HHS Public Access

Author manuscript

J Occup Health Psychol. Author manuscript; available in PMC 2024 August 01.

Published in final edited form as:

J Occup Health Psychol. 2023 August ; 28(4): 263–276. doi:10.1037/ocp0000357.

The Effects of a *Total Worker Health*® Intervention on Workplace Safety: Mediating Effects of Sleep and Supervisor Support for Sleep

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Abstract

We tested the effects of a randomized controlled trial *Total Worker Health*® intervention on workplace safety outcomes. The intervention targeted employee sleep at both the supervisor-level (e.g., sleep-specific support training) and employee-level (e.g., sleep tracking and individualized sleep feedback). The intervention components were developed using principles of *Total Worker Health*® approach and theory of triadic influence for health behaviors. We hypothesized that employees in the treatment group would report greater safety compliance, safety participation, and safety motivation, and would be less likely to experience a work-related accident or injury following the intervention through improvements in sleep quantity and quality, as well as increased perceptions of supervisors' support for sleep. It was theorized that the indirect effects of the intervention on workplace safety outcomes via sleep mediators operated through a resource pathway whereas the supervisor support for sleep mediator operated through an exchange pathway. Results broadly revealed that employees in the treatment group, compared to those in the control group, reported greater workplace safety behaviors and safety motivation, and reduced workplace accidents and injuries 9 months post-baseline, through lower dissatisfaction with sleep, reduced sleep-related impairments, and greater supervisor support for sleep 4 months post-baseline. Intervening on sleep and supervisor support for sleep in an integrated *Total Worker Health*® framework can have a positive impact on workplace safety.

Keywords

workplace intervention; *Total Worker Health* ® ; sleep; supervisor support; workplace safety

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The authors have no other conflicts of interest to disclose. Regarding dissemination, the findings included in the manuscript were presented at the virtual Work, Stress, & Health Conference in 2021. Results will also be shared on the project website: https://www.meshstudy.org/.

Unsafe work environments are detrimental to the health, well-being, and livelihood of workers, are associated with costly workers' compensation claims, medical expenses, and lost work time, and can negatively impact organizations and broader national economies (e.g., Leigh et al., 2011; World Health Organization; WHO, 2017). In 2018, approximately 2.4 million U.S. workers were treated in emergency departments for nonfatal workplace injuries (National Institute for Occupational Safety and Health; NIOSH, 2021). Globally, an estimated 2 million individuals lose their lives to work-related injuries and diseases each year (International Labor Organization, 2021; WHO, 2021). Organizations have a responsibility to create workplaces that are safe for their employees, which can be achieved by implementing evidence-based strategies for improving workplace safety.

Past workplace safety interventions have primarily targeted safety climate (e.g., Lee et al., 2019a). Safety climate interventions focus on safety-related education and training (e.g., awareness of risks and hazards) and communication (e.g., discussion of safety issues), and often include leadership support, such as safety-specific leadership trainings, and developing communication skills to signify the importance of safety (e.g., Clarke & Taylor, 2018; Lee et al., 2019a; Mullen & Kelloway, 2009; Zohar & Polachek, 2014). Although safety climate interventions tend to improve workplace safety outcomes, scholars have called attention to the inconclusiveness of findings in the workplace safety literature due to methodological shortcomings, like reliance on correlational or quasi-experimental designs rather than true experimental designs (e.g., Aburumman et al., 2019; Beus et al., 2016; Lee et al., 2019a). This work demonstrates that there is a need to broaden the approaches used to protect employees at work, particularly through the implementation and evaluation of randomized controlled trial interventions. We address these needs in the present study.

A substantial body of research has demonstrated that workers who get enough sleep and high-quality sleep are more likely to exhibit safe behaviors and are less likely to experience a workplace accident or injury (e.g., Barnes & Wagner, 2009; Brossoit et al., 2019; Kao et al., 2016; Uehli et al., 2014; Wong et al., 2021). Thus, interventions aimed at fostering healthy employee sleep may subsequently improve safety. In the present study, we evaluate the effects of a rigorously designed and implemented *Total Worker Health*® (TWH) intervention that targeted sleep on workplace safety outcomes. Although safety is not explicitly targeted in the intervention, we examine whether sleep-related mechanisms in turn relate to more distal workplace safety outcomes. Given the challenges and limitations of current safety climate interventions, this as an important contribution to the workplace safety literature.

Based on recommendations from sleep scholars, we conceptualize sleep as being comprised of both sleep quantity and quality indicators (e.g., Barnes, 2012; Buysse et al., 2014; Crain et al., 2018). Buysse's (2014) model of sleep health highlights five unique dimensions of sleep – duration, satisfaction, timing, alertness/sleepiness, and continuity/efficiency. In the present study, we measure four of these sleep dimensions. Specifically, we assess sleep quantity (i.e., duration) and three indicators of sleep quality, including insomnia symptoms (i.e., difficulty falling or staying asleep; continuity/efficiency), dissatisfaction with sleep (i.e., subjective assessment of one's sleep quality; satisfaction), and sleep-related impairments (i.e., cognitive and behavioral issues due to poor sleep and fatigue; alertness/

sleepiness). We examine these different facets of sleep, as well as employees' perceptions of their supervisors' sleep-specific support, as proximal intervention outcomes. As described in past work, the influence of sleep on cognitive and safety-related measures can take time and does not always manifest immediately (e.g., Brossoit et al., 2019), so distal intervention outcomes were also explored. Regarding distal workplace safety outcomes, we evaluate employees' safety compliance (i.e., adherence to safety protocols), safety participation (i.e., application of extra effort to support safety), motivation for being safe at work, and experiences of workplace accidents and injuries (See Figure 1).

Contributions

This study has methodological, empirical, and theoretical contributions. We 1) identify whether an intervention designed to improve sleep can also improve workplace safety, 2) apply an integrative TWH framework in conjunction with principles from the triadic theory of influence to create an intervention intended to improve sleep by intervening on both supervisors and employees, 3) assess various sleep-related mechanisms that rely on different theoretical pathways (i.e., a resource pathway and exchange pathway), and 4) evaluate the intervention in a high-risk sample of National Guard service members.

First, although some research has found a quasi-experimental or correlational link between employee sleep and safety outcomes (e.g., Barnes & Wagner, 2009; Brossoit et al., 2019; Gharibi et al., 2020), this is the first study to date that uses a randomized controlled trial intervention to evaluate the causal links between employee sleep and workplace safety outcomes. In a review of workplace safety research, Beus and colleagues (2016) find that there is only weak-to-moderate (rather than strong) empirical evidence for factors that influence safety outcomes at work, given the overall lack of rigorous, experimental designs. Consequently, Beus and colleagues (2016) called for research that investigates modifiable personal resources – "factors that reflect an individual's level of personal energy or capacity to accomplish work" (pg. 361) – and their associations with workplace safety. We argue that employee sleep is critical to the replenishment of personal resources and a worthwhile and modifiable intervention target that holds promise for organizations interested in improving safety. Even when a strong safety-promoting climate is in place, poor employee sleep has the potential to increase safety risks, given the essential role of sleep as a basic biological process that maintains neurocognitive performance (i.e., executive functioning, sustained attention, memory), which is necessary for engaging in safe work. In this way, we expect that targeting different aspects of sleep (i.e., sleep duration, indicators of sleep quality, supervisor support for sleep) in an intervention will have downstream impacts on safety behaviors, motivation, and outcomes. This advances the safety literature by identifying novel approaches to improve workplace safety, and providing a better understanding of why employees may choose to enact safety behaviors, as suggested by Beus et al (2016).

