

Ethical Use of Wearable Device Data in Occupational Settings

Perspectives From the Fire Service

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Objective: Despite interest in using wearable technology to improve firefighter health and safety, there is little evidence on data privacy preferences in the fire service. **Methods:** We conducted interviews and focus groups with career firefighters and fire department and union leaders in Maryland and Virginia and with national-level leaders (March to November 2023). **Results:** We conducted 4 focus groups and 35 interviews (65 participants). Leaders were optimistic about using wearable data to help firefighters obtain benefits, improve safety, conduct prevention, and advance administrative priorities. Firefighters described tradeoffs between safety and autonomy, privacy, and job status. Firefighters opposed using wearables on calls, whereas leadership was supportive. Participants identified implementation barriers and conditions for ethical implementation of wearables. **Conclusions:** Wearable data could protect health and safety but must be utilized in a way that respects autonomy and privacy preferences.

Keywords: occupational health and safety, wearable devices, data privacy, firefighters, autonomy

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LEARNING OUTCOMES

- Fire service leaders were optimistic about using wearable data to protect firefighters.
- Firefighters had concerns about the tradeoffs between using wearables to protect safety and their autonomy, privacy, and job status.
- Firefighters and leaders described similar preferences for how to ethically manage wearable data.

There is growing interest among fire service leaders, government officials, and researchers in deploying wearable technology to reduce firefighter injury and save lives.^{1–4} Firefighters experience high rates of occupational injury and fatality. In the United States in 2023, there were more than 60,000 on-duty injuries and 89 fatalities.^{5,6} Although fires account for only 4% of the overall calls in the fire service, a disproportionate share of firefighter injury and fatality occurs on firegrounds: in 2023, 30% of firefighter injuries and 36% of firefighter fatalities occurred at firegrounds.^{5–7}

Devices worn by individual firefighters could be used to collect large swaths of biometric, exposure, or geographic location data in real time as they respond to incidents. For example, a firefighter responding to a structure fire might wear clothing outfitted with sensors that collect data on his/her heart rate, blood pressure, temperature, respiratory rate, or ergonomics, as well as real-time exposure and location data.^{1–4} An incident commander could use this data to ascertain when firefighters are in distress or reaching short-term exposure limits and make staffing decisions accordingly.¹ Experts also envision using wearable data to inform department health and fitness training programs, to reassess exposure limits, or for research.^{1,2} Data could also be used to facilitate workers' compensation: many states have presumptive benefit laws that designate certain diseases that are presumed to be work-related; these laws are designed to facilitate coverage for these conditions.^{8,9} Firefighters have indicated that filing for coverage under these laws still requires significant documentation of occupational exposures, which a wearable could potentially provide. Appendix A (see Table, SDC, <http://links.lww.com/JOM/B968>) contains examples of wearable devices, associated data, and use cases.

The rise of wearable technologies in occupational settings prompts concerns about privacy and confidentiality.^{1,2} Wearable devices are poised to collect sensitive health information that could be shared with an employer, government entities, or researchers. Some firefighters may be concerned about the general privacy of their information—the extent to which such information is known or used. Others might be more concerned with ensuring that their data are treated confidentially, meaning that their data are handled in accordance with specific constraints on who can access it or how it can be used.^{10–12}

There are few studies that empirically examine data privacy perspectives among fire service members or partners. Studies assessing firefighter acceptance of wearable technology have identified generalized privacy concerns, although their focus is on technology acceptance, not privacy. The general concerns include questions about

who can access firefighter data and the nature of data collected.^{13–15} One study examined the impacts of a biometric device used in training settings on the workplace environment. Firefighters in southwestern fire departments viewed these devices as negatively impacting their identities as firefighters and power in the workplace and did not want to use wearables while responding to calls.¹⁶ Research from other occupational settings suggests that workers are hesitant about sharing biometric information with their employers and that leadership anticipate these concerns but remain optimistic about the benefits of wearables.^{17,18} Although these studies raise important concerns about attitudes toward wearable technology itself, we lack evidence on underlying data privacy preferences and how wearable data should be handled.

There are ethical and practical arguments for understanding firefighters' data privacy preferences. From a normative standpoint, experts examining wearables in occupational settings generally have called for examinations of employee views.^{19–22} Many experts cite the biomedical ethics principles of beneficence, nonmaleficence, respect for autonomy, and justice when describing employers' obligations to minimize safety risks,^{23–25} and some emphasize the need to treat employee health and safety data as confidential as a key component of respecting autonomy.²³ There are also practical reasons for assessing firefighters' privacy preferences. Evidence from other fields shows that workers have historically resisted workplace surveillance, both through formal channels such as union negotiations, and informal channels through which they alter or evade new technologies.^{26,27} If firefighters are concerned about how their employer may use or access their data, they may resist the implementation of wearables, which is already underway.

Our study examined firefighter and fire service leadership perspectives on wearable data. Firefighters and leaders may have distinct preferences about who should have access to potentially sensitive biometric data and how such data should be used. It is essential that we understand firefighter perspectives alongside the views of department and national-level leaders who might wish to utilize wearables and might be responsible for their implementation. Our findings reveal the conditions under which firefighters and leaders view new technology as ethically acceptable and where their views align and diverge.

