National Safety Council

MSD Solutions Lab
an nsc program

Frontline Worker Perceptions of MSD Prevention Technology

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Executive Summary

Musculoskeletal disorders (MSDs) are one of the most persistent and costly workplace injuries despite growing investment in technologies intended to reduce physical risk. Consequently, understanding how technology adoption and worker perceptions interact is essential to turning technological innovation from promise into measurable reductions in MSDs. To better understand how these technologies are experienced by the workers who use them, the MSD Solutions Lab conducted a survey of 405 frontline employees across sectors, including high-risk industries such as manufacturing, construction, health care and transportation and warehousing, who have used at least one MSD prevention technology in their current roles.

This report presents a worker-centered examination of MSD prevention technologies, including wearable sensors, computer vision, exoskeletons, robots and collaborative robots (cobots), extended reality, and digital twins. Findings offer insight into how these tools influence physical strain, mental stress, ergonomic awareness and job satisfaction – factors that ultimately shape adoption, effectiveness and long-term sustainability. Our findings confirm that frontline workers continue to experience significant physical and mental burden, emphasizing the urgency for effective prevention solutions. Across all technology types, respondents largely viewed these solutions as beneficial, reporting enhanced job satisfaction, improved posture, reduced concern about workplace injury and neutral to positive effects on mental stress. Technologies that directly reduce physical workload, such as exoskeletons, robots and cobots, were perceived to provide the greatest physical benefits. Importantly, the perceived value of technology was positively correlated with more participatory approaches to implementation when workers were involved in the process.

Introduction

Technologies are increasingly embedded across workplace safety, health and injury prevention efforts, reshaping how organizations identify, assess and mitigate a wide range of occupational risks (Brancati, 2024; Gonzalez Vazquez et al., 2024; Trask & Linderoth, 2023). Within this broader shift toward technology, the prevention of work-related musculoskeletal disorders (MSDs) has emerged as a major area of focus (Iyer et al., 2025).

MSDs are consistently among the most prevalent and costly workplace injuries. Despite substantial investment in safety technologies over the past decade, U.S. organizations still lose $1 billion per week to MSDs and other workplace injuries (Liberty Mutual Insurance, 2025). In response, employers are increasingly adopting MSD prevention technologies aimed at measuring physical risk exposure, modifying work demands and supporting workers during physically demanding tasks. These tools are often positioned as scalable, data-driven solutions that can supplement or enhance traditional ergonomic approaches. This is supported by current evidence indicating that wearable sensors and **Industry 4.0** technologies can deliver measurable reductions in injuries while improving productivity and return on investment when deployed effectively, largely through real-time sensing, AI-enabled risk detection, and digital training and design tools (Naranjo et al., 2025).

The persistent MSD burden emphasizes the need to look beyond injury outcomes and examine how workers actually perceive, adopt and engage with prevention solutions in real work settings. Understanding the interplay between workplace injuries, technology use and worker perceptions is critical to closing the gap between the promise of technology innovations and their demonstrated effectiveness in reducing the ongoing MSD-related injury burden. A **growing ecosystem of technologies** and innovations is now being used for MSD prevention across industries.

Wearable Sensors

Wearable sensors are used to collect data on workers' movements, postures and physical exertion during job tasks. These devices may be worn on the back, arms, wrists, hips or other body locations and can capture information such as joint angles, movement frequency and duration of exertion. Some systems provide real-time feedback when potentially hazardous movements occur, while others aggregate data for later analysis. In the context of MSD prevention, wearable sensors are intended to help identify high-risk tasks, support ergonomic assessments, and increase awareness of movement patterns that may contribute to discomfort or injury over time.

Computer Vision

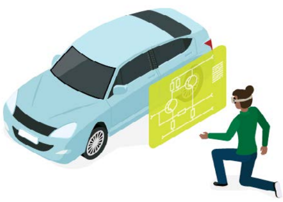
Computer vision technologies use cameras and software algorithms to analyze images or video of workers performing job tasks. By estimating body positions and movements, these systems can identify ergonomic risk factors such as awkward postures, repetitive motions or sustained static positions. Computer vision is often promoted as a scalable approach to ergonomic risk assessment, as it can be deployed without requiring workers to wear additional equipment. For MSD prevention, these tools are used to prioritize high-risk tasks, inform workstation redesign and support data-driven decision making related to ergonomic interventions.

Exoskeletons

Exoskeletons are wearable devices designed to support the body and reduce physical strain during physically demanding tasks. Passive exoskeletons use mechanical structures such as springs or elastic elements to redistribute loads, while powered exoskeletons incorporate motors or actuators to actively assist movement. These devices are typically used during tasks involving lifting, overhead work or sustained postures. In MSD prevention efforts, exoskeletons are intended to reduce muscle fatigue and biomechanical load, particularly when engineering or elimination controls are not feasible.

Robots or Cobots

Robots and collaborative robots (cobots) are used to automate or assist with tasks that involve repetitive motion, heavy lifting or forceful exertion. Unlike traditional industrial robots that operate separately from workers, cobots are designed to work alongside people, often sharing tasks within the same workspace. In MSD prevention, these technologies aim to reduce worker exposure to high-risk physical demands by partially or fully transferring strenuous tasks to machines. Their use can change the physical nature of work, shifting workers' roles from manual execution to monitoring or guiding automated systems.



Extended, Augmented or Virtual Reality

Extended reality (XR) encompasses virtual reality, augmented reality and mixed reality technologies that create immersive or digitally enhanced environments. These tools are commonly used for training, task simulation and workstation design. In MSD prevention, XR technologies allow workers and organizations to practice tasks, evaluate ergonomic risks or visualize work processes without real-world physical exposure. By simulating job demands and movements, XR can support safer training, ergonomic design decisions and early identification of potential MSD risks.

Digital Twins

Digital twins are virtual representations of physical systems, processes or workplaces that are continuously updated using real-world data. By integrating information from sensors, equipment and work processes, digital twins can model how tasks are performed and how changes to workflows or workstation design may affect physical demands. In MSD prevention, digital twins are used to simulate job tasks, predict ergonomic risks and evaluate potential interventions before they are implemented in the physical workplace. This approach supports proactive risk identification and informed decision making during system design and redesign.

Objective

Previous work, including the MSD Solutions Lab **report on emerging technologies for MSD prevention**, has documented these technologies, their intended applications, and implementation experiences from employers and solution providers. That work has helped clarify the rapidly evolving technology landscape and highlighted both opportunities and challenges associated with adoption.

However, much of the existing evidence in the emerging technology space has focused on organizational decision makers, technology developers or pilot outcomes, with comparatively limited attention to the perspectives of frontline workers who directly interact with these technologies in their daily work. A recent review found that technologies can substantially improve occupational safety and health in high-risk industries, such as construction, mining, transportation, manufacturing, logging, and oil and gas, but widespread adoption is constrained by technical, behavioral and organizational barriers. These barriers included privacy concerns, resistance to change and misalignment with existing systems (Doodo et al., 2024), supporting the idea that understanding worker perspectives is critical to the success of technology-based MSD prevention efforts. Similarly, Jacobs et al. (2019) found that employee acceptance of wearable technology is driven by perceived safety benefits, organizational safety climate and worker involvement in implementation, emphasizing the importance of employee participation in device selection and transparency in data use. Findings from a previous **MSD Solutions Lab survey of 1,000 nonmanagerial workers** show that **participatory ergonomics** practices, defined by worker involvement in decision making, are consistently linked to more positive perceptions of organizational MSD prevention and increased openness to prevention technologies.

Frontline workers are uniquely positioned to assess how technologies affect their physical comfort, fatigue, pain and overall wellbeing, as well as how these tools influence job satisfaction, trust and day-to-day work practices. Their experiences can reveal unintended consequences, barriers to use and contextual factors that may not be visible through injury metrics or productivity measures alone. Moreover, frontline workers can provide valuable feedback on usability, acceptability and perceived effectiveness – insights that are essential for refining interventions, improving implementation and ensuring technologies support, rather than undermine, human-centered safety goals.