The intervention was developed using principles from NIOSH's TWH framework, which was created to extend traditional occupational health and safety approaches by jointly addressing worker health protection and promotion (Anger et al., 2015; Schill & Chosewood, 2013). Our intervention content was developed around the integration principle that is unique to the TWH framework (Punnett et al., 2020); we combine supervisor

training on sleep (i.e., health protection) with tracking of employee sleep and individualized feedback (i.e., health promotion). Prior TWH interventions have been criticized as health protection and health promotion are rarely integrated and are often implemented and evaluated in isolation, without the development of intervention activities at different levels that are simultaneously implemented and tied to one another in content (Punnett et al., 2020). Moreover, in reviewing the safety climate intervention literature, which is also very limited, Lee and colleagues (2019a) advocate for future workplace safety intervention research to incorporate multiple intervention targets, including behavior modification programs in combination with managerial behavior targets. This call to integrate multiple intervention targets has also been made more broadly in general workplace well-being intervention reviews (Fox et al., 2021), and thus we make an important empirical contribution by utilizing the TWH approach in this way.

This is the first sleep intervention designed using the TWH approach. As such, it is currently unclear how to jointly improve sleep through both the supervisor- and employee-levels. We make theoretical contributions in how we designed the two primary intervention components. Situated in the theory of triadic influence of health behaviors (Flay & Petraitis, 1994), we provided training to improve supervisors' knowledge and behaviors around sleep (i.e., health protection), and at the same time, directly targeted the sleep of those supervisors' employees (i.e., health promotion). We designed these two components with a strong theoretical grounding in improving intrapersonal, interpersonal, and cultural-environmental influences that can facilitate improvements in sleep (Flay & Petraitis, 1994). Although the theory of triadic influence is centered around improving health behaviors, most of the past intervention work using this theory has targeted behaviors like substance use, physical activity, and diet, rather than sleep (Flay et al., 2009). Additionally, unique from past work using the theory of triadic influence (much of which has focused on adolescents in school or community interventions), we evaluate adults in a workplace intervention (Flay et al., 2009).

Next, few intervention studies in the workplace well-being literature incorporate mechanisms of change (Fox et al., 2021). In contrast, we evaluate intervention effects on both proximal sleep-specific intervention targets 4 months post-baseline and more distal safety outcomes 9 months post-baseline. Additionally, although each mediator is related to sleep, the mechanisms operate through unique pathways. Whereas we expect the sleep duration and quality indicators to influence workplace safety due to the replenishment of cognitive and affective resources (i.e., what we characterize as "the resource pathway"), we expect supervisor support for sleep to engender a social-exchange process whereby employees reciprocate the support they receive with safer behaviors at work (i.e., what we characterize as "the exchange pathway"). By exploring mediating mechanisms of the intervention (i.e., the proximal intervention targets), which rely on different theoretical pathways, we uncover whether and how a TWH intervention can extend beyond the proximal targets and produce subsequent benefits on more distal workplace safety outcomes. Our evaluation of mechanisms will provide an understanding of the processes by which this novel intervention impacts workplace safety. Examining unique mediating pathways will provide options for sleep-related intervention targets in future work (i.e., targeting indicators of sleep or supervisor support for sleep). Developers of future interventions that

build off this work will have the ability to then add or refine elements of the intervention content to target alternative mechanisms or outcomes. Ultimately, we see the inclusion of five theoretically motivated proximal targets and four distal targets in this study as being a necessary, foundational evaluation for future adaptations of the intervention.

Finally, we examine a military sample of National Guard members. It is relevant to examine both sleep and safety in high-risk occupations that present the possibility of substantial and unpredictable danger (Gunia et al., 2015). Approximately half of U.S. military personnel experience at least one injury per year (Army Public Health Center, 2022) which was estimated to cost the U.S. government over $4.7 billion in direct medical and indirect costs in 2018 (Forrest et al., 2022). Members of the National Guard are on-call for hazardous and high-stress situations, such as domestic emergencies, counter-drug efforts, and combat. Moreover, some positions within the National Guard are safety-sensitive due to direct contact with heavy machinery such as airplanes or military-grade weapons. Regarding sleep, individuals in high-risk positions such as the National Guard are susceptible to sleep restriction due to prolonged stress or poor sleeping environments (Akerstedt & Wright, 2009; Gunia et al., 2015; Linton et al., 2015; Seelig et al., 2010; Elliman et al., 2020). Military personnel are also at higher risk for insufficient and poor-quality sleep due to their increased propensity for developing post-traumatic stress disorder, in which sleep disruptions are a typical symptom (e.g., Cameron et al., 2019; Vanderheyden, et al., 2014). For these reasons, it is especially advantageous to implement a sleep-specific intervention and evaluate safety-related outcomes among members of the National Guard.

Theoretical Rationale

We used TWH principles to design an organizational intervention targeting both supervisors and employees and use the theory of triadic influence to explain why the specific intervention components are expected to change the health behavior of sleep. Then, to explain why employees' sleep and sleep-related support they receive from their supervisors should in turn improve their safety at work, we draw from resource-based and exchange-based theories.

Workplace Intervention Designed to Improve Sleep

We developed and implemented a TWH intervention and evaluated the effects using a cluster randomized controlled design among a National Guard sample. By using a TWH approach to guide our intervention design, both supervisor and service member intervention components were developed. Supervisors were trained on the importance of sleep and how to support their employees' sleep. Following the training, supervisors also monitored the extent to which they enacted sleep-specific support behaviors. In addition, service members participated in activities to track their sleep, learn about their sleep patterns, and set goals to improve their sleep. In this way, we relied on principles related to behavioral health leadership, supervisor support, behavior-tracking, and goal-setting for improving sleep (e.g., Adler et al., 2014; Adler et al., 2017; Guina et al., 2015; Strecher et al., 1995). These practical intervention components can be explained using the theory of triadic influence for health behaviors, which was developed to guide interventions (Flay & Petraitis, 1994). We

focus specifically on the health behavior of sleep, which has received scant attention in the literature using the theory of triadic influence (Flay et al., 2009). Health behaviors are theorized to result from three "streams of influence", including a) intrapersonal influences, b) interpersonal influences, and c) cultural-environmental influences. These three influences in concert result in decisions or intentions to engage in the health behavior, and ultimately the enactment of the health behavior.

The first stream of influence is related to intrapersonal factors, including biology, personality, but also one's self-efficacy and behavioral control related to the health behavior. Flay and colleagues (2009) identify two ways to promote health-related efficacy: 1) teaching self-regulation and self-management skills and 2) having health promoters instill confidence in achieving healthy behaviors. In our intervention, participants developed sleep-related skills by tracking their sleep and setting sleep goals, while simultaneously receiving encouragement from their supervisor to engage in healthy sleep practices. These intervention components were both expected to enhance employees' self-efficacy in improving their sleep. Flay and Petraitis (1994) also describe that inherited biological traits and dispositional personality additionally contribute to the enactment of health-related behaviors. However, given that biology and personality are rather enduring and not considered immediately and easily malleable within an organizational context, we refrained from attempting to alter these influences within our sleep-specific intervention. Rather, we aimed to create and evaluate an intervention that was broadly applicable and effective across a diversity of individuals within an organizational setting, irrespective of these intrapersonal traits.

The second stream, interpersonal (i.e., social situation-context) influences, is representative of other individuals in the environment forming a bond with the target individual, exhibiting positive health-related behaviors and attitudes for the target individual, helping to establish perceived norms around the health behavior, and acting as a motivating factor for the target individual to comply (Flay & Petraitis, 1994; Flay et al., 2009). This process results in the target individual forming social normative beliefs about the health behavior. The supervisor support component of our intervention was designed to encourage supervisors to establish connections with service members that would allow them to provide support around sleep, role model and espouse their own promotive sleep behaviors and attitudes for service members, which should then result in service members perceiving positive sleep-related norms and feeling motivated to comply with such norms. In other words, having a supervisor who learned to support sleep was proposed to translate into social normative beliefs for service members around healthy sleep.