METHODS

Sample/Recruitment

Our sample consisted of three subgroups: career (or "paid") firefighters, fire department leaders, and national leaders in government, research, and advocacy organizations. We included department-level union leaders in the career firefighter category based on their roles as firefighters advocating for peers in their departments. We sampled career firefighters and department leaders from within the same fire departments. A member of our study team created a validated safety climate assessment for the fire service (Firefighter Organizational Culture of Safety, or FOCUS), which is now used in practice settings.²⁸ We selected departments that had participated in FOCUS, recruiting four departments in total: two in Maryland and two in Virginia.

We worked with a point of contact in each department to invite firefighters to participate in focus groups. Firefighters had to be career rank-and-file firefighters to be eligible. We were unable to recruit participants for a focus group in Maryland and conducted a semistructured interview instead. In departments that were unionized, we invited union leaders to participate in a semistructured interview. To recruit leaders in each department, we worked with our departmental points of contact to invite individuals from overall leadership, health and safety, or human resources to participate in semistructured interviews. For national leadership, we invited individuals from government, research, and advocacy to participate in semistructured interviews. Government participants were current government officials, research participants were active in research on firefighter health or safety, and advocates worked at

national-level third-party organizations that represented fire service stakeholders. These participants were selected using purposeful sampling and snowball sampling.²⁹

Data Collection

We developed semistructured interview and focus group guides for each subgroup that explored views toward wearable technologies and the data they might generate. The guides and topics discussed varied slightly based on each group's unique perspectives. For instance, we asked department and national leaders about their views on how wearable data might impact diversity, equity, and inclusion (DEI) in their departments. We asked leaders, and not firefighters, this question because we anticipated they would have unique insights based on their roles overseeing or accessing organizational data and setting priorities. When discussing wearables in the semistructured interviews, we asked open-ended questions about wearable technology and how wearable data should be collected, used, and shared. For firefighter focus groups, we developed scenarios describing three examples of wearable technology. We opted to use scenarios for these participants in part based on suggestions from the leadership interviews and because we wanted to provide more structured examples for the focus groups to allow sufficient time for a complex discussion among a larger group of participants. For consistency, we also utilized these scenarios in the semistructured interview in Maryland. The scenarios were modeled on examples from the literature and discussions with leaders, and included a mandatory biometric vest that would be used both in real time on a fireground and after the fact for health and safety purposes; a mandatory wearable sensor collecting exposure data on all calls, to be used in real time and after the fact; and a voluntary health and fitness watch, the data from which firefighters could choose to share with the department.^{1,4} Appendices B–F (see interview and focus groups guides in SDC, <http://links.lww.com/JOM/B968>) include high-level discussion topics and questions and an exit survey for collecting focus group participants' demographic information.

We conducted interviews over Zoom and focus groups in person at fire stations. Some focus groups were held while participants were on-duty but out of service (not available to respond to calls), whereas for others, firefighters remained in service. For in-service groups, if some participants received a call, the group was paused until they returned or continued without them, always ensuring that half the group remained for the discussion to continue. We collected data from March to November 2023. The interviewer/moderator drafted memos following each interview/focus group to record initial themes and notes.³⁰ All interviews and focus groups were audio recorded then transcribed verbatim. We obtained oral consent from all participants. This research was approved by the Johns Hopkins Bloomberg School of Public Health Institutional Review Board (no. 24091).

Analysis

We used a thematic analysis approach for qualitative data analysis.³⁰ We began to develop a codebook after partially completing data collection. One team member reviewed the memos and interview/discussion guides and drafted an initial codebook, which was subsequently reviewed and refined by a second team member. These team members conducted two rounds of double coding transcripts (double coding 10% in total). Coders met regularly to compare coding, resolve disagreements, and revise the codebook. The team members then independently coded the remaining transcripts, meeting as needed to discuss questions. The two coders shared codes and initial themes with the full study team periodically. Coding was conducted in Dedoose.³¹

For analysis, we organized participants into two categories: firefighters and leadership. The firefighter category consisted of career firefighters and union representatives, whom we categorized with rank-and-file firefighters because they were active firefighters who also served in leadership in their local union and advocated on behalf

of their members. The leadership category captured department and national leaders. We present our findings primarily in terms of these two groups.

The data collection and analysis described in this article were completed as part of the first author's doctoral dissertation research.³²

RESULTS

Sample

We had a total of 65 participants: 31 career firefighters, 2 union leaders, 11 national leaders, and 21 department leaders (Table 1). Focus groups ranged in size from 5 to 9 participants. The leadership sample was more diverse than the firefighter sample, with a higher share of women (34% vs. 12%) and non-White participants (25% vs. 9%). Firefighters were less experienced and younger than leaders (mean of 12 years of experience vs. 25 years; mean of 35 years of age compared with 48 years). Table 2 shows participant characteristics. On average, focus groups were 77 minutes, firefighter and union leader interviews were 39 minutes, and department and national leadership interviews were 45 minutes.

Themes

We identified nine themes in three categories: (1) benefits of wearable data, (2) tradeoffs accompanying wearable data, and (3) implementation considerations (Table 3). Although firefighters and leaders agreed on some benefits, firefighters expressed concerns about loss of privacy and autonomy and changes in job status. Leadership was optimistic about the benefits outweighing any drawbacks. Participants were most supportive of wearables that would collect exposure data, whereas biometric devices prompted the widest range of views. Despite divergent views on the benefits and tradeoffs of wearables, leaders and firefighters both identified barriers to implementation and described some similar preferences for the ethical use of wearable data.