This current report addresses a key gap by examining frontline worker experiences with emerging technologies for MSD prevention. It presents findings from a survey of nonmanagerial workers who have used at least one of the following technologies to prevent MSDs: wearable sensors, computer vision systems, exoskeletons, robots or cobots, XR, or digital twins. The survey explores workers' perceptions of how these technologies impacted signs and symptoms of MSDs, their perceived usefulness, and their effects on wellbeing and job satisfaction. By centering the voices of workers most directly affected by technology adoption, this report aims to complement existing employer- and technology-focused research by the MSD Solutions Lab and others and inform more effective, participatory approaches to MSD prevention.

Methodology

Materials and Measures

Survey items were designed to capture experiences and attitudes toward MSD prevention technologies among frontline workers. The survey included multiple subsections addressing key focus areas:

1. General MSD Risks and Symptoms
2. Technology Use and Utility
3. Impact on Wellbeing and Job Satisfaction
4. Organizational Support and Training

Survey items were developed by the MSD Solutions Lab, reviewed by subject matter experts and iteratively refined to produce the final questionnaire. Questions included multiple-choice, yes/no, Likert-scale and open-ended formats. Screening questions ensured eligibility based on job role and technology use. The final survey contained 33 items, plus demographic questions. Informed consent was obtained electronically prior to participation.

Participants

A total of 405 respondents completed the survey. Eligibility criteria included:

- Being at least 18 years old
- Employment in a nonmanagerial, non-director role
- Personal experience using MSD prevention technology in their current role

Industries with high MSD risk (e.g., manufacturing, warehousing, construction, health care, transportation) were prioritized during recruitment, though participation was not restricted by industry.

Procedure and Data Collection

The survey was administered online by a third party. Invitations were distributed via email and platform notifications. Screening questions determined eligibility, and respondents who did not meet criteria were removed from the sample. Data collection was conducted between September 16 and September 30, 2025.

Data Analysis

After survey closure, data were reviewed for completeness and cleaned for analysis. Analyses were conducted using Statistical Package for the Social Sciences version 30 (SPSS, Chicago, IL). Descriptive statistics summarized demographic characteristics and technology usage patterns. Pearson correlations examined relationships among perceptions of technology utility and safety culture indicators. Chi-square tests and Z-tests assessed the statistical significance of differences across technology types and demographic subgroups. A significance level of $\alpha = .05$ was used for all statistical tests.

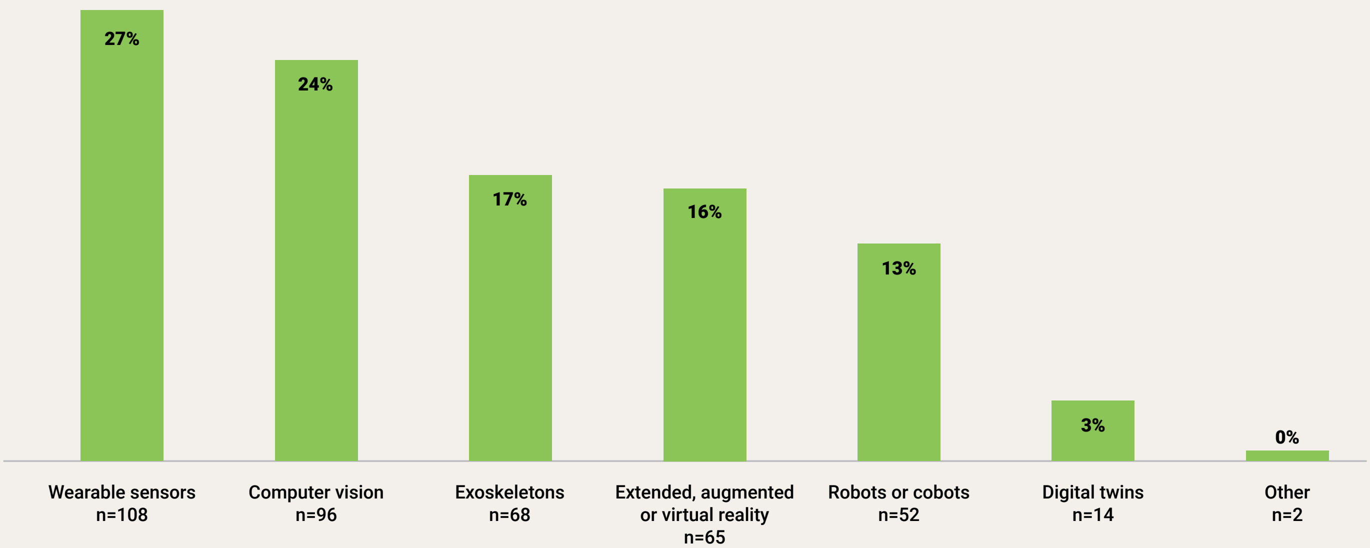
Respondents were asked to select the type of MSD prevention technology with which they had the most experience (wearable sensors, exoskeletons, robots or cobots, computer vision, extended, augmented or virtual reality, digital twins), and subsequent questions relating to their direct experience utilizing technology were answered in reference to that specific technology. Two respondents selected “other” and specified that their experiences were with automatic patient lifts and ceiling lift or transfer devices. These respondents were included in all overall analyses but were excluded from any analyses that compared results across specific technology types.

Results

Description of Final Dataset and Demographics

The final sample included 405 frontline workers who completed the survey. All respondents provided information on MSD experiences and technology use, with subsets of respondents contributing to technology-specific analyses based on their reported experience. Wearable sensors and computer vision systems were the most commonly used technologies, while digital twins were used infrequently (Figure 1).

Figure 1. *Most Utilized Technology Types for MSD Prevention in Current Work Role Among Respondents*

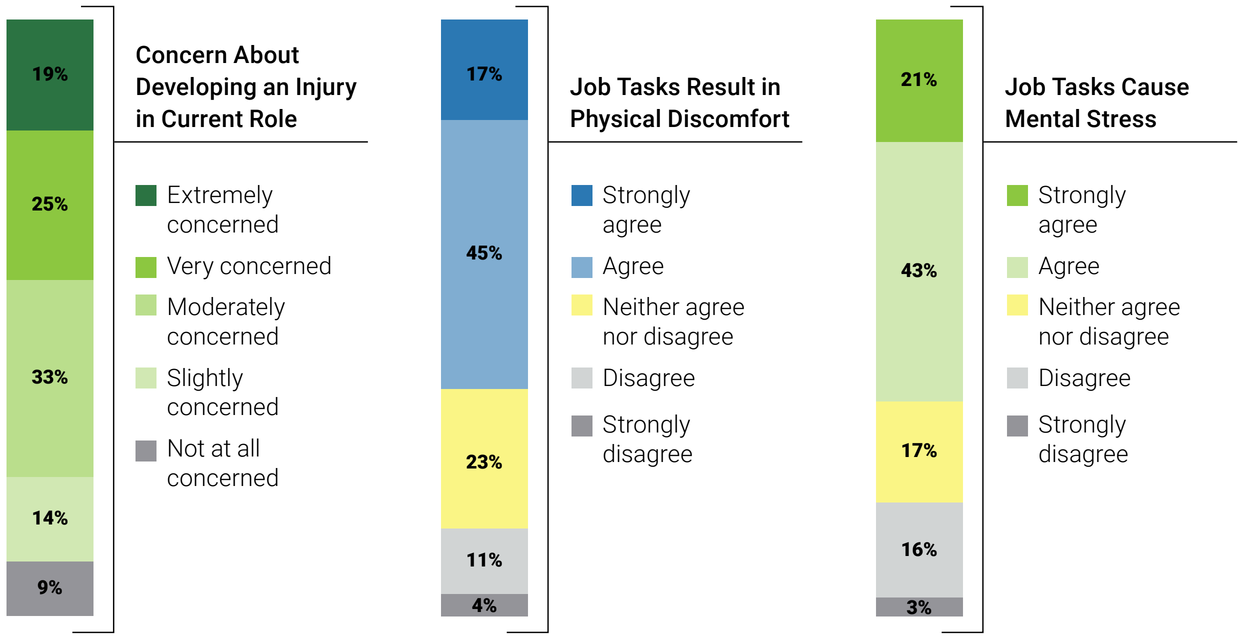


Participants worked across a wide range of job roles, with the largest groups employed in skilled or manual labor and health care. Industry representation was similarly diverse, spanning construction, manufacturing, health care and social assistance, transportation and warehousing, retail, and numerous other sectors. The sample included a nearly even distribution of men and women. About half of the respondents were between 18 and 40 years old, and education levels ranged from less than high school to advanced graduate degrees, with the majority reporting at least some college experience. Tenure in current positions varied as well, though most had been in their roles between three and nine years. Detailed demographic breakdowns and percentages for all categories are provided in the Appendix.