The third stream of influence, culture and environment, represents the broader context wherein values and knowledge about the health behavior are fostered (Flay & Petraitis, 1994; Flay et al., 2009). Values in turn lead to evaluations of the consequences of engaging or not engaging in the health behavior, while knowledge allows for subsequent expectations about the behavior. Evaluations and expectations then result in attitudes about the health behavior, which are critical for having an intention to engage in the behavior. Overall, the cultural-environmental stream identifies how values and knowledge, provided by the broader environment (rather than intrapersonally or interpersonally) ultimately influence attitudes about a health behavior. Specific to the present study, the workplace reflects the

broader environment through which we aimed to enhance service member sleep knowledge and values during feedback sessions where participants learned about their sleep, while also assisting service members in a goal setting process that allowed for reflection around consequences of engaging in unhealthy versus healthy sleep behaviors. We expected that the cluster-randomization (i.e., randomization of work groups rather than individuals) would also foster broader cultural shifts and related changes in attitudes surrounding the importance of sleep for the treatment groups.

In summary, our specific intervention components can be understood using the theory of triadic influence; the intervention was intended to 1) enable service members to develop skills and self-efficacy surrounding sleep, 2) teach supervisors within the social context how to support service member sleep and facilitate social normative beliefs about sleep, and 3) foster sleep-related knowledge and values within the broader environment by providing service members with sleep feedback and goal-setting opportunities, each with the objective of increasing healthy sleep behaviors. Safety-related behaviors are conceptually similar to health-related behaviors, as each have important consequences for the overall well-being and livelihood of employees. Therefore, our study will elucidate the extent to which intervening on health behaviors, like sleep, can also have downstream positive impacts on safety-related behaviors.

Sleep-Related Mechanisms: Resource and Exchange Pathways

To understand why improved employee sleep should in turn improve workplace safety outcomes, we draw on resource-based theories of sleep and organizational behavior to describe a “resource pathway”. In the work, nonwork, and sleep (WNS) framework, Crain and colleagues (2018) refine earlier resource-based theories to describe how sleep quantity and quality replenish human energies, thereby impacting work attitudes, behaviors, and states. In the WNS framework, human energy is conceptualized as physical energy (the physiological state of being energized, e.g., low fatigue) and energetic activation (feeling energized, e.g., positive moods; Crain et al., 2018). At the heart of the theoretical argument for deficient sleep limiting human energy are more basic physiological processes whereby sleep serves to maintain a host of necessary neurocognitive, emotion regulation, and behavioral functions. For example, healthy sleep is imperative for capacities like response time and consistency, memory consolidation, learning, and insight (e.g., Cziesler, 2015; Kerkhof & Van Dongen, 2010; Killgore, 2010; Walker, 2009), each of which are critical precursors to safe behavior. Healthy sleep is also necessary for regulating moods and emotions, which can also impact safety behaviors at work (Wong et al., 2021). Employees with sufficient sleep quantity and quality are better able to maintain foundational neurocognitive, emotional, and behavioral functioning that in turn allows for the management of their own goal-directed behavior (i.e., self-regulation), whereas poor sleep can prevent the replenishment of resources, and consequently impair employees’ ability to self-regulate. In this way, employees who do not obtain adequate and high-quality sleep will not have the available resources required to perform their job safely.

In contrast to the resource pathway, we argue that the link between supervisor support for sleep and workplace safety outcomes operates through an “exchange pathway”. Social

exchange theory asserts that individuals evaluate the extent of "give and take" within relationships and aim to achieve balance. It has been theorized that there is a universal norm to return or reciprocate help that has been received by others (Blau, 1964; Gouldner, 1960). In the context of work, employees assess the extent to which they feel supported by their organization, which typically involves the treatment they receive from leaders or supervisors, and in turn adjust the degree to which they reciprocate with performance-related behaviors (Cropanzano & Mitchell, 2005). Relatedly, organizations and supervisors that provide more socioemotional fulfillment to their employees, in turn receive more effort and dedication from their employees, while also improving employee job attitudes and health (e.g., Baran et al., 2012; Cropanzano & Mitchell, 2005; Eisenberger et al., 1986; Hammer et al., 2021; Rhoades & Eisenberger, 2002). We draw on theories of social exchange and perceived organizational support to describe why leaders who provide social support around sleep should then have employees who feel inclined to work safely and support the organization's safety goals.

Hypotheses

The Resource Pathway: Improved Sleep Quantity and Sleep Quality as Intervention Mechanisms

The primary goal of the TWH intervention was to improve employee sleep, but more distal safety outcomes were also explored given the need to identify new ways to improve workplace safety. Past research has demonstrated that poor sleep is associated with unsafe behaviors and increased risk of accidents and injuries at work (e.g., Barnes & Wagner, 2009; Brossoit et al., 2019; Kao et al., 2016; Uehli et al., 2014; Wong et al., 2021). In this way, the TWH intervention should have a favorable impact on workplace safety outcomes, via the improvements in sleep that employees in the treatment group experience. Indeed, it is not uncommon for the benefits of organizational interventions to extend beyond their primary targets, as demonstrated by past work that has found intervention effects on distal outcomes (e.g., Hammer et al., 2021; Olson et al., 2015), though only a few studies to date have captured these mechanisms of change in addition to downstream effects (Fox et al., 2021). To explore resource-based pathways of intervention effectiveness, we evaluate whether intervention effects on sleep are in turn predictive of workplace safety outcomes.

Recent research has focused on uncovering the mechanisms that explain the relationships between employee sleep and workplace safety outcomes. For instance, poor sleep can lead to cognitive impairments at work (e.g., trouble remembering safety procedures or difficulty paying attention to job tasks), which in turn reduces workers' ability to perform their job in a safe manner (e.g., Brossoit et al., 2019). Other researchers have found that negative affect also plays a role in the link between poor sleep quality and experiences of workplace injuries (Wong et al., 2021). Each of these perspectives are situated in theories of resource replenishment, in which sleep enables one's ability to regulate cognitive processes and emotions through increases in energy (Barnes, 2012; Crain et al., 2018; Mullins et al., 2014). Thus, in the resource pathway, deficient sleep reduces employees' ability to perform one's jobs safely.

Individuals who sleep longer (i.e., greater sleep duration), can fall asleep and remain asleep throughout the night (i.e., fewer insomnia symptoms), are satisfied with the quality of their sleep (i.e., less dissatisfaction with sleep), and who do not experience trouble completing their daily activities due to poor sleep (i.e., less sleep-related impairment), should have the self-regulatory resources needed to work in a safe manner. These individuals should have the cognitive and affective resources to be able to engage in the required safety behaviors that are expected of them at work (i.e., safety compliance), engage in voluntary behaviors that contribute to a safe environment in the workplace (i.e., safety participation), and be more likely to hold a personal belief around the importance of safety at work (i.e., safety motivation), while also experiencing fewer workplace accidents and injuries. Sleep enables the cognitive resources employees need to pay attention to and remember safety-related protocols, as well as the affective resources employees need to regulate their emotions (Brossoit et al., 2019; Wong et al., 2021). Illustratively, an employee with poor sleep may have decrements in their attention or memory for safety-related protocols and may also experience negative moods and emotions at work that reduce their ability to perform their jobs safely, willingness to engage in extra-role safety behaviors, and diminish the value they see in supporting workplace safety. Taken together, we expect that employees who obtain sufficient and high-quality sleep, as a result of being randomized to the intervention group, will have positive safety experiences at work:

Hypothesis 1:

The effects of the intervention on increased safety compliance, safety participation, safety motivation, and decreased workplace accidents and injuries 9 months post-baseline will be mediated by longer a) *sleep duration,* and reduced b) *insomnia symptoms*, c) *dissatisfaction with sleep*, and d) *sleep-related impairments* 4 months post-baseline.