Benefits of Wearable Data

Participants anticipated a range of positive impacts from the rollout of wearable technology, including facilitating firefighter benefits, ensuring safety on calls, improving prevention activities, and meeting administrative priorities.

Facilitating Benefits

There was nearly unanimous support among all participants for collecting exposure data to help firefighters file presumptive benefit claims. Firefighters were enthusiastic about the exposure wearable, as its data could be used to file workers' compensation claims. Many indicated that they preferred this example over the other two scenarios because it had clear benefits to them and fewer drawbacks. Several characterized exposure data as inherently less personal:

TABLE 1. Participant Roles by Jurisdiction

	Virginia	Maryland	National	Total
Firefighters				
Career FFs	30	1	—	31
Union leaders	1	1	—	2
Leadership				
Department	7	14	—	21
Government	—	—	3	3
Advocacy	—	—	6	6
Research	—	—	2	2
Total	38	16	11	65

TABLE 2. Participant Characteristics by Role

	Firefighters	Leadership
Gender		
Male	29	21
Female	4	11
Race		
White	30	24
Non-White	3	8
Age mean, y	35	48
Experience, mean, y	12	25

One firefighter did not report age. Two leaders did not report years of experience.

Participant 8: *That's fine. Because we're all in the same environment. It'd be all the, you know...*

Participant 3: *Yeah, same—*

Participant 5: *That'd be the one that's going to help us more.*

Many: *Mhmm, yeah.*

Participant 1: *Especially in the long run.*

Participant 5: *If then we could use—to me, that's one. Don't even like de-identify. Make that known and make that identifiable. So that way if one of us gets cancer down the road, they got all this data to pull from.*—Firefighters

In a few instances, leaders and firefighters expressed concern that collecting this information could backfire. Firefighters pointed out that even with robust documentation, workers' compensation might deny their claims, arguing that a firefighter's personal protective equipment should have protected them. Leaders noted that presumptive laws often come with specific eligibility criteria, and if exposure records do not meet these criteria, claims could be denied. However, these participants still supported an exposure wearable, as they believed the benefits would outweigh the risks.

Safety on Calls

When initially asked an open-ended question about the use of wearable technology, department and national leaders suggested and strongly endorsed the use of biometric wearable data in real time when responding to calls, citing the potential to save lives. Several acknowledged that this might entail the collection of sensitive information but believed this was justified. One department leader explained:

I am extremely keen to see [biometric] information operationalized at the street level. And there's two main reasons for that. One I want to be able to know when a firefighter is in distress before they are in distress, or that their vital signs clearly reflect that they are in distress, even if they themselves don't perceive they are, so that I can withdraw them from an IDLH [immediately dangerous to life and health] environment and save their life beforehand. ...And second, I want to prevent other firefighters from dying trying to recover a deceased member.—Department leader 9

Although firefighters acknowledged this lifesaving potential, only a small share supported this use case. Participants in one focus group endorsed using biometric data on calls, highlighting the potentially lifesaving impacts. In another group, participants preferred limited use of wearable data on calls, such as using only location data, which was perceived as less personal and more likely to help in the event that a firefighter was lost in a structure fire. Ultimately, participants in three of the four groups opposed using biometric data on calls, citing tradeoffs described in more detail in the "Tradeoffs Accompanying Wearable Data" theme.

Prevention

Nearly all leadership participants were supportive of using data from a range of wearable devices to improve long-term health and

TABLE 3. Overview of Themes by Participant Group

Themes	Firefighters	Leadership
Benefits		
Facilitating benefits	Firefighters and leadership were optimistic about using wearable exposure data to facilitate benefits.	
Safety on calls	Firefighters saw limited use for biometric wearables on calls.	Leadership strongly endorsed using biometric data to save lives on a fireground.
Prevention	Firefighters saw individual-level prevention benefits such as encouraging healthier habits.	Leadership saw potential for using biometric and health/fitness data to enhance injury prevention efforts.
Advancing administrative priorities	N/A	Some leaders described potential for wearable data to help obtain funding and to advance diversity, equity, and inclusion in the fire service.
Tradeoffs		
Loss of autonomy, privacy	Firefighters expressed serious concerns about the tradeoffs accompanying biometric and health/fitness devices.	Leaders had mild concerns about privacy.
Changes in job status	Firefighters were concerned that biometric and health/fitness wearables could result in job loss, punitive action, or changes in job status if they uncovered health risks.	Leaders anticipated some firefighter pushback but thought this concern could be overcome or was overblown.
Implementation considerations		
Barriers to implementation	Firefighters and leaders raised logistical concerns. Firefighters were skeptical about data subjectivity, and some leaders described cultural challenges.	
Preferences for ethical data collection, use, and sharing	Firefighters called for limiting or preventing the sharing of identifiable data in departments and for access to their own data.	Leaders suggested implementing wearables in limited settings and supported firefighter access to their own data.
Messaging and engagement strategies	Leadership, especially in advocacy organizations, and firefighters emphasized the need for education, trusted messengers, union engagement, and conveying the benefits to firefighters.	

safety. Many were in favor of using individual-level sleep, diet, exercise, exposure, or biometric data to improve individual health and aggregating data to assess risk factors across a department. Participants from all departments as well as advocacy organizations discussed the value of offering firefighters access to their own data from a wearable. Several believed that firefighters had a right to this information and that it might encourage better diet, exercise, or health practices, resulting in a healthier and fitter workforce. Some department leaders were also supportive of using wearables in training environments to track temperature or hydration and prevent injuries.