Risk Perceptions and MSD Experience

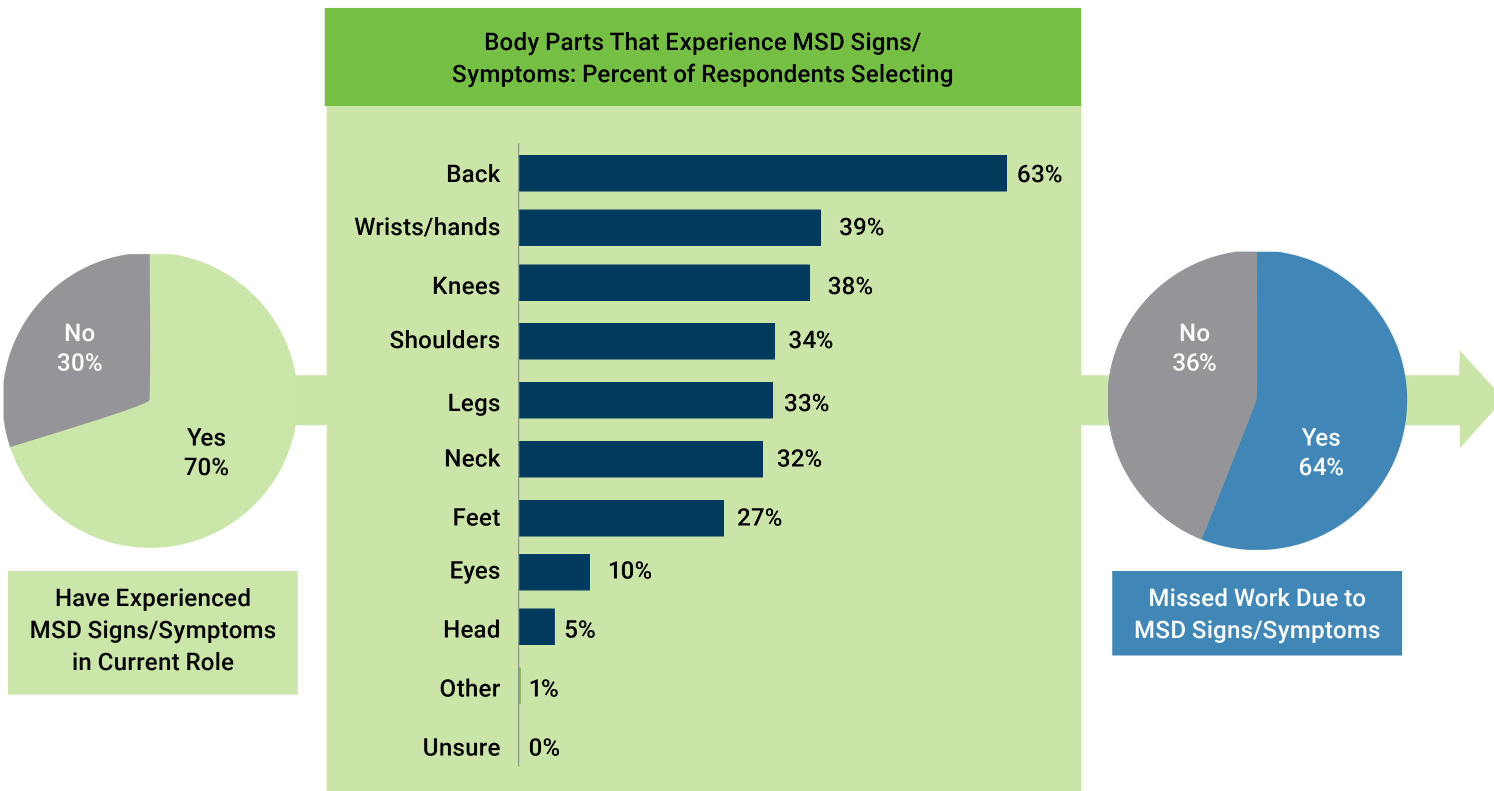
Overall, respondents reported substantial workplace safety burdens: 77% were at least moderately concerned about injury, 62% agreed their tasks cause physical discomfort, and 64% agreed their tasks cause mental stress (Figure 2). Concern about injury differed by gender, with men reporting higher levels of concern ($\chi^2 = 14.98$, $p < .01$). Age showed small but significant negative correlations with injury concern ($r = -.12$, $p < .05$), physical discomfort ($r = -.16$, $p < .001$) and mental stress ($r = -.15$, $p < .01$), indicating younger workers reported higher levels of all three issues in their roles.

Figure 2. *Levels of Injury Concern and Perceived Impact of Job Tasks on Discomfort and Stress*



Respondents were provided with a definition of work-related MSDs (i.e., injuries or disorders of the muscles, nerves, tendons, joints, cartilage and spinal discs that develop or worsen over time due to work conditions), along with examples of common signs and symptoms (i.e., pain, tenderness, swelling, redness, burning, cramping, stiffness, loss of strength, reduced range of motion, tingling, numbness). Seventy percent of respondents (n = 283) reported experiencing MSD-related signs or symptoms in their current roles; however, that includes 16% (n = 63) of respondents who were unsure whether these symptoms were work-related or attributable to non-work activities. Among those who identified their symptoms as work-related, men were significantly more likely than women to report experiencing them (61% versus 47%, $p < .05$). Among those who reported symptoms (work-related or not), 64% had missed work due to these issues. In terms of body region, the back was the most frequently affected, followed by the wrists, knees, shoulders, legs and neck (Figure 3). Workers aged 55 and older were more likely to report symptoms affecting the back and wrists/hands ($p < .05$). Additionally, individuals who reported symptoms in their legs or their feet had significantly higher odds (1.9 and 1.8 times, respectively) of having missed work due to MSDs compared to those who reported experiencing the symptoms in other body parts.

Figure 3. *Prevalence of MSD Signs and Symptoms among Respondents, Affected Body Regions and Work Absences*



Technology Perceptions

Most respondents expressed at least some concern about both data privacy when using new technologies at work and the influence of technology or artificial intelligence (AI) on their work activities (Figure 4). Education level showed small but significant positive correlations with both privacy concerns ($r = .17$, $p < .001$) and concerns about technology or AI influencing work ($r = .16$, $p < .01$), indicating that respondents with higher education tend to report slightly greater concern. It is promising, however, that about 80% of respondents reported being comfortable addressing concerns about technology use with their organizations' leadership (Figure 5).