The Exchange Pathway: Perceptions of Supervisor Sleep Support as an Intervention Mechanism

Educational training for supervisors on the importance of employee sleep and how to support employee sleep are core components of the TWH intervention. There is evidence that the TWH intervention increased employee reports of their supervisor's sleep leadership behaviors (i.e., asking about employee sleep and encouraging behaviors that promote sleep health; Hammer et al., 2021). Other work has shown that employees with supervisors who ask about their sleep, encourage them to get enough sleep, and teach them about behaviors that can improve sleep, report sleeping longer and experiencing greater sleep quality (Gunia et al., 2015, Gunia et al., 2021; Sianoja et al., 2019). In addition, it is widely agreed upon that leadership, management, and frontline supervisors' commitment and support for workplace safety is paramount to solidifying a strong, positive safety climate and creating a safe work environment for employees (Casey et al., 2017; Christian et al., 2009; Clarke, 2006; Hoffman et al., 2017; Lee et al., 2019a).

More broadly, a well-established literature on social exchange and organizational support also suggests that supervisors who are generally more supportive of employees (i.e., showing care, concern, and appreciation for employees), in turn have direct reports who engage in higher levels of task and extra-role performance (e.g., Rhoades & Eisenberger,

2002; Shanock & Eisenberger, 2006), more ethical behaviors (e.g., Sguera et al., 2018), and positive safety behaviors (e.g., Mearns & Reader, 2008). The relationship quality between supervisors and employees is related to the sense of obligation employees feel to reciprocate in the form of performance outcomes (e.g., Lee et al., 2019b). There is also evidence that employees with sleep-supportive supervisors report a host of additional favorable outcomes beyond performance, including more positive job attitudes, less stress before bedtime, reduced impairment in personal and social domains (Hammer et al., 2021), and are better able to self-regulate (Gunia et al., 2021). Therefore, in line with the exchange pathway, employees should respond to a sleep-supportive supervisor with positive outcomes related to workplace safety.

Considering this prior research and theory, we suggest that supervisors who are supportive of their employees' sleep will provide employees with a reason for reciprocating with positive workplace safety behaviors in. The exchange pathway delineates how receiving sleep-specific support from one's supervisor should instill an increased sense of obligation to perform safely on the job (i.e., safety compliance), exhibit extra-role safety behaviors (i.e., safety participation), see the value in being safe at work (i.e., safety motivation), thereby preventing workplace accidents and injuries. By supporting workplace safety, employees are, in a way, "repaying" their supervisor and organization for the socioemotional support they experienced from their sleep-supportive supervisor. Therefore, we expect that employees in the intervention group will view their supervisors as supportive of their sleep and subsequently exhibit greater workplace safety behaviors, safety motivation, and experience fewer accidents and injuries at work.

Hypothesis 2:

The effects of the intervention on increased safety compliance, safety participation, safety motivation, and decreased workplace accidents and injuries 9 months post-baseline will be mediated by increased perceptions of *supervisor support for sleep* 4 months post-baseline.

Methods[1]

Recruitment and Randomization of Participants

The research team first received buy-in from top leadership and unit leaders at the National Guard in the state where the study was conducted. Service Members were then recruited by their unit leaders. We requested that unit leaders send emails to each of their full-time staff members to share relevant information about the project and instructions for how to sign up to participate in the study. To incentivize involvement and compensate participants, up to $125 was offered for participation; specifically, a $25 gift card was provided for those who completed each of the three surveys outside of work time and a $50 gift card was provided to those who participated in the sleep tracking data collection.

Of the 1,170 individuals who were eligible to participate, 975 signed up for the study, and 944 provided informed consent to participate. Participants who were deemed to be

[1]We encourage readers to see Hammer et al (2021) for additional details regarding the recruitment and randomization strategies, study design, and intervention components.

supervisors rather than employees (N = 215) were excluded from the Service Member sample. A total sample of 704 full-time Army and Air National Guard Service Members completed the baseline survey and were randomized to intervention (N = 358) and control (N = 346) groups (additional details are provided in Hammer et al.'s 2021 CONSORT diagram). Approximately 60 National Guard units were included in the study and were organized into 20 groups. The randomization strategy we used first matched the 20 work groups based on similar features (e.g., location, size, branch) and then randomly assigned work groups into either the intervention (N = 10 groups) or control group (N = 10 groups).

Participant Demographics

Of the 704 full-time Army and Air National Guard Service Members, most were white (80.7%), male (74.7%), and were on average 36.2 years old (SD = 9.08). Most participants worked a regular daytime shift (82.5%), reported working an average 42 hours per week (SD = 5.0 hours), and being in their current job for an average tenure of 4.7 years (SD = 5.5 years). Participants worked in positions that support the functioning of the National Guard (e.g., mechanics, maintenance, technicians, engineers, and human resources).

Intervention Design and Procedure

A cluster randomized controlled trial design with a waitlist control group was used to evaluate the intervention. Online surveys were administered at three different occasions: baseline, 4-months post-baseline, and 9-months post-baseline, with actigraphic sleep tracking at baseline and 9-months post-baseline to facilitate individualized sleep feedback reports. The intervention was implemented 1–2 months after the baseline data collection, and follow-up data were collected approximately 1 and 6 months after the intervention was implemented (i.e., 4-months post-baseline and 9-months post-baseline; see Figure 1 in Hammer et al., 2021). We expected supervisors and employees to need about one month to form new habits surrounding sleep support and sleep behaviors before resulting in detectable behavior change (Gardner & Rebar, 2019). The Institutional Review Board at the Principal Investigator's university approved the project.

The primary aims of the TWH intervention were to educate supervisors on the importance of healthy sleep and how to effectively support their service members' sleep and non-work lives, while also providing service members opportunities to understand and improve their sleep. To achieve this, the intervention included an hour-long, computer-based, interactive training for supervisors to learn how to support their employees lives outside of work (i.e., family-supportive supervisor behaviors; Hammer et al., 2011) and particularly how to encourage their employees to obtain healthy sleep (e.g., suggesting behaviors to improve sleep, such as discouraging caffeine or nicotine consumption within several hours before sleeping; Gunia et al., 2015). During the training, supervisors completed quizzes to ensure their understanding of the training content. Evaluation of pre- and post-test scores revealed that supervisors who were randomized to the treatment group demonstrated large learning effects (Hammer et al., 2021). To ensure training transfer, supervisors also monitored and logged their supportive behaviors.

Additionally, participants in both the treatment and control groups wore an actigraph wristwatch to track their sleep. Following the actigraphy data collection, participants in the intervention group received tailored sleep reports that depicted their sleep patterns (e.g., duration of sleep, awakenings during sleep, consistency of timing of sleep). Trained members of the research team provided one-on-one feedback to help participants understand their sleep patterns and set sleep goals. Specifically, participants in the intervention group set two sleep goals intended to improve their sleep duration and/or sleep quality (e.g., avoiding alcohol in the evening, establishing a "wind-down" routine before bed, refraining from using electronics close to bedtime). Follow-up communication between participants and members of the research team fostered accountability and encouragement towards goal progress.

Measures

Sleep Quantity and Quality—Sleep duration was assessed using the Pittsburgh Sleep Quality Index (Buysse et al., 1989). Sleep duration was computed as a difference score between when participants reported they typically went to bed and when they typically woke up in the last month.