Some firefighters agreed that health or fitness data could inform individual decision-making. There were mixed views on the benefits of an optional fitness device such as an Apple Watch or FitBit. Approximately half of firefighters indicated they would opt into participating, with most wanting to use the data to inform decisions about their own health or fitness.

Participant 9: *I'm a numbers person. I think in the moment it's just, interesting to see. But aggregate data over a year. When I get back from a call, my heart rate is still pounding for the next 30 minutes. What can I do to drop that before we go to bed? You don't have to use it. And then sleep data would be great too.*

Participant 8: *The sleep data is huge.*

Participant 4: *Like take it to the doctor if there's abnormalities, take it to trainers and say, hey, this is what I want to train for. How I'm adjusting that.*

Participant 3: *My resting pulse over the last year went up 15 beats per minute. I've done everything the same. Why is this trending?—Firefighters*

Most firefighters were comfortable sharing deidentified or aggregated biometric and health data for the purpose of injury or disease prevention, so long as there were appropriate privacy protections in place (described in detail under the “Preferences for Ethical Data Collection, Use, and Sharing” theme below).

Advancing Administrative Priorities

A small number of department leaders described using data from wearables as a tool to justify funding requests. For example, some suggested that data could help illustrate staffing needs at a fire

by showing how firefighters are overtaxed on a fireground. When asked about the potential impact of technology on DEI priorities, leadership held mixed views on whether technology was a helpful, neutral, or harmful tool. Some characterized data as a tool that could be wielded for positive or negative purposes:

Again, data's a double-edged sword. And I always look at data as like statistics. I mean, you can pretty much make your data say what you want it to say if you just kind of manipulate it and twist it and handpick, especially when you handpick parts of the data set, right. ...the data is the tool and it's kind of up to, we can go either way with it.—Department leader 10

Others in government, advocacy, and departments viewed technology as a tool that could be used to advance DEI priorities. For instance, participants thought that having more data on female firefighters could help address gender equity issues. Several explained that the standards for recruitment or recurring fitness examinations are based on male performance and that women are taught techniques designed for male physiology.

NFPA [National Fire Protection Association] recommends 12 METS [metabolic equivalents] as the standard aerobic capacity. That's what they recommend for you to be able to do as a firefighter. But females and males biologically, there's a difference when it comes to oxygen uptake. ...Some of our fittest females are still not hitting 12. So, I would say in that sense, if they could collect data on females and see what their work capacity is at a fire, then they would be able to have like, hey, females should be able to hit maybe 11 METS and then males 12 METS kind of thing. ...I think that women are at a disadvantage if the standard is just a group of White males they collected data on that are in college. Which is typically where all fitness data is collected from.—Department leader 7

Most firefighters did not discuss administrative benefits of wearable data. We did not directly ask firefighters about their views on DEI impacts, and it did not come up during discussions. Some firefighters suggested that wearable data could be used to make a case for hiring staff or increasing funding. Several pointed out that concrete evidence (e.g., on sleep patterns) could show how difficult their jobs are and the negative impacts on their health. There were mixed views on whether such evidence would result in real changes, but several were hopeful that such data could be used positively.

Tradeoffs Accompanying Wearable Data

Discussion of the benefits of wearable technology was closely accompanied by concerns about the tradeoffs that would accompany such devices. Firefighters discussed fears about the loss of autonomy and privacy and changes in job status. In some cases, firefighters viewed these tradeoffs as significant enough that they did not support the use of wearable technology. Leaders anticipated some of these concerns but did not believe they would be widespread.

Loss of Autonomy and Privacy

Many firefighters discussed wearable data in the context of the overall risk calculus inherent to their profession. Several pointed out that there are inherent tradeoffs between maintaining their health and safety and performing core job functions such as fighting fire. Many believed that wearable data would place undue emphasis on the risks of firefighting, undermining firefighters' decisions to accept these risks in order to protect the public. Participants emphasized their commitment to firefighting despite the sacrifices it might require and expressed concern that wearable data would threaten their ability to carry out their responsibilities.

Seems like they always try to take all the risk out of our job. Well, our job is inherently risky anyway. Like we knew that getting into it, we all knew there was a percentage we'd get hurt or maybe even die. Hopefully, that wouldn't happen. But, you know, like the more data and stuff they collect on us sometimes, like the less and less they allow us to do our job, or the harder it is to do our job.—Firefighter

Others viewed a biometric wearable worn on calls as a direct threat to their autonomy on a fireground, inhibiting individual decision-making on-scene. They believed that individuals should be able to make their own decisions about how to operate on a call, such as knowing when he/she needed to come out of a structure fire or spend more time recovering from a taxing incident. Many were concerned that using wearable data to make real-time decisions would inhibit their ability to make decisions and ultimately perform their duties:

Participant 5: *I don't want that. Like if you can use it, if it's going to help somebody down the road. Like if it's data collection we're going to use for the future, that's fine. But don't bring it into where the rubber meets the road because that's where we got to do our job. Like I'd hate to think that a battalion chief—you know, we go to a fire entrapment, and we got a victim in there and the battalion chief is like, "Hey, you got to come out, your heart rate is this." Because I'd say no.*

Participant 3: *Me too.*—Firefighters

Many of these sentiments were related to firefighters' autonomy, whereas others were more privacy-oriented. Firefighters in one group described hesitation about others in the department learning personal information:

Participant 8: *I'd be a little uncomfortable if it was like, oh, [Participant 8] got pulled off the fireground because his blood pressure was 200 over 100. I don't care if these guys [in participant's station] know it, but if the nerds at the [other station] know about it, I don't want them to know about it. [laughter]*—Firefighter

For the majority of firefighters, the loss of privacy and autonomy that would accompany a biometric wearable device was too great to justify its use. Most concluded that they would not support using a wearable on calls because it would interfere with their ability to do their jobs. In some cases, firefighters opposed using biometric devices on calls when it would be shared with leaders in the department, but supported individual use of biometric data from a fitness device (e.g., a personal FitBit). This would allow individual firefighters to benefit from the health information while maintaining their autonomy.