Figure 4. *Concerns About Data Privacy and Technology Influence at Work*

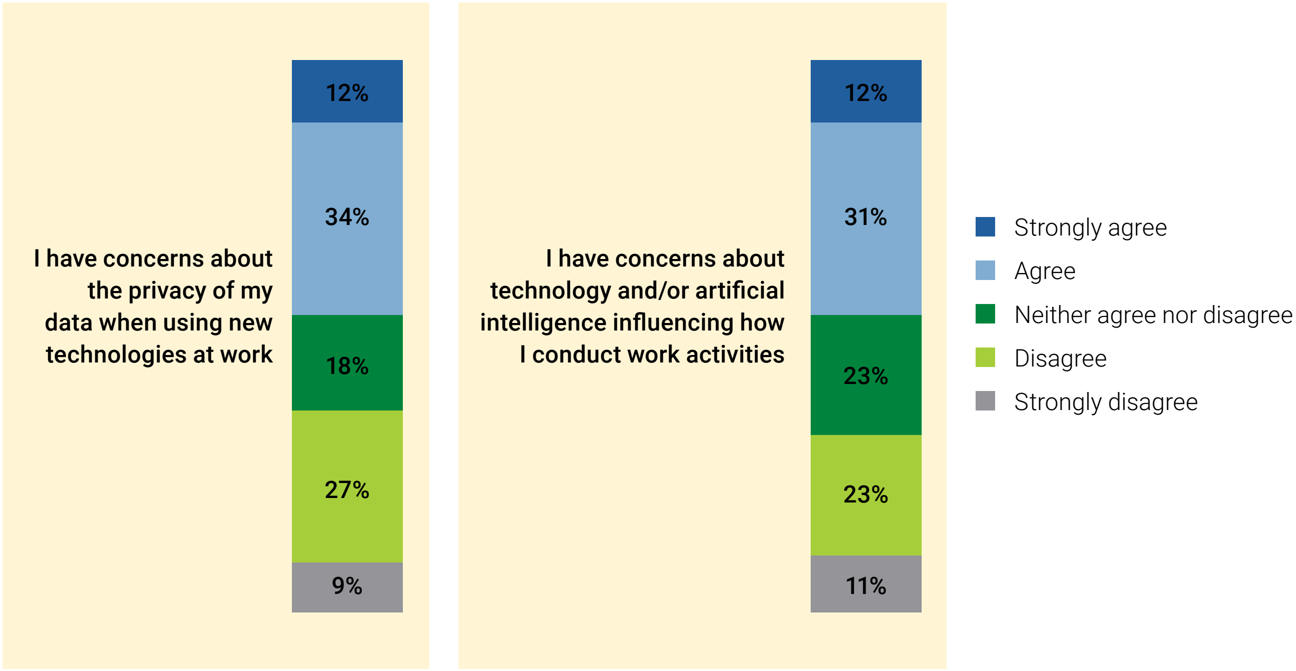
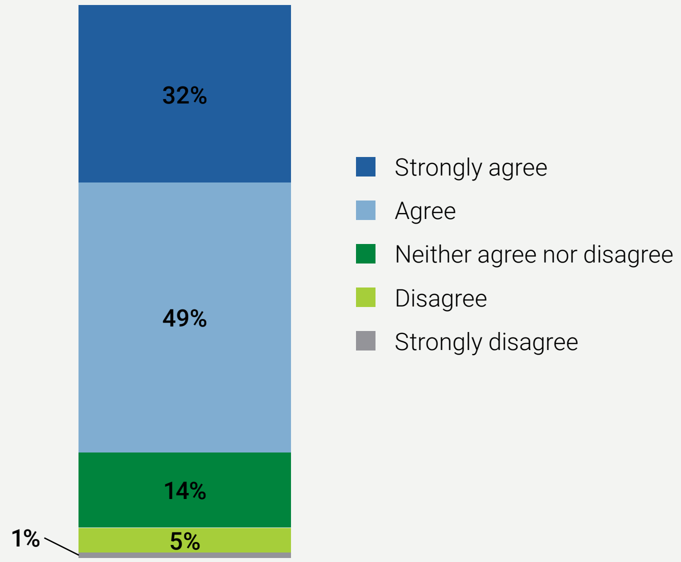


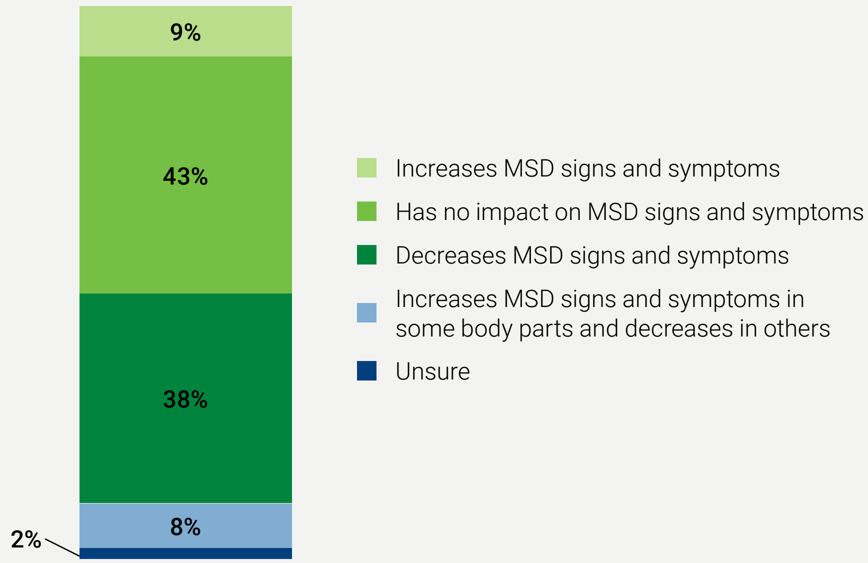
Figure 5. *Level of Agreement Among Respondents That They Are Comfortable Bringing Up Concerns About Technology Use to Their Organizations' Leadership*



Experience With MSD Prevention Technology

Respondents generally reported positive experiences with their organizations' use of MSD prevention technology. Across respondents, only about 17% reported an increase in MSD symptoms associated with MSD prevention technology use, with approximately 8% noting concurrent symptom increases in some body parts and decreases in others. Respondents aged 18 – 40 were significantly more likely than those aged 41 – 54 and those 55 and older to report that the technology increases MSD signs and symptoms (13% versus 5% and 3%, respectively; $\chi^2 = 16.21$, $p < .05$);[1] however the vast majority of participants (81%) reported that the technology only decreases MSD symptoms or has no impact (Figure 6)[2].

Figure 6. *Perceived Impact of MSD Prevention Technology*



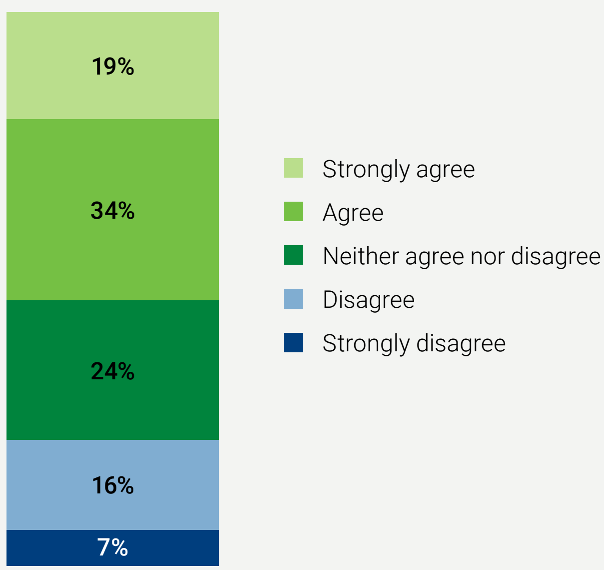
[1]Note there are some cell sizes of < 5 in 55 or older category

[2]The "Had no impact" category included respondents who were not asked this question because they previously indicated they had not experienced any MSD signs or symptoms in their current roles. Because all respondents had used MSD prevention technology as part of the eligibility criteria for the survey, individuals without symptoms were reasonably assumed to have experienced no impact – positive or negative – of the technology on MSD symptoms.

Training was viewed favorably, with 85% reporting they received adequate instruction on how to properly utilize the technology, 83% agreeing they had opportunities to practice using the technology and provide feedback, and 83% feeling comfortable suggesting improvements. Perceptions of involvement in decision making were somewhat more mixed, with just over half agreeing they played a role in decisions around their organizations' use of MSD prevention technology (Figure 7).

Greater participation within organizational environments, where workers feel comfortable speaking up, suggesting improvements, participating in decision making and providing feedback on technology, was associated with increasingly positive perceptions of MSD prevention technologies (correlation table in the Appendix). These factors associated with participatory environments were moderately correlated with agreement that the technology reduces concern about injury (r = .28–.27, $p < .001$), increases awareness of ergonomic risk factors (r = .22–.35, $p < .001$) and improves posture at work (r = .25–.34, $p < .001$). Participatory environments were also associated with lower perceived mental stress related to technology use (r = −.11 to −.21, $p < .05$) and higher overall job satisfaction (r = .21–.25, $p < .001$). Notably, women perceived themselves to be less involved in their organizations' decision making around technology use than men (58% of men versus 47% of women agreed they are involved, while 18% of men versus 28% of women disagreed; $p < .05$).