Insomnia symptoms were measured with four items from the sleep disturbance scale from the Patient-Reported Outcome Measurement Information System (PROMIS; Yu et al., 2012). Participants were asked to rate the extent to which they experienced insomnia symptoms in the past 7 days (e.g., "I had difficulty falling asleep"; Cronbach's α at 4 months post-baseline = .88). Items were initially rated on five-point scales (e.g., 1 = Never; 5 = Always), then T-score transformations were computed using the HealthMeasures (2021) scoring system. T-scores allow for comparisons to a referent population, such as the general US population for PROMIS measures (Rothrock et al., 2020). Higher scores indicate more insomnia symptoms.

Dissatisfaction with sleep was measured using four items from the PROMIS sleep disturbance scale (Yu et al., 2012). Participants were asked to rate the extent to which they experienced dissatisfaction with the quality of their sleep in the past 7 days (e.g., "I was satisfied with my sleep"; Cronbach's α at 4 months post-baseline = .91). Items were initially rated on five-point scales (e.g., 1 = Not at All; 5 = Very Much), then T-score transformations were computed. Higher scores reflect greater dissatisfaction with sleep.

Sleep-related impairment was measured using the eight-item PROMIS scale (Yu et al., 2012). Employees were asked to rate the extent to which they experienced daytime sleepiness and disruptions to their mood and behavior due to their sleep in the past week (e.g., "I had a hard time getting things done because I was sleepy"; Cronbach's α at 4 months post-baseline = .91). Items were initially rated on a five-point scale (1= Not at All; 5 = Very Much), before converting to T-scores. Higher scores reflect greater sleep-related impairment.

Supervisor Support for Sleep—Perceptions of supervisor support for sleep were assessed with an eight-item version of Gunia and colleagues' (2015) sleep leadership scale[2]. Participants rated the extent to which their supervisors engaged in sleep-supportive behaviors (e.g., "your supervisor encourages subordinates to get adequate sleep";

Cronbach's α at 4 months post-baseline = .94). Response options were on a five-point scale (1 = Never; 5 = Always), with higher scores reflecting greater sleep support from one's supervisor.

Workplace Safety—Safety compliance was assessed using three items (Neal & Griffin, 2006). Participants rated the extent to which they adhere to the safety protocols at work (e.g., "I use the correct safety procedures for carrying out my job"; Cronbach's α at 9 months post-baseline = .95). Response options were on a five-point scale (1 = Strongly Disagree; 5 = Strongly Agree), in which higher scores represent greater safety compliance.

Safety participation was assessed using three items (Neal & Griffin, 2006). Participants rated the extent to which they voluntarily promote safety at work (e.g., "I put in extra effort to improve the safety of the workplace"; Cronbach's α at 9 months post-baseline= .87). Response options were on a five-point scale (1 = Strongly Disagree; 5 = Strongly Agree), with higher scores reflecting greater safety participation.

Safety motivation was assessed using three items (Neal & Griffin, 2006). Participants rated the extent to which they personally value safety at work (e.g., "I feel that it is worthwhile to put in effort to maintain or improve my personal safety"; Cronbach's α at 9 months post-baseline = .93). Response options were on a five-point scale (1 = Strongly Disagree; 5 = Strongly Agree), such that higher scores indicate greater safety motivation.

Workplace accidents and injuries were assessed with a single item: "During the last 6 months, did you have any injuries or accidents that required professional healthcare; resulted in loss of consciousness, loss of awareness, or amnesia for any length of time; or restricted your normal activities for 4 hours or more that were work-related?" (Hemingway & Smith, 1999). Participants responded with either "yes" or "no".

Analytic Strategy—To account for the clustering of employees within work groups, multilevel regression analyses in Mplus Version 7 (Muthén & Muthén, 2012) were used. Linear regression analyses were used for continuous outcome variables and probit regression analyses were used for the binary outcome variable. We used an analysis of covariance (ANCOVA) approach, in which baseline values of the mediator and dependent variables were modeled as control variables (Bodner & Bliese, 2018). The ANCOVA approach maximizes estimation precision and power to detect intervention effects in randomized designs (Bodner & Bliese, 2018). To test for indirect intervention effects, we employed bootstrapping with 5,000 bias-corrected bootstraps (Fritz & MacKinnon, 2007) and statistical significance was determined as asymmetrical 95% confidence intervals that did not contain zero. Given that our hypotheses were not focused on the unique effect of each mediator over and above other mediators, and to prevent potential multicollinearity issues, indirect effect hypotheses were evaluated in separate models. All analyses were conducted within a conservative intent-to-treat framework (McCoy, 2017). We follow the exact analytic approach presented by Hammer and colleagues (2021).

[2]One item about supporting the use of prescription medications was dropped due to concerns about this being a service-limiting condition for some military jobs.

Results

Descriptive statistics and correlations are presented in Table 1. Intraclass correlation coefficients (ICCs) were explored to understand the extent to which employee responses were related to the work groups they were nested within. Although the average ICC values across the continuous mediator and outcome variables were small (i.e., .004; range of .001 to .009), we modeled the nesting of employees within distinct groups across all analyses.

Sleep Intervention Mechanisms

Results indicate significant indirect effects of the intervention on greater safety participation and safety motivation, and fewer accidents and injuries, 9 months post-baseline via dissatisfaction with sleep 4 months post-baseline. Yet, there were no indirect effects of the intervention on safety compliance through dissatisfaction with sleep. Analogously, there was a significant indirect effect of the intervention on greater safety participation and safety motivation, and fewer accidents and injuries, 9 months post-baseline via sleep-related impairment 4 months post-baseline, but no indirect effects of the intervention on safety compliance through sleep-related impairment. Moreover, there were no indirect effects of the intervention on safety outcomes through sleep duration or insomnia symptoms.

Supervisor Support Intervention Mechanism

Results indicate significant indirect effects of the intervention on improved safety compliance and safety participation 9 months post-baseline via greater supervisor support for sleep 4 months post-baseline. There were no indirect effects of the intervention on safety motivation, or accidents and injuries, through supervisor support for sleep. Hypotheses 1 and 2 were partially supported (See Table 2 and Figure 2).

Discussion

Participants in the treatment group of the TWH intervention reported improved sleep quality and greater sleep-specific support from their supervisors, which in turn led to greater workplace safety behaviors and reduced accidents and injuries. Specifically, regarding indirect effects of sleep, employees in the treatment group reported being more satisfied with their sleep and experiencing reduced daytime sleep-related impairment, which in turn predicted more voluntary safety behaviors at work (i.e., safety participation), greater valuing of workplace safety (i.e., safety motivation), and fewer workplace accidents and injuries that required medical attention. Pertaining to indirect effects of supervisor support, employees in the treatment group perceived their supervisors to be more supportive of their sleep following the intervention, which was related to being more likely to adhere to safety protocols and procedures at work (i.e., safety compliance) and putting in extra effort to support workplace safety (i.e., safety participation). These findings provide support for the benefits of integrated intervention approaches, like TWH, and for the critical roles of employee sleep and supervisor support for workplace safety motivations, behaviors, and outcomes.

