J. Environ. Res. Public Health* **2021**, *18*, 9702. [CrossRef] [PubMed]
21. Ray, T.K.; Pana-Cryan, R. Work Flexibility and Work-Related Well-Being. *Int. J. Environ. Res. Public Health* **2021**, *18*, 3254. [CrossRef]
22. Hernandez, R.; Pyatak, E.A.; Vigen, C.L.P.; Jin, H.; Schneider, S.; Spruijt-Metz, D.; Roll, S.C. Understanding Worker Well-Being Relative to High-Workload and Recovery Activities across a Whole Day: Pilot Testing an Ecological Momentary Assessment Technique. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10354. [CrossRef]
23. Davis, J.; Rohlman, D.S. Winter Weather-Related Crashes during the Commute to Work: An Opportunity for Total Worker Health®. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10268. [CrossRef]
24. Tumlin, K.; Liu, S.; Park, J.-H. Framing Future of Work Considerations through Climate and Built Environment Assessment of Volunteer Work Practices in the United States Equine Assisted Services. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10385. [CrossRef]
25. Hebert-Beirne, J.; Felner, J.K.; Berumen, T.; Gonzalez, S.; Chrusfield, M.M.; Pratap, P.; Conroy, L.M. Community Resident Perceptions of and Experiences with Precarious Work at the Neighborhood Level: The Greater Lawndale Healthy Work Project. *Int. J. Environ. Res. Public Health* **2021**, *18*, 11101. [CrossRef] [PubMed]
26. Hudson, H.L.; Schill, A.L.; Richards, R. An Exploratory, Qualitative Study of How Organizations Implement the Hierarchy of Controls Applied to Total Worker Health®. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10032. [CrossRef]
27. Fukumura, Y.E.; Gray, J.M.; Lucas, G.M.; Becerik-Gerber, B.; Roll, S.C. Worker Perspectives on Incorporating Artificial Intelligence into Office Workspaces: Implications for the Future of Office Work. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1690. [CrossRef] [PubMed]
28. Pratap, P.; Dickson, A.; Love, M.; Zanoni, J.; Donato, C.; Flynn, M.A.; Schulte, P.A. Public Health Impacts of Underemployment and Unemployment in the United States: Exploring Perceptions, Gaps and Opportunities. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10021. [CrossRef]
29. Peters, S.E.; Sorensen, G.; Katz, J.N.; Gundersen, D.A.; Wagner, G.R. Thriving from Work: Conceptualization and Measurement. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7196. [CrossRef]
30. Peters, S.E.; Grogan, H.; Henderson, G.M.; López Gómez, M.A.; Martínez Maldonado, M.; Silva Sanhueza, I.; Dennerlein, J.T. Working Conditions Influencing Drivers' Safety and Well-Being in the Transportation Industry: "On Board" Program. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10173. [CrossRef]
31. Tenney, L.; Huebschmann, A.G.; Brown, C.E.; Schwatka, N.V.; Newman, L.S. Leveraging an Implementation Science Framework to Measure the Impact of Efforts to Scale Out a Total Worker Health®Intervention to Employers. *Int. J. Environ. Res. Public Health* **2022**, *19*, 1372. [CrossRef]
32. Ng, M.A.; Naranjo, A.; Schlotzhauer, A.E.; Shoss, M.K.; Kartvelishvili, N.; Bartek, M.; Ingraham, K.; Rodriguez, A.; Schneider, S.K.; Silverlieb-Seltzer, L.; et al. Has the COVID-19 Pandemic Accelerated the Future of Work or Changed Its Course? Implications for Research and Practice. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10199. [CrossRef] [PubMed]
33. Pishgar, M.; Issa, S.F.; Sietsema, M.; Pratap, P.; Darabi, H. REDECA: A Novel Framework to Review Artificial Intelligence and Its Applications in Occupational Safety and Health. *Int. J. Environ. Res. Public Health* **2021**, *18*, 6705. [CrossRef]
34. Horan, K.A.; Shoss, M.K.; Mejia, C.; Ciarlante, K. Industry Context as an Essential Tool for the Future of Healthy and Safe Work: Illustrative Examples for Occupational Health Psychology from the Hospitality Industry. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10720. [CrossRef]
35. Rogers, B.; Schill, A.L. Ethics and Total Worker Health®: Constructs for Ethical Decision-Making and Competencies for Professional Practice. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10030. [CrossRef] [PubMed]
36. Streit, J.; Felknor, S.; Edwards, N.; Howard, J. Leveraging strategic foresight to advance worker safety, health, and well-being. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8477. [CrossRef] [PubMed]
37. Guerin, R.J.; Harden, S.M.; Rabin, B.A.; Rohlman, D.S.; Cunningham, T.R.; TePoel, M.R.; Parish, M.; Glasgow, R.E. Dissemination and Implementation Science Approaches for Occupational Safety and Health Research: Implications for Advancing Total Worker Health. *Int. J. Environ. Res. Public Health* **2021**, *18*, 11050. [CrossRef] [PubMed]
38. Flynn, M.A.; Check, P.; Steege, A.L.; Sivén, J.M.; Syron, L.N. Health Equity and a Paradigm Shift in Occupational Safety and Health. *Int. J. Environ. Res. Public Health* **2022**, *19*, 349. [CrossRef] [PubMed]