Leaders were attuned to concerns about privacy, and several anticipated pushback against wearables based on general ideological resistance to monitoring. Some anticipated greater concern if the information collected was sensitive (e.g., greater opposition to biometric data collection than exposure data collection) or if data were collected

over a longer time period (e.g., an entire shift). Some leaders preemptively suggested limiting the duration of data collection or the settings in which wearables would be used in an effort to protect firefighter privacy. However, most leaders were not seriously worried about firefighters' privacy and autonomy concerns. Although many acknowledged the validity of firefighter concerns, they stated that their department would not use data inappropriately and thought that firefighters' concerns could be assuaged.

Changes in Job Status

Firefighters' concerns about autonomy and privacy were closely linked to fears about the impact of wearables on their job status. Many believed that biometric data, which might uncover underlying health risks, could be used to fire them.

The more health and safety stuff we do, sometimes it almost gets to the point where they're almost trying to push you out of your job. ... You know, like sometimes I would rather not even know than them to find some little illness that I lose my job over. And I feel like for us as a department, just knowing how we've been, like if they had that data right at hand. God forbid, my heart rate would reach a certain level and they would pull me off the incident or, you know, or would there be repercussions from it?—Firefighter

Several firefighters also worried that biometric or fitness data could be used punitively or could force changes that were not technically punitive but would negatively impact them, such as changes to the shift schedule, station transfers, or delayed promotions.

Participant 8: *If it would be de-identified it would be fine. The issue would be if it wasn't, someone could pick you out. You get punished all of a sudden because...*

Participant 6: *You get nervous. You need remedial training if you get nervous.*

Many: *Yeah, yeah.*

Participant 5: *I can see that. Like held against you promotionally.*—Firefighters

Nearly all leadership participants anticipated some pushback against wearable devices from firefighters. Most believed that a share of firefighters would resist devices collecting health or medical information that could be used to take them off the fire truck, terminate their employment, or simply change the way the job is done. Several participants described firefighting as an identity and framed fears about losing one's job as fear about losing identity as a firefighter or losing the community that comes with being a firefighter.

There's concern among both the career and the volunteer service about how would that data be used? Could I lose my job? In other words, if I had a physiological condition that was identified, could I be taken off the line, where would I work? ... Firefighting is a passion. A lot of firefighters have a passion for that. And they don't want to give it up.—National leader 1

However, most leaders concluded that fears about job repercussions could be overcome. Department leaders stated that they would not use wearable data for punitive or discriminatory purposes and anticipated that a small share of firefighters would oppose wearables. Advocacy participants were more aligned with firefighters, as several expressed hesitation about sharing identifiable firefighter information with department leadership based on concerns about firefighters losing their jobs.

Implementation Considerations

Participants discussed a number of barriers to implementation, citing concerns about logistics, the usability and quality of wearable data, and cultural factors. Both leadership and firefighters articulated specific preferences regarding how new technology should be deployed, including preferences for ethical data collection, use, and sharing, and messaging and engagement strategies.

Barriers to Implementation

Firefighters identified a host of logistical challenges to implementing wearables. In many cases, participants' initial reaction to the wearable scenarios was skepticism about the ease of use or durability. Most wanted to make sure that a wearable would be comfortable and would not delay response times. Several were frustrated by the amount of protective gear that they were already required to wear and were exhausted by the thought of adding an additional item.

Ultimately, some firefighters suggested that wearable data would be impossible to use on a fireground. Many firefighters were skeptical about the objectivity of data and did not think it was reasonable to use quantitative thresholds to make decisions. For instance, several anticipated that it would be unrealistic to pull a firefighter from a structure fire based on a high heart rate or blood pressure:

Participant 4: *No the idea of like, hey, listen, we want to collect all this to know more about what you're doing and how it's impacting you. That's a great idea. But it would be difficult for me because then they would develop a threshold like, okay, your heart rate can't be over 210. If it's over 210, then it's unsafe. But is it 210 because he's working hard or is it 210 because he's nervous?...*

Participant 1: *But like everybody's different. Like we're talking about the parameters of like when to pull someone out would have to be...*

Participant 2: *Very broad. It would have to be because a lot of times we rely on that adrenaline in the fire, it gives us that boost of strength, whatever, that we need. So, the parameters would just have to be very...*

Participant 1: *Extremely high, extremely low.*—Firefighters

Others pointed out that even if data were available on a fire scene, an incident commander is inundated with information, and tactical objectives should take priority. Some anticipated that if an incident commander had access to biometric data and a firefighter experienced an adverse event such as a cardiac event, it would place greater liability on the department.