Theoretical Implications

Our findings suggest that a TWH intervention, which used intrapersonal, interpersonal, and cultural-environmental "streams of influence" to impart sleep-related skills, social normative beliefs, knowledge, and values, can indirectly improve workplace safety through sleep quality indicators and perceived supervisor support for sleep. Yet, the effects were not uniform across mediators and outcomes, which has implications for both theory and future intervention design. First, reduced dissatisfaction with sleep and sleep-related impairment mediated the intervention effects on greater safety participation, greater safety motivation, and fewer workplace accidents and injuries, but not safety compliance. Thus, subjective perceptions of sleep quality and experiences of alertness throughout the workday may reflect resource replenishment and seem to be especially critical for workplace safety. On the other hand, the only mediator between the intervention and safety compliance, or adherence with workplace safety protocols, was supervisor support for sleep. Supervisor support for sleep also mediated the effects between the intervention and safety participation. Having a supervisor who asks about sleep and encourages healthy sleep behaviors may signal to employees that the supervisor cares about their health and wellbeing (which may include their safety at work), thereby providing socioemotional benefits for the employee. Consequently, in line with social exchange theory, employees seem to reciprocate the support they receive from their supervisors by following the organization's safety rules and putting forth extra effort to improve workplace safety (i.e., safety behaviors). The exchange pathway, however, does not appear to impact motivations or values surrounding safety or actual safety incidents at work.

We believe these discrepant findings are due to sleep and supervisor support for sleep influencing safety outcomes through different processes. The sleep indicators are theorized to influence safety outcomes through a resource pathway and may be operating through unexplored cognitive mediators (e.g., workplace cognitive failures), affective mediators (e.g., mood, emotion regulation), or energetic mediators (e.g., fatigue, depletion). Supervisor support for sleep is theorized to impact safety outcomes through an exchange pathway and may be operating through perceived organizational support or felt obligations to reciprocate with safe behaviors at work. Although a limitation of the study is that we were not able to evaluate a multiple mediator process model with only three timepoints, it is also possible that supervisor support for sleep could be acting more proximally to impact employee sleep, which in turn would affect safety outcomes. Analogously, safety motivation should precede safety behaviors, which should then lead to accident and injury outcomes (Griffin & Neal, 2000); and sleep-related impairment and dissatisfaction with sleep may follow from sleep duration and insomnia symptoms experienced the prior evening — these processes could be explored more precisely in future work by collecting data across additional time points. To further inform theory, an important next step is for researchers to directly measure variables that reflect the resource pathway and exchange pathway as additional mediators connecting sleep and supervisor support for sleep with workplace safety, while also disentangling the serial ordering of mediators and outcomes.

There were no indirect effects of the intervention on safety outcomes via sleep duration. Although in contrast to tenets of the work, nonwork, and sleep framework, these findings

are in line with other work that has found effects of sleep quality, but not quantity, on workplace safety outcomes, as well as meta-analytic findings that sleep quality tends to be a stronger predictor of work-related performance outcomes than sleep duration (e.g., Brossoit et al., 2019; Henderson & Horan, 2021). However, insomnia symptoms (i.e., a sleep quality indicator) also did not act as a mediator between the intervention and safety outcomes. Theoretically, this suggests that sleep indicators that measure the subjective assessment of one's sleep and experiences of sleep-related impairments were more sensitive to our TWH intervention (and subsequently predictive of workplace safety) than the actual amount of sleep someone receives or trouble sleeping someone experiences. Rather than serving to replenish energetic resources, measures of dissatisfaction with sleep and sleep-related impairment tap more directly into human energy, particularly energetic activation (i.e., the perception of being energized; Crain et al., 2018), and may therefore be more proximal to the safety outcomes than sleep duration or insomnia symptoms. There are a few alternative explanations. First, participants reported obtaining an adequate amount of sleep throughout the study (i.e., over 7 hours on average; Watson et al., 2015), which may explain why sleep duration did not mediate intervention effects on safety outcomes. Additionally, despite significant associations between insomnia symptoms and workplace safety variables in the expected directions (i.e., reduced insomnia symptoms predicted more favorable workplace safety outcomes), there were no indirect effects of the intervention on safety outcomes via insomnia symptoms, a finding that is likely due to the absence of a main effect of the TWH intervention on insomnia symptoms.

Practical Implications

Broadly, organizations interested in improving the safety of their workplace would benefit from targeting employees' sleep quality (particularly satisfaction with sleep and low sleep-related impairments) and the sleep-specific support they receive from their supervisors. To achieve this, organizations could implement the TWH intervention in their workplace. However, considering our results, targeting only some of the mediating mechanisms in future intervention work would theoretically result in some gaps in employee safety behaviors and less holistic positive results. We agree with scholars who have called for TWH interventions to adopt a truly integrated approach that involves both health protection with health promotion, rather than one or the other as has been traditionally done (Anger et al., 2015; Punnett et al., 2020; Schill & Chosewood, 2013). Moreover, we suggest that these intervention efforts be fully integrated, such that supervisor training content is tied to the content employees receive in their sleep feedback, to effectively communicate a shared goal and to ensure consistency of information provided to individuals at different levels of the organization.

To this end, we also suggest that future intervention work should simultaneously address safety climate more broadly alongside sleep (e.g., training supervisors to support and encourage both workplace safety behaviors and sleep health behaviors), while also incorporating redesign strategies and policies that directly protect employees from workplace safety hazards and sleep issues. These ideas are in line with calls from Lee and colleagues (2019) and Fox and colleagues (2021), who note the importance of addressing multiple intervention targets that are integrated and complementary in the development of

interventions. Furthermore, our results suggest that the intervention had effects on safety compliance through supervisor support for sleep, yet not employee sleep mechanisms. Given that prior safety climate intervention work has shown effects on safety compliance, a holistic intervention that addresses safety more broadly, in conjunction with sleep, is likely to have even stronger effects on a range of both expected and extra-role safety behaviors. However, because we found an effect on safety compliance through supervisor support for sleep, the TWH intervention holds promise in addressing employees' ability to follow required safety protocols.

Limitations & Future Research Directions

The TWH intervention indirectly reduced serious workplace accidents and injuries (i.e., those which required emergency medical care), which likely have lower base-rates compared to minor workplace injuries (e.g., muscle strains) or near misses. Therefore, researchers could explore the potential impact of employee sleep, and supervisor support for sleep, on a broader range of safety outcomes in future work. We chose to focus specifically on safety-related outcomes, rather than general behaviors (e.g., task performance), given the interconnectedness among workplace safety and employee health and well-being (e.g., Halbesleben & Bellairs, 2015; Smith et al., 2020). However, other work outcomes could also be assessed in future research, particularly those that rely on similar resource and exchange pathways. For example, future research could explore the effect of interventions targeting sleep and/or support for sleep on outcomes like task performance, organizational citizenship behaviors, interpersonal behaviors (e.g., incivility), absenteeism, and turnover (Barnes, 2012, Mullins et al., 2014).

A limitation of the present study is the magnitude of the significant indirect effects is small. Relatedly, many of the correlation coefficients between the intervention condition indicator and variables of interest are small and non-significant (see Table 1). One possible reason is that we relied on an intent-to-treat approach, in which all participants are included in the groups to which they were randomized to, regardless of their adherence to the intervention ("once randomized, always analyzed"; McCoy, 2017). This approach is advantageous because it provides a conservative and unbiased method for identifying the efficacy of an intervention but may also make it harder to detect large effects of an intervention. Alternatively, the length of the time-lags between data collections may also explain the relatively small effects. Exploring intervention effects across shorter time intervals may capture more immediate and stronger effects. For example, weekly- or daily-level fluctuations in sleep, supervisor support, and workplace safety, as well as the array of potential explanatory variables (e.g., cognitive or mood-based variables, perceived organizational support), could be assessed in future work. In addition, our intervention design was informed by the TWH framework and the triadic theory of influence, but the integration of intervention components presents challenges in disentangling the relative contributions of each component (i.e., improved supervisor support for sleep versus improved sleep duration and quality). Although comparative effectiveness study designs are complex and require large sample sizes, it would be advantageous for researchers to consider designs that would allow for the comparison of effects across a control group, a supervisor

support training intervention group, a sleep tracking and goal-setting intervention group, and a combined intervention group with all components.