Figure 7. *Level of Agreement Among Respondents That They Are Involved in Decision Making Around Their Organizations' Use of Technology*



Findings by Technology Type

Across technology types, distinct patterns were reported in perceived impact on MSD signs and symptoms, psychosocial outcomes, and awareness of ergonomic risk factors such as forceful exertions, repetition and awkward postures. Perceived impact on MSD signs and symptoms differed significantly by technology type ($\chi^2 = 48.71$, $p < .01$). Technologies that provided direct physical assistance (exoskeletons and robots/cobots) were most likely to be perceived as decreasing MSD signs and symptoms, whereas computer vision and wearable sensors were most commonly perceived as having no impact (Figure 8). Perceived increased ergonomic risk awareness was high across all technologies, though there were some significant differences across technology type ($\chi^2 = 23.42$, $p < .05$). Exoskeletons, digital twins and wearable sensors were especially likely to increase awareness (over 90% agreement), though computer vision, XR technologies, and robots and cobots also showed strong perceived impact (Figure 9). Across all technology types, the majority of respondents indicated that the technology has a positive impact on job satisfaction (Figure 10), has either a positive or neutral impact on mental stress (Figure 11), improves posture (Figure 12), and decreases injury concern at work (Figure 13).

Figure 8. *Perceived Impact of MSD Prevention Technologies on MSD Signs and Symptoms*

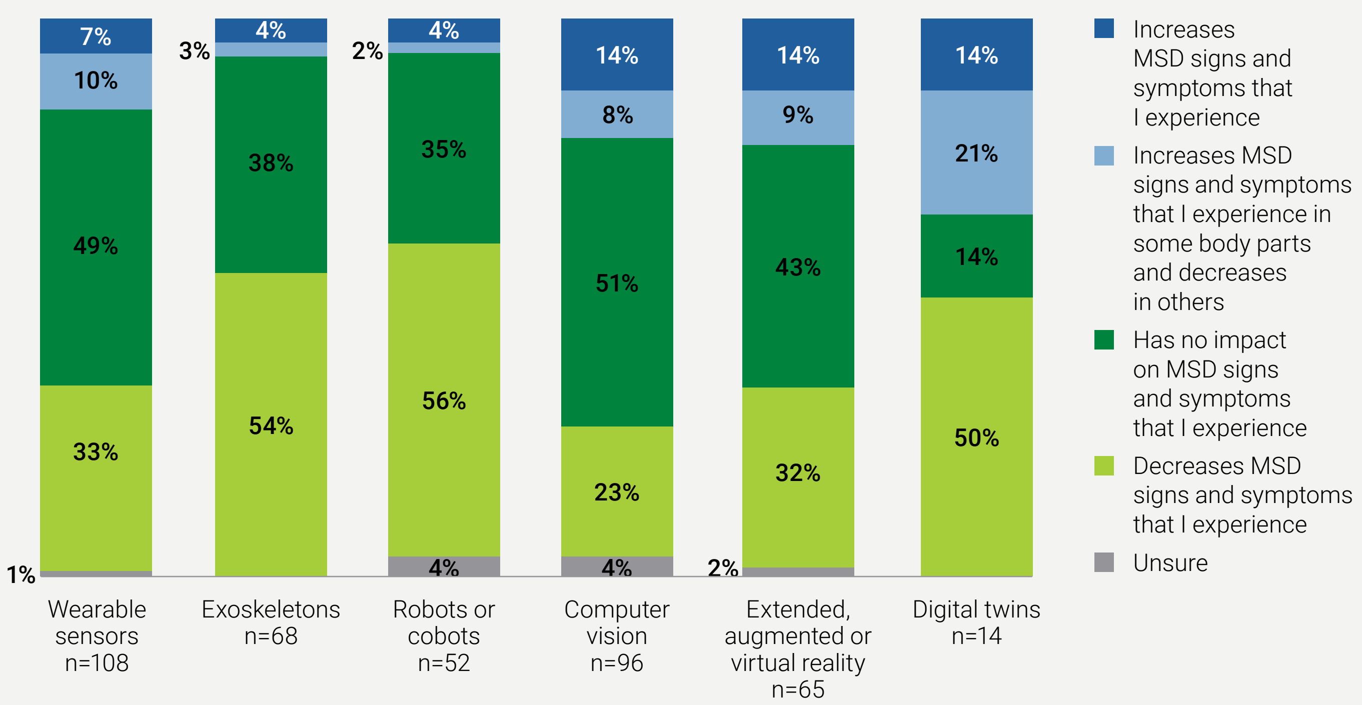


Figure 9. *Level of Agreement That MSD Prevention Technologies Made Respondents More Aware of Ergonomic Risk Factors Such as Forceful Exertions, Repetition and Awkward Postures*