Several firefighters indicated that it was also unrealistic to use biometric or health data outside of calls, such as for prevention. Some described a history of the fire service in general or their departments failing to act on evidence, suggesting that there was no point to collecting more data if it would not be used. Others expressed the belief that there is sufficient evidence on many health risks. One firefighter questioned the benefit of collecting biometric data to inform health and fitness programs:

I guess what I'm saying is, the changes they're going to want to make from that data you can make without even having the data. Like we know that we need to be in shape. We know that we need to be working out. We know that we need to be getting ready to do our job. So you don't really need the data to push those initiatives because it's a known fact.—Firefighter

Leadership participants described a range of barriers to successfully implementing wearables, largely related to resource limitations and device design and maintenance. Leaders anticipated resource challenges, as wearables would be costly for departments and likely too expensive for small, rural, or volunteer departments. Many department leaders were skeptical that they could obtain funding or persuade local governments to adopt a subscription model, an increasingly common payment model for technology. Leaders shared firefighters' concerns that devices would not be able to stand up to fire conditions and noted the challenges of maintaining existing equipment or getting firefighters to wear bulky devices.

Some leadership participants believed that fire department culture and fire service culture as a whole would hinder the implementation of wearables. Many leaders cited a general resistance to change, especially from older generations of firefighters who liked things the way they had always been done. They anticipated that acceptance of new technology would split on generational lines. One national leader and former firefighter stated:

Since you're diving into the role of the fire service, there are two phrases that you should know. Number one, the fire service is 200 years of tradition unimpeded by progress. Two, the two things the fire service hates the most are change for one and two, the way things have always been. To answer your question, this is where generationally, there's going to be a huge dichotomy.—National leader 3

A few firefighters acknowledged cultural resistance to change but did not raise this as a serious barrier to implementation. Some discussed concerns about negative impacts of wearables on department culture. For instance, in one group, firefighters anticipated negative cultural impacts if a wearable collected sleep data that led to station transfers. Some indicated that firefighters would resist these kinds of changes on the basis that they would be poor for morale, ultimately hindering implementation.

Preferences for Ethical Data Collection, Use, and Sharing

Despite their divergent views on the tradeoffs associated with wearables, firefighters and leaders described similar desired privacy protections for wearable data (Table 4).

Firefighters called for preventing, or at least limiting, access to identifiable data, although they had mixed views on whom such data should be shared with. Firefighters in one group preferred to keep identifiable information within their departments and share only deidentified information with external entities like researchers:

Like if we're doing something for the greater good, that's not a deep dive on me and doesn't identify me personally, then I'd be all for that.—Firefighter

TABLE 4. Conditions for Acceptable Use of Wearable Data Supported by both Firefighters and Leadership

Data Practice or Policy	Overview
Prioritize devices collecting less sensitive but useful data	Collecting exposure data would be helpful to firefighters in obtaining benefits, and few participants saw downsides to collecting this kind of data.
Deidentify data whenever possible	Some firefighters preferred that data not be collected with identifiers. Nearly all participants preferred deidentifying data whenever possible, especially if it would be shared with larger groups of department or national-level leaders.
Conduct high-quality data translation and dissemination	Leadership emphasized the importance of communicating about the purpose of a wearable program and disseminating any aggregated results. Firefighters wanted to understand the purpose of a wearable and be offered interpretation of their own data.
Limit the settings in which a wearable is used	Participants advocated for introducing wearables in limited settings such as during training or recruitment activities or in a pilot program. Some suggested making a wearable voluntary.
Give firefighters access to their own data	Firefighters and leaders emphasized the importance of providing individual firefighters with access to the data that would be collected from a wearable.
Prevent punitive use of wearable data	Participants described the need for protections against the punitive use of wearable data, including explicitly punitive actions like termination, and less apparent actions such as station transfers.

In other groups, firefighters were more comfortable with sharing their data externally and did not want their information accessible to leadership within the department:

I would [be] fine being monitored, but I wouldn't want our department to have it. If it's going out for research or whatever, I'm completely okay with that.—Firefighter

Firefighters also emphasized the importance of having access to their own data for the prevention and benefits use cases described earlier. Several noted that they had a right to access their own data in a timely and easily accessible fashion to use as they wished. A few also expressed a preference for using wearable data during training as opposed to during calls.

Leaders were aligned with firefighters in supporting individual access to one's own data and otherwise limiting access to identifiable information. Some department leaders noted that they would sometimes want to use identifiable data, such as if it was being used to track vital signs on a fireground. However, most indicated that they would limit access on a need-to-know basis, sharing it only with an incident commander or with health and safety personnel. Many supported deidentifying data for research and for reporting aggregated trends within their departments.

Leaders also suggested that wearables be implemented in limited settings. Some favored using wearable data for research as opposed to ongoing departmental priorities. Others would limit data collection to work settings or only during certain work tasks. Several department leaders suggested piloting wearables in training or recruitment settings, where they could be deployed in a controlled environment and preempt concerns about ongoing surveillance:

I think in a training environment, that would probably be the place where we would start with it. ... We see a lot of injuries in recruit school from folks that are just not used to this type of profession. So to be able to monitor that at a closer level, especially during not only our evolutions, but some of our physical fitness training [would be helpful].—Department leader 16

Leaders also emphasized the importance of ensuring that wearable data were used in nonpunitive ways and storing data securely. Most department leaders and advocates suggested making wearables voluntary, at least at the outset, to gain buy-in.