The development, implementation, and evaluation of a randomized controlled trial TWH intervention using nested and longitudinal data are methodological strengths of this study. Furthermore, participants included National Guard service members and their supervisors – a sample with some unique features. Notably, the military has a hierarchical structure and a culture of respect for authority, which may have increased leaders' ability to establish social normative beliefs surrounding sleep and service members' inclination to practice the sleep behaviors suggested by their supervisors. Indeed, research has demonstrated that targeting leaders in workplace interventions can lead to beneficial employee outcomes due to leaders' position in the organization (e.g., Hammer et al., 2021). The culture surrounding sleep in the US military (e.g., viewing the need for sleep as a "weakness"; Ryan, 2021) may also limit the generalizability of our results. Therefore, it would be worthwhile for to explore effects of a comparable TWH intervention in non-military populations, such as employees who have disrupted sleep (e.g., shift workers, new parents), who work in unsafe or hazardous professions (e.g., construction, agriculture, manufacturing workers), are in precarious positions (e.g., migrant workers, contract workers), or have jobs that can impact the health and safety of others (e.g., nurses, pilots).

Conclusion

A novel TWH intervention impacted multiple sleep-specific mechanisms, which in turn influenced a range of employee safety outcomes, including safety behaviors, safety motivation, and serious accidents and injuries at work. We answer calls in the literature for interventions designed around the TWH integration principle, while also uncovering new modifiable sleep factors at both the employee and supervisor levels that can be considered alongside broader workplace safety intervention work. This research contributes to our understanding of change factors that can improve workplace safety and has resulted in an intervention that can be further refined, adapted, and implemented in organizations.

Acknowledgments

The U.S. Army Medical Research Acquisition Activity, 820 Chandler Street, Fort Detrick MD 21702-5014 is the awarding and administering acquisition office. This work was supported by Office of the Assistant Secretary of Defense for Health Affairs, through the Psychological Health and Traumatic Brain Injury Research Program - Comprehensive Universal Prevention/Health Promotion Interventions Award, under Award No. W81XWH-16-10720. Opinions, interpretations, conclusions, and recommendations are those of the author and are not necessarily endorsed by the Department of Defense. This work was also partly supported by the Oregon Institute of Occupational Health Sciences at Oregon Health & Science University via funds from the Division of Consumer and Business Services of the State of Oregon (ORS 656.630). Additionally, work on this article was supported by the Grant #T03OH008435 awarded to Portland State University, funded by the Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH, CDC, or HHS. Finally, *Total Worker Health*® is a registered trademark of the U.S. Department of Health and Human Services (HHS). Participation by the authors does not imply endorsement by HHS, the Centers for Disease Control and Prevention, or the National Institute for Occupational Safety and Health. Regarding conflicts of interest, Leslie Hammer has a financial interest in Work Life Help, LLC., a company that may have a commercial interest in the results of this research and technology. This potential conflict of interest has been reviewed and managed by OHSU.

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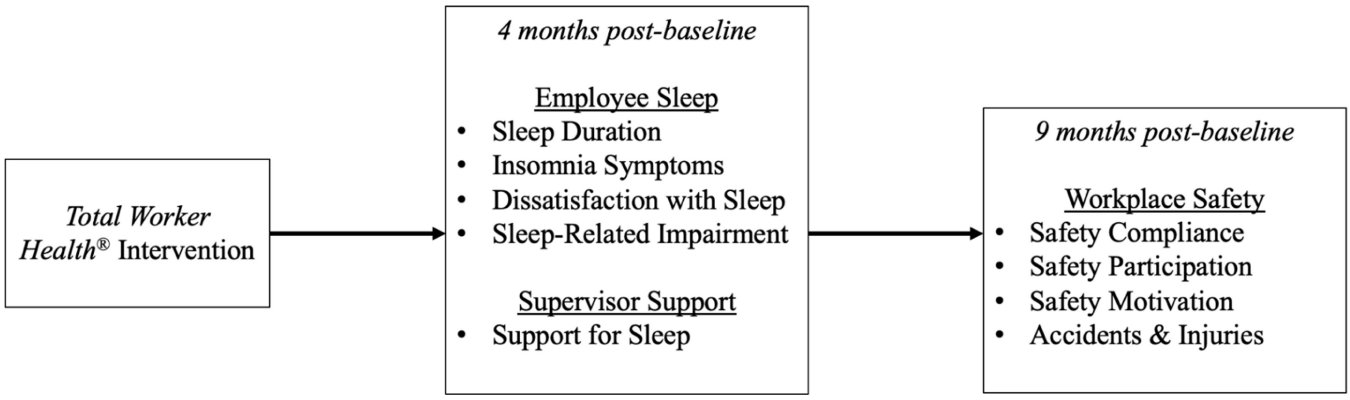

Figure 1.
Conceptual model of hypothesized effects.

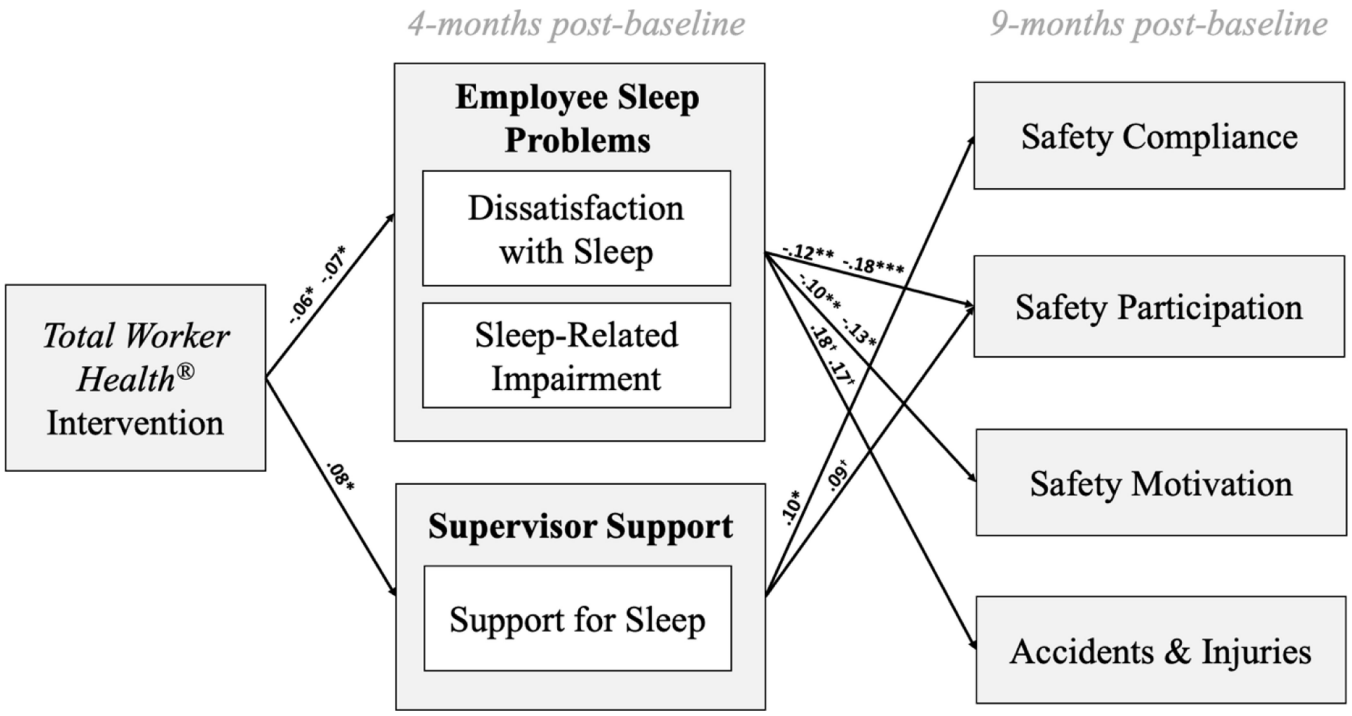

Figure 2.