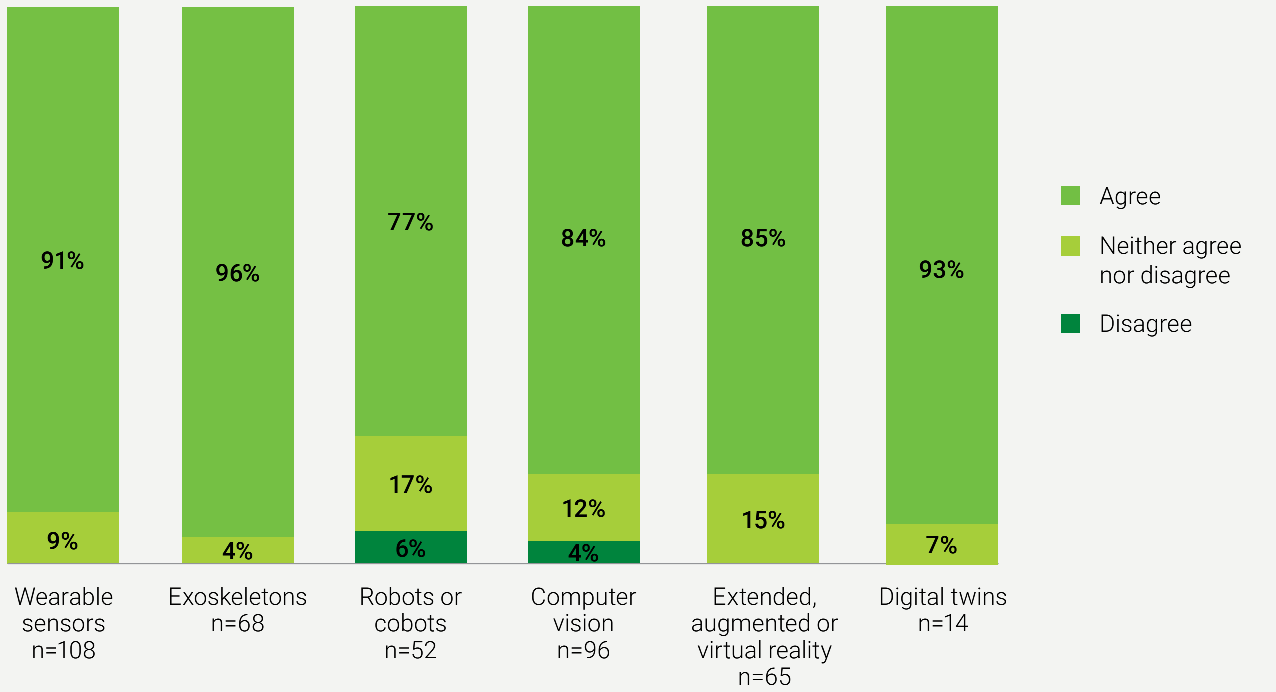


Figure 10. *Perceived Impact of MSD Prevention Technologies on Mental Stress*

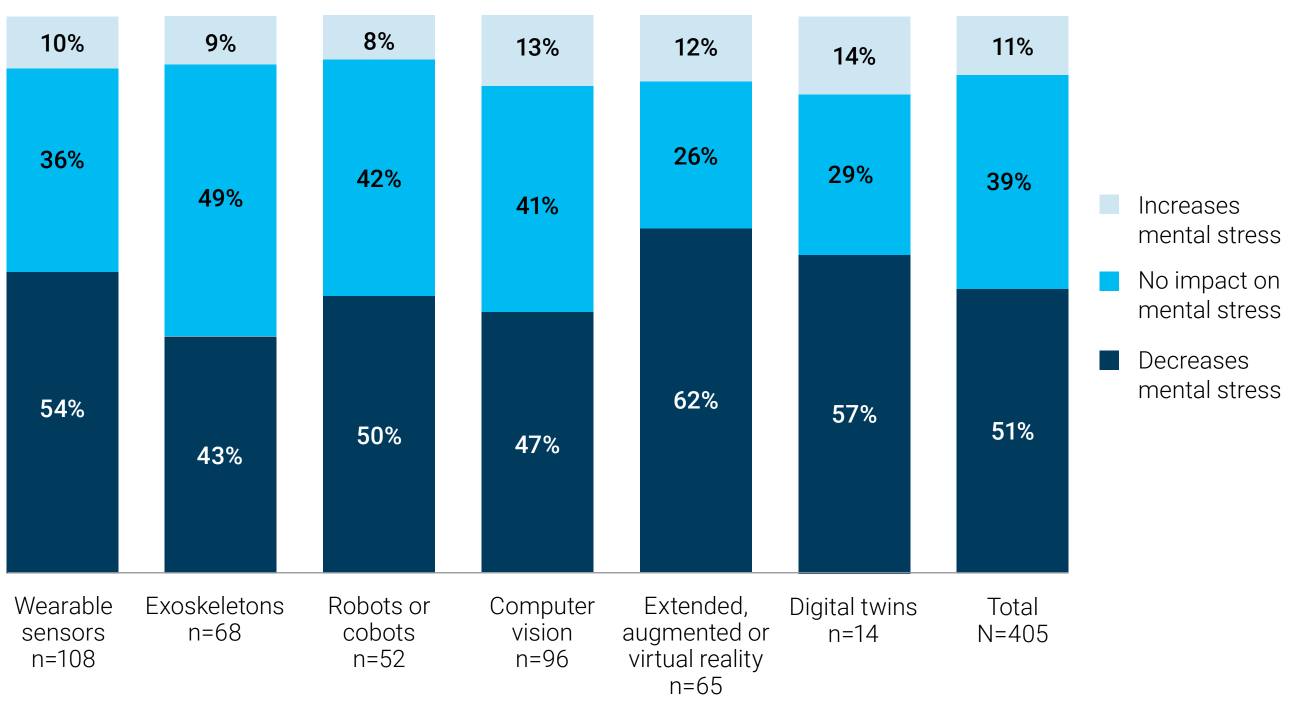


Figure 11. *Perceived Impact of MSD Prevention Technologies on Job Satisfaction*

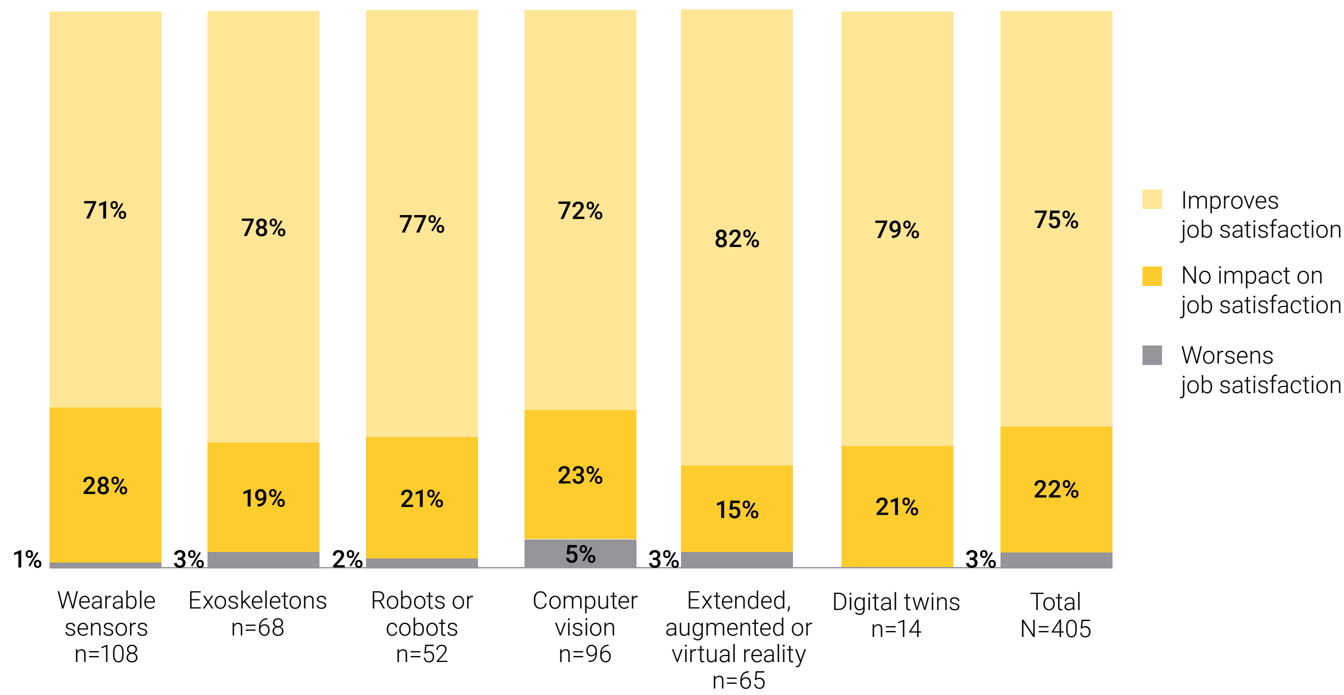


Figure 12. *Level of Agreement That MSD Prevention Technologies Improved Respondents' Posture*

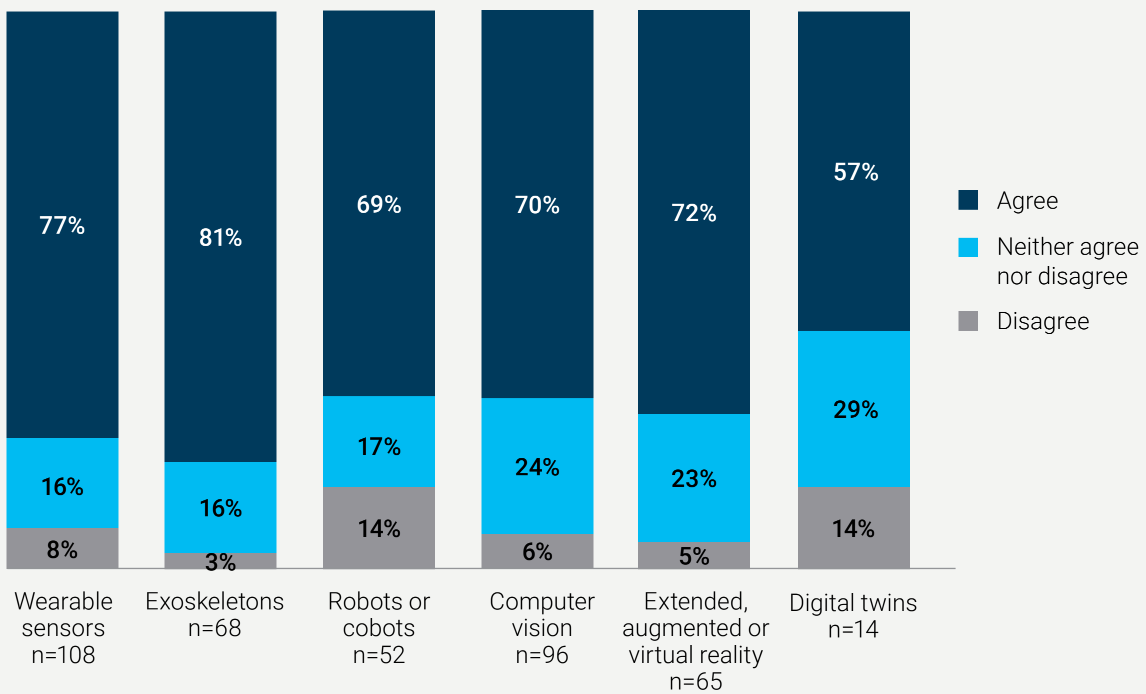
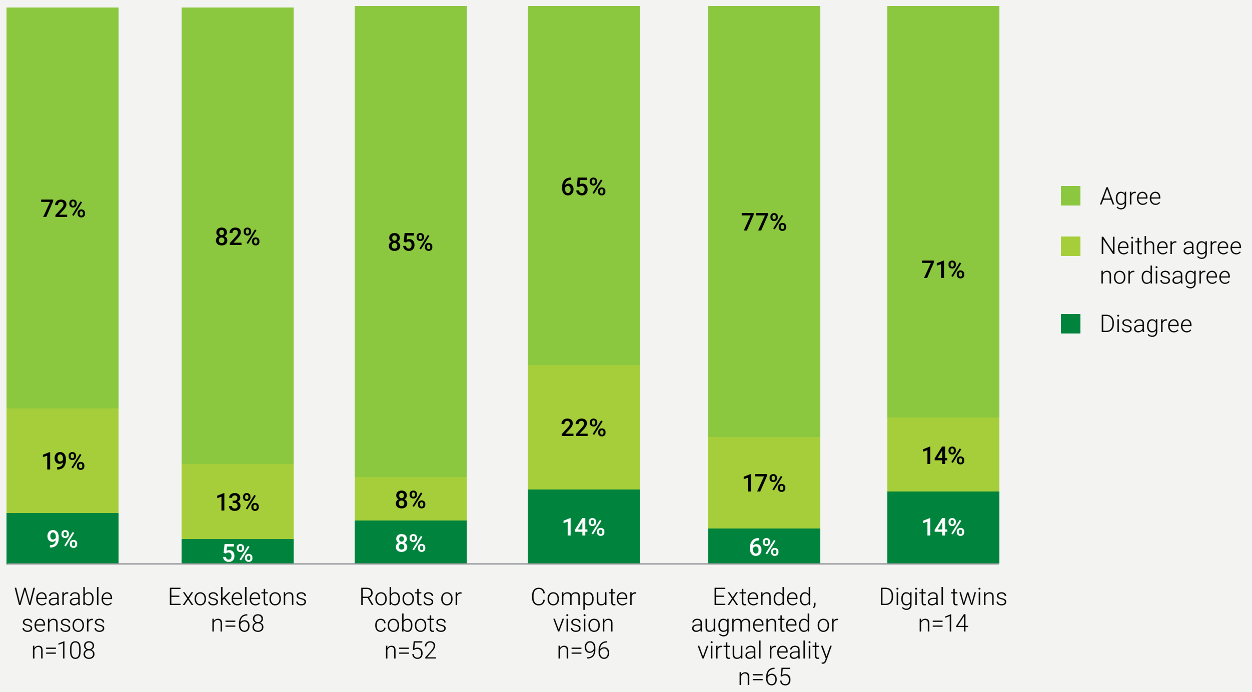