Messaging and Engagement Strategies

Department leaders and advocates emphasized the need for good communication and stakeholder engagement to effectively implement wearables. A department leader explained:

I think we could do a better job of communicating out to the field. I think data would come into [the] health and safety bureau. And then from there they take that aggregate data and they push it out to the field in some format that people can actually look at it and understand it and appreciate it. ... I just think data is no good if you don't share it with people, right?—Department leader 15

Other leaders described the need to gain buy-in from respected leaders such as a local union or to build trust with individual firefighters. Some department and advocacy leaders supported partnering with the international union or nationally prominent figures from major metropolitan fire departments. Participants also emphasized the importance of highlighting the benefits to firefighters, explaining the use cases for the data, and clearly communicating who would have access to the data. A few department and advocacy leaders suggested drawing parallels to existing technology to assuage firefighters' fears.

I think there would be definitely more acceptance if the firefighters knew we were doing it for their protection. It's just like when self-contained breathing apparatus were introduced to the fire service, there was resistance from the old timers, and then now it's the standard. ... So, I think the same thing would be used for the biometric data. Hey, we're using this to protect you, if you get too hot or if the temperature that you're in is too hot, we're going to pull you out

and make recommendations. I think it would be adopted pretty well.—Department leader 19

Firefighters were less focused on communication but emphasized that they wanted to understand the purpose behind collecting wearable data and would need to see positive impacts to support long-term use (e.g., using data to justify increased staffing). One firefighter noted that she expected the union to engage if the department implemented a wearable.

DISCUSSION

Our findings capture enthusiasm about the promise of wearable technology alongside serious hesitations about the use and sharing of wearable data. In line with research in other occupational settings, we discovered that leadership viewed wearables as a powerful tool for saving lives, but that this was coupled with firefighter concerns about their autonomy, privacy, and livelihoods.¹⁸ This dichotomy was most apparent for the use of biometric data in real time on calls. Consistent with a prior study examining a biometric device in the fire service, we found that firefighters were concerned about their autonomy on a fire scene.¹⁶ However, our participants situated their concerns about wearable data in the context of the broader relationship between health and safety and autonomy. Firefighters identified a core tension between doing their jobs, which come with inherent hazards, and mitigating health and safety risks. Participants viewed the tradeoffs that accompany the use of wearable data on this spectrum, in which some participants were willing to take on greater risks to preserve autonomy, and others preferred to emphasize risk mitigation.

Experts have highlighted the importance of respect for worker autonomy in the context of an employer's obligations to provide a safe workplace, including respect for the confidentiality of health and safety data.^{23–25} Although data confidentiality is an important priority that we discuss in detail in the “Preferences for Ethical Data Collection, Use, and Sharing” theme, our findings suggest that respect for firefighter autonomy in this context is complex. The firefighters in our sample emphasized that they had each decided to enter a high-risk occupation and wanted to be afforded the ability to make their own decisions about acceptable risk on a day-to-day basis. Most preferred to maintain their autonomy rather than use a wearable on calls, even if the wearable was designed to protect them, if it was used to override independent judgment.

These findings offer insights on the impact of technology and data on the relationship between worker autonomy and worker safety. There are limited studies examining the confluence of occupational health and safety, autonomy and risk, and data. The occupational health and safety literature suggests that worker autonomy is positively associated with attitudes toward health and safety behaviors and safety outcomes.^{33–35} However, from a data privacy perspective, workplace surveillance negatively impacts worker autonomy.^{27,36} Our findings suggest that there is inherent tension in health and safety technology, in which monitoring workers can improve their safety but infringes on their autonomy. Future efforts to deploy health and safety technology in the fire service should attempt to balance these tradeoffs. Our findings on firefighters' preferred conditions for using wearables, detailed in the “Preferences for Ethical Data Collection, Use, and Sharing” theme, offer initial insights into how this might be carried out.

Our work builds upon the existing literature on wearables in the fire service by identifying specific preferences for how different kinds of wearable data should be used. Participants were more comfortable with wearables that collected exposure data than those collecting biometric or fitness information. Researchers, technology developers, and fire departments should prioritize the development and use of devices that can document exposures. As firefighters pointed out, these data could help them obtain presumptive benefits, and an exposure wearable could be designed to account for the kinds of data that firefighters need to file for benefits. Beyond individual-level benefits, exposure

data could be used to expand our understanding of the occupational hazards that firefighters encounter and to evaluate exposure limits.

Participants also shed light on the conditions under which wearable data could be ethically utilized, describing the need for limiting the settings in which wearables were deployed and developing restrictions on how wearable data could be used or shared. In line with previous studies, participants suggested that departments should try deploying biometric devices in limited settings such as in training or during recruitment or fire academy activities.^{16,17,37} Collecting biometric data in training environments might prevent injury and fatality without threatening firefighters' autonomy on a fire scene or ability to provide services. In general, leadership participants favored making any wearable program voluntary, at least initially, to gain trust and buy-in from their staff. This aligns with research in other sectors, which indicates that both employers and employees prefer voluntary wearable programs.^{17,37} Offering wearables as voluntary measures might help build confidence in the benefits of technology while respecting individual firefighters' privacy preferences.