Empirical results of the significant indirect intervention effects. Control variables (i.e., baseline values of the mediator and outcome variables) are not shown for parsimony. Standardized coefficients from the indirect effect models are provided on the arrows. Coefficients for dissatisfaction with sleep are listed first, followed by sleep-related impairment. †$p < .10$, *$p < .05$, **$p < .01$, *** $p < .001$

Table 1

Descriptives and Correlations Among Study Variables

	N	*M (SD)*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Condition	704	0.51 (0.50)	-																	
2. Sleep Duration (B)	678	7.29 (1.01)	−.01	-																
3. Sleep Duration (4m)	540	7.39 (1.10)	.05	.59**	-															
4. Insomnia Symptoms (B)	686	52.63 (8.20)	−.02	.00	.01	.86														
5. Insomnia Symptoms (4m)	541	51.34 (8.37)	−.05	.01	−.04	.62**	.88													
6. Dissatisfaction w/ Sleep (B)	685	53.98 (7.51)	−.01	−.14**	−.11*	.62**	.47**	.88												
7. Dissatisfaction w/ Sleep (4m)	541	52.78 (8.03)	−.06	−.13**	−.24**	.45**	.62**	.61**	.91											
8. Sleep-Related Impairment (B)	686	53.21 (8.63)	−.02	−.06	−.06	.52**	.38**	.61**	.45**	.91										
9. Sleep-Related Impairment (4m)	542	51.72 (9.14)	−.07	−.02	−.18**	.37**	.52**	.43**	.63**	.61**	.91									
10. Sleep Support (B)	693	2.23 (0.98)	.05	.01	.03	−.13**	−.13**	−.23**	−.13**	−.16**	−.14**	.92								
11. Sleep Support (4m)	567	2.43 (1.00)	.11**	.04	.09*	−.09*	−.09*	−.13**	−.15**	−.06	−.15**	.59**	.94							
12. Safety Compliance (B)	691	4.38 (0.65)	.08*	−.06	.04	−.08*	−.12**	−.08*	−.12**	−.11**	−.15**	.08*	.08	.94						
13. Safety Compliance (9m)	505	4.29 (0.65)	.03	−.07	.00	−.04	−.11*	−.10*	−.16**	−.08	−.19**	.03	.10*	.48**	.95					
14. Safety Participation (B)	687	4.01 (0.77)	.08*	−.02	.06	−.01	−.06	−.04	−.06	−.08*	−.11*	.09*	.14**	.63**	.40**	.88				

	N	*M* (*SD*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
15. Safety Participation (9m)	506	4.02 (0.71)	.03	−.06	.05	−.04	−.13**	−.06	−.15**	−.02	−.17**	.05	.13**	.41****	.73**	.53**	.87			
16. Safety Motivation (B)	689	4.44 (0.59)	.06	−.08*	−.02	−.05	−.12**	−.07	−.11*	−.14**	−.15**	.03	.04	.72**	.48**	.54**	.39**	.88		
17. Safety Motivation (9m)	511	4.33 (0.61)	.02	−.10*	.00	−.01	−.11*	−.04	−.14**	−.06	−.17**	.02	.08	.45**	.81**	.40**	.64**	.55**	.93	
18. Accidents & Injuries (B)	688	0.08 (0.27)	−.02	−.02	.01	.14**	.13**	.13**	.13**	.12**	.09*	−.06	−.03	.01	.00	.02	.00	.08*	.02	-
19. Accidents & Injuries (9m)	510	0.08 (0.27)	.02	−.08	.00	.12**	.12**	.13**	.13**	.11*	.12**	.02	.02	−.06	−.09*	−.02	−.06	−.02	−.07	.27**

Note. The nesting of the participants within clusters is not accounted for in this table. Condition: 0 = control group, 1 = treatment group. B = baseline, 4m = 4 months post-baseline, 9m = 9 months post-baseline. SRI = sleep-related impairment. Alpha reliability coefficients are provided on the diagonal. Insomnia symptoms, dissatisfaction with sleep, and sleep-related impairment measures are based on T scores. The response option for workplace accidents and injuries is on a dichotomous scale (0 = no, 1 = yes).

* $p < .05$

** $p < .01$

Table 2

Intervention Effects Mediated by Employee Sleep and Supervisor Support for Sleep

Indirect Effect	*ab*	*SE*	αβ	95% CI (Lower, Upper)
Employee Sleep Mediators				
Ix → Duration 4m → Safety Compliance 9m	0.004	0.006	0.003	−0.004, 0.022
Ix → Duration 4m → Safety Participation 9m	0.004	0.005	0.003	−0.002, 0.020
Ix →Duration 4m → Safety Motivation 9m	0.007	0.008	0.005	−0.001, 0.030
Ix → Duration 4m → Accidents & Injuries 9m	0.003	0.021	0.002	−0.035, 0.050
Ix → Insomnia 4m → Safety Compliance 9m	0.005	0.006	0.004	−0.003, 0.021
Ix → Insomnia 4m → Safety Participation 9m	0.005	0.005	0.004	−0.003, 0.018
Ix → Insomnia 4m → Safety Motivation 9m	0.005	0.006	0.004	−0.002, 0.020
Ix → Insomnia 4m → Accidents & Injuries 9m	−0.009	0.016	−0.004	−0.065, 0.009
Ix → Dissat 4m → Safety Compliance 9m	0.008	0.008	0.006	0.000, 0.031
Ix → Dissat 4m → Safety Participation 9m	0.010	0.008	0.007	**0.001, 0.030**
Ix → Dissat 4m → Safety Motivation 9m	0.007	0.005	0.006	**0.001, 0.021**
Ix → Dissat 4m → Accidents & Injuries 9m	−0.024	0.017	−0.011	**−0.069, −0.001**
Ix → SRI 4m → Safety Compliance 9m	0.013	0.010	0.010	0.000, 0.043
Ix → SRI 4m → Safety Participation 9m	0.016	0.010	0.011	**0.002, 0.041**
Ix → SRI 4m → Safety Motivation 9m	0.010	0.008	0.009	**0.001, 0.037**
Ix → SRI 4m → Accidents & Injuries 9m	−0.024	0.019	−0.011	**−0.083, −0.001**
Supervisor Support for Sleep Mediator				
Ix → Sleep Supp 4m → Safety Compliance 9m	0.012	0.007	0.009	**0.002, 0.033**
Ix → Sleep Supp 4m → Safety Participation 9m	0.010	0.008	0.007	**0.001, 0.036**
Ix → Sleep Supp 4m →Safety Motivation 9m	0.008	0.009	0.007	−0.002, 0.033
Ix → Sleep Supp 4m → Accidents & Injuries 9m	−0.001	0.024	0.000	−0.053, 0.046

Note. Indirect effects account for nesting within randomized workgroups as well as baseline values of the mediator variables. *ab* = unstandardized indirect effect. *SE* = standard error for the unstandardized effect. αβ = standardized indirect effect. CI = confidence interval for the unstandardized effect. 95% asymmetrical CI obtained from 5,000 bias-corrected bootstrap samples. Ix = intervention condition. Insomnia = insomnia symptoms. Dissat = dissatisfaction with sleep. SRI = sleep-related impairment. Supp = support for sleep. 4m = 4 months post-baseline, 9m = 9 months post-baseline. Bold CI indicates a significant indirect effect.