Figure 13. *Level of Agreement Among Respondents That MSD Prevention Technologies Led to Less Concern Around Developing an Injury at Work*



Wearable Sensors

Wearable sensors were the most frequently used MSD prevention technology (Figure 1). Respondents reporting they had the most experience with this technology were primarily from the construction (24%), health care and social assistance (18%), manufacturing (14%), and transportation and warehousing (12%) industries. Users commonly reported that wearable sensors increase their awareness of ergonomic risk factors (91%) and improve posture (76%). Wearable sensors were perceived as particularly effective in reducing MSD signs and symptoms in the knees and wrists/hands. Many users reported reduced concern about developing injuries (71%) and decreased mental stress (54%) due to the technology.

Open-ended responses revealed that the decrease in mental stress was commonly due to the sensors monitoring their body movements for them, allowing them to worry less about work tasks that might lead to pain or injury.

One respondent in the health care and social assistance industry wrote, **"I'm always so stressed about my pain and where it comes from, and the wearable sensor is so helpful. It tells me where [my pain comes from] so I don't need to be stressed anymore."**

Another respondent in the transportation and warehousing industry wrote, **"I feel like I have an extra layer of protection and something that is monitoring my body's health and strain."**

A respondent in the construction industry noted, **"I like that I can monitor my movement to analyze what to do differently."**

While few respondents indicated the sensors increase mental stress, those that did most commonly reported it was due to increased mental load.

One respondent who works as a customer service representative wrote that the sensors **"are a distraction to me at work and interfere with my ability to give full concentration to my job."**

Although 91% agreed that wearable sensors were easy to use, challenges were reported by some users, including discomfort and an adjustment period when learning how to use the devices, though approximately half reported no challenges.

Computer Vision

Computer vision systems were among the most widely used technologies. Respondents who indicated having the most experience with computer vision were largely in the health care and social assistance (19%), construction (10%), retail trade (9%), and manufacturing (8%) industries, with about (19%) being used in office-based industries (i.e., professional, scientific and technical services, finance and insurance, information). While the majority of respondents agreed that computer vision is effective at increasing awareness of ergonomic risks (84%) and leads to improvements in posture (70%), it was perceived as less effective than other technologies at increasing awareness of ergonomic risk factors and reducing overall MSD signs and symptoms.

Reported benefits mostly related to reduced stress and increased awareness due to computer vision observing their tasks.

A respondent in the health care and social assistance industry wrote that the utilization of computer vision at their organization decreased stress levels: **"I am more focused on patient care and less worried that I am injuring myself because the [technology] can catch it."**

A majority of respondents reported they hadn't experienced any challenges with computer vision, though few respondents noted some concerns around accuracy and privacy, and several respondents noted the technology taking some time to get used to.

Exoskeletons

Respondents in the health care and social assistance (34%), construction (15%), manufacturing (13%), and transportation and warehousing (10%) industries made up the majority of the sample who indicated having the most experience with exoskeletons. Exoskeletons were perceived as one of the most effective technologies for reducing MSD signs and symptoms overall, with users indicating they particularly help reduce symptoms in the back and knees. Of all of the technologies, respondents agreed most that exoskeleton use increases awareness of ergonomic risk factors (96%) and improves posture (80%).

Users frequently cited the physical support provided by exoskeletons as a key benefit and reported that they make the job easier and less strenuous.

A respondent in the manufacturing industry wrote what they like most about using an exoskeleton at work: **"The fact that they make your posture more firm and comfortable … I don't feel like I'm in immense pain staying in one position, or lifting objects that are heavy, or having to bend down multiple times a day constantly over and over."**

Another respondent in transportation and warehousing wrote, **"It has made me more comfortable doing my job, which also makes me more effective at doing my job."**

While some users reported discomfort or usability challenges (e.g., getting used to how it feels, not being able to move as freely), exoskeletons were generally viewed positively in terms of injury prevention and physical relief.

A respondent in the health care and social assistance industry noted that wearing an exoskeleton **"helps posture, balance and discomfort but can be itchy to wear throughout the day."**

Robots or Cobots

The majority of respondents who indicated having the most experience with robots or cobots were in the manufacturing (35%), health care and social assistance (15%), or transportation and warehousing (14%) industries. Robots and cobots were the least likely of the technologies to increase awareness of ergonomic risk factors (77%) and among the least likely to improve posture (69%) but had the highest proportion of users reporting that using the technology only decreases MSD signs and symptoms (56%) and reduces concern around developing an injury at work (85%).

Respondents commonly noted that robots and cobots improve job satisfaction and reduce mental stress by making work tasks easier and less physically demanding, reducing perceived pressure and workload.

A respondent in the manufacturing industry noted, **"Using robots at work makes you feel better because you know that you don't have to do all of the work yourself."**

Respondents frequently reported that the robots or cobots increase overall job satisfaction for these reasons but that they sometimes face challenges if the machines malfunction. Although few respondents reported concerns about using robots or cobots, those who did expressed apprehensions related to work pace and job security.

One respondent in warehousing and transportation felt pressure to work faster to keep up, while another in manufacturing raised concerns about potential job replacement, stating, **"I feel more comfortable and confident in completing my job, which helps alleviate mental stress, but I am also afraid of eventually being replaced by robots, which increases my mental stress."**

Extended, Augmented or Virtual Reality

XR technology was used across a range of industries, with the highest representation among respondents from construction (14%), health care and social assistance (14%), and manufacturing (14%), followed by educational services (11%) and retail trade (8%). While their direct impact on MSD symptoms was less frequently cited, most XR users reported that using the technology increases their awareness of ergonomic risk factors (85%) and improves their posture at work (72%).

XR technologies were reported to provide peace of mind and support training and task understanding.