To our knowledge, our study is the first to assess firefighters' preferred data privacy protections for health and safety data derived from a wearable device. Many participants emphasized the need to deidentify firefighter data, prevent punitive use of data, and share personal data with individual firefighters. Even though firefighters did not reach consensus on who they thought should have access to their information, there was strong support for deidentifying and aggregating firefighter data if it was going to be used by fire department health and safety staff or researchers. Although there is very little research on empirical data preferences in occupational health and safety settings, these findings align with prescriptive suggestions found in the normative literature on data privacy in occupational settings.^{19–21,23,26,36} In future instances where firefighter data might be reported to government agencies or researchers or used by department leaders, it should be deidentified as much as possible. Completely deidentifying a dataset is a complex task, and more work may be needed to determine the feasibility of truly deidentifying or anonymizing firefighter datasets. However, departments and researchers could make efforts to aggregate data and remove identifiers such as names, job titles, age, and station and shift assignments to begin this process.

Our findings also reflect a need to ensure that the collection and use of firefighter data are accompanied by safeguards to prevent retaliation or discrimination. Firefighters raised concerns about explicitly punitive actions, such as termination, as well as less overtly negative consequences such as station transfers. These concerns echo those surrounding workplace wellness programs, in which employees fear that their decisions to disclose health information (or not) will be penalized.^{26,38,39} Departments or researchers utilizing wearables should ensure that they are accompanied by policies that clearly define how data will be used (e.g., only for safety purposes) or prohibit punitive use cases. In unionized departments, the union can play a role in negotiating for these protections. Union contracts in Maryland and Virginia contain a range of provisions related to data privacy; some do not address data privacy considerations at all, whereas others authorize general surveillance for health and safety purposes.³² Going forward, unions may wish to negotiate specific limits on when wearables could be used and prohibitions on using data punitively or sharing identifiable data.

Firefighters also indicated that if they are asked to share personal information, they should receive access to their data along with interpretation of the data both on an individual and population level. Sharing the findings from a wearable program or study could help ensure the ethical rollout of a device and bolster trust in wearables. As is well-described in the literature addressing incidental and collateral findings from research, this kind of communication could be challenging if a wearable identifies a serious underlying medical condition or incidental findings.^{40,41} If the device identifies clinically actionable results, issues pertaining to follow-up care responsibilities might also arise.⁴² There is some evidence that workers in other sectors want

medically significant information from a wearable,⁴³ but more research is needed to determine appropriate guidelines for returning these kinds of results to workers, especially if they vary in terms of actionability.

Collectively, participants' preferred conditions for the collection, use, and sharing of wearable data offer insights on the parameters that might constitute confidential treatment of firefighter health and safety data. The confidentiality of health or medical information is typically discussed in the context of a provider-patient relationship or in a research context, in which a patient or a research subject expects that his/her information will be used or shared only in authorized ways.¹² There is some professional guidance for occupational health and safety professionals requiring that they maintain the general confidentiality of employee information, but few specifics on what confidentiality means.^{44–46} In addition, not all employer representatives who might access firefighter data are health or safety professionals or medical professionals and may not be bound by professional codes of conduct. Whereas some of our participants' preferences address larger questions related to data privacy (e.g., whether wearables data should be used on a fire call), others reveal what confidential use of data might entail (e.g., providing researchers access to deidentified data to use for injury prevention). Future research should further unpack the factors that constitute confidentiality in an occupational context.

Finally, in addition to these normative preferences, participants highlighted a number of structural or logistical challenges to implementing wearables. Departments or jurisdictions will need to consider how to fund new technology, which might require new funding models for subscription services, negotiations with technology companies over data storage and ownership, and obtaining funds. Participants also raised concerns about the wearability and durability of wearable devices in the context of the fireground and the demanding environments in which they work. Although not the primary focus of this study, these logistical challenges may pose major hurdles to implementing new technology in the fire service and merit additional consideration.

Our study has limitations. We spoke with a small number of firefighters in Maryland compared with Virginia due to low recruitment rates, which we attribute to an overworked and understaffed workforce, survey fatigue, and scheduling challenges. Although we did not find differences across states, speaking with more Maryland firefighters may have revealed a wider range of opinions. Our sample was largely White and male, in line with the overall demographics of the fire service. Women in our sample identified opportunities for data to advance gender equity, but evidence from other occupational settings suggests that women are less likely to support workplace surveillance than men.^{17,47} We did not discover differences based on race, but a large body of work has established the ways in which technology is often not designed for or accessible to racial minorities and how data are often used in discriminatory fashion.^{48,49} Although we did gain some insights on the perspectives of underrepresented minorities, future research should focus on further unpacking their preferences. We did not ask firefighters about their views on how wearable data might impact DEI priorities, which should be explored in future studies. Future research should also examine this topic among a wider range of fire departments to assess views across geographic locations and department cultures. The wearable technology scenarios varied in terms of the type of technology and voluntariness. Our findings captured participants' expressed views but might differ from actual preferences in a practice setting. Future research should systematically unpack the factors associated with willingness to participate in a wearable intervention, such as the type of device, kind of data collected, or data access provisions.

CONCLUSION

Firefighters and fire service leaders are optimistic about using wearable technology to document firefighter exposures, but expressed diverging views on the acceptability of using biometric data in real

time on calls. Participants characterized their preferences in terms of the tradeoffs accompanying wearable data, which could be used to save lives and bolster health and safety, but also threaten firefighter autonomy, privacy, and job status. Despite this disagreement, firefighters and leaders discussed specific conditions under which they would support wearables, including using biometric data in limited settings or in voluntary programs, limiting access to identifiable data, prohibiting punitive use of wearable data, and ensuring high-quality communication about firefighters' data.

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