For example, a respondent in the health care and social assistance industry wrote that the XR technology they use at work is **"very specific and detailed in demonstrating how to avoid such injuries at work, [and] further it guides you through how to perform certain work requirements. … I am confident in performing my duties and the work atmosphere is much better."**

The most common challenge described by respondents is that there can be a learning curve.

For example, a respondent in the retail trade industry noted that they appreciate how the XR technology helps them understand ahead of time what to expect at work but that **"sometimes it's difficult to understand the diagrams and positions"** that are shown when using the system.

Digital Twins

Digital twins were used by a small subset of respondents (n = 14), limiting the ability to draw strong conclusions. Those who reported having the most experience with digital twins were most commonly from health care and social assistance (29%), followed by educational services (14%), finance and insurance (14%), and transportation and warehousing (14%). Despite the limited sample, most users indicated that digital twins increase their awareness of ergonomic risk factors (93%). A majority also agreed that using digital twins makes them less concerned about developing a workplace injury (71%). More than half of respondents (57%) reported improvements in posture while using digital twins. Qualitative findings indicated that users appreciated gaining tools and knowledge in a simulated environment, especially related to posture.

Discussion

Prior research has primarily documented the functionality, promise and implementation considerations of MSD prevention technologies from the perspectives of employers, safety professionals and technology developers (e.g., Schall et al., 2018). This study contributes to the growing body of research on these emerging technologies by centering the lived experiences of frontline workers.

Consistent with prior literature, MSDs were highly prevalent among frontline workers in this sample, with nearly 70% reporting work-related signs or symptoms and many missing work as a result. The most frequently affected body regions, including the back, wrists and hands, knees, shoulders, legs, and neck, align with established patterns across high-risk industries (Govaerts et al., 2021; Greggi et al., 2024). While men in this sample reported having experienced work-related MSD symptoms more frequently than women, along with higher concern around developing an injury, some studies have found the opposite (Cavallari et al., 2016; Rickert et al., 2021). This could be explained by the higher proportion of men in this sample who work in higher-risk industries (Bureau of Labor Statistics, 2020), with men making up the significant majority in industries with generally higher MSD risk, including construction (86%), manufacturing (77%), and transportation and warehousing (71%). The health care and social assistance industry is an exception, however, with women making up 71% of the respondents.

Perceived effectiveness of MSD prevention technologies varied by technology type. Wearable sensors and computer vision systems (the most commonly used technologies in this sample) were the least commonly perceived to impact MSD signs and symptoms, although they are widely reported to increase awareness of ergonomic risk factors and improve posture (particularly wearable sensors). This finding is consistent with the primary role of wearables and AI-based computer vision (i.e., sensing technologies) that monitor and assess risk by generating data rather than directly altering task demands, unless paired with targeted interventions. Qualitative findings further support this distinction: Workers noted that both technologies enhanced ergonomic awareness and lowered stress by monitoring movements or tasks for them but also introduced challenges such as discomfort, distraction, accuracy concerns, privacy worries or occasional interference with work. While research points to the effectiveness of such technology to help prevent MSD risks and subsequent injuries (Alenjaregh et al., 2026), workers may perceive limited tangible benefits, especially if data generated by these technologies is not translated into observable changes in how work is performed (Iyer et al., 2025).

In contrast, technologies that directly alter physical job demands and reduce biomechanical load, particularly exoskeletons and robots and cobots (i.e., assistive technologies), were most consistently perceived as effective in reducing MSD signs and symptoms. Exoskeletons were frequently associated with symptom reduction in high-risk body areas such as the back and knees, improved posture, and reduced concern about injury. These findings align with **evidence from passive exoskeleton pilots** and **case studies** demonstrating reductions in fatigue and pain, along with productivity gains linked to decreased physical strain (Rodzak et al., 2024). They are further supported by recent survey data showing strong worker interest in exoskeletons and their potential to improve job accessibility and employee retention when paired with implementation strategies that emphasize fatigue reduction, performance gains and workforce inclusion (Gutierrez et al., 2024). In the current sample, exoskeletons were among the most positively perceived technologies; however, concerns have been documented in the literature that exoskeleton effectiveness is highly task dependent and may introduce new constraints or discomfort if poorly matched to work context, duration of use or individual fit (Baldassarre et al., 2022).

Robots and cobots were similarly perceived as highly effective, with workers emphasizing reduced physical demands, simplified tasks and lower workload pressure. Qualitative findings further highlighted psychosocial benefits, as many workers described decreased mental stress and improved job satisfaction as linked to reduced physical strain. At the same time, a small subset of respondents expressed concerns about machine malfunctions, increased pace expectations and potential job replacement, indicating that even highly valued assistive technologies may introduce new anxieties. These perceptions align with experimental evidence showing that robot and cobot assistance can enhance postural stability and reduce biomechanical load (Bibbo et al., 2025) and with findings that collaboration with a cobot reduces MSD risk but can decrease production and negatively impact the fluidity of tasks (Bouillet et al., 2023). Concerns around technology replacing jobs have also been well documented, with perceived robot-related job insecurity linked to stress and negative workplace attitudes (Wang et al., 2023).

Extended, augmented and virtual reality technologies demonstrated notable associations with reduced mental stress and improved wellbeing. Workers described benefits related to training, task understanding and peace of mind, even when direct impacts on MSD symptoms were less pronounced. Qualitative findings indicated that XR systems enhanced confidence and preparation for physically demanding tasks, though some users noted learning curves and occasional difficulty interpreting system guidance. These patterns suggest that XR technologies influence MSD risk indirectly by strengthening readiness, situational awareness and system-guided decision making – a conclusion supported by broader ergonomics and Industry 4.0 research showing that AI-enabled visualization and simulation tools enhance worker preparation and reduce exposure to risky postures (Díaz Martínez et al., 2025). Digital twins, though used by relatively few respondents, showed similar patterns of increased ergonomic awareness and reduced stress, aligning with evidence that digital twins can enhance safety and wellbeing through personalized risk insights (Davila-Gonzalez & Martin, 2024) and support workers' abilities to self-manage and reduce exposure to ergonomic risks via simulated feedback (Ogunseiju et al., 2020).

While experiences with MSD prevention technology were generally positive among this sample, the concerns that were expressed were primarily around usability challenges, discomfort, accuracy issues, privacy concerns, and increased mental load or distraction. Some workers also reported interference with job tasks, adjustment or learning curves, and in a few cases, stress tied to monitoring or performance expectations. Although these concerns varied by technology, they reflected a shared theme of workers needing time, comfort and trust in the system before fully embracing the tools. Additionally, most respondents expressed some degree of concern about data privacy and the influence of technology or AI on their work, consistent with patterns observed in broader workforce surveys. For example, recent national research has found that many workers feel worried or uncertain about how AI will be used in workplace settings and its potential impact on their roles and future job prospects, with these concerns evident across demographic groups (Pew Research Center, 2025). Workers with higher education tended to be more aware of and concerned about such issues, paralleling our finding of small but significant positive correlations between education and both privacy and AI-influence concerns. Other studies also indicate that data privacy is among the top concerns employees hold regarding AI and emerging technologies in organizational environments, underscoring fears about personal data use and transparency (OECD, 2024). Managers have raised similar concerns, noting that while algorithmic management systems (software-driven automation of managerial tasks, often using AI) can improve decision quality and efficiency, their use is often characterized by opaque algorithms, unclear accountability and inadequate worker protections (OECD, 2025). These findings together reveal urgent policy gaps for responsible and trustworthy use of AI.

In the current survey, respondents reported mixed effects of technology on mental stress (51% reduced, 39% no change, 11% increased), highlighting that technology can be a psychosocial intervention or a stressor depending on design and implementation. Most workers in the sample associated prevention technologies with higher job satisfaction, and qualitative findings indicate that safety technologies can enhance motivation, comfort and perceived job quality by reducing physical strain and injury risk. While perceptions were largely positive in this study, poorly implemented or intrusive technologies that increase workload, introduce complexity or reduce autonomy may diminish satisfaction (Flor-Unda et al., 2025).

Across all technology types, participatory environments emerged as a key contextual factor shaping worker perceptions. Workers who felt comfortable speaking up, suggesting improvements, participating in decision making and practicing with technology consistently reported more positive ergonomic, psychosocial and job-related outcomes. Recent evidence from a previous survey among **frontline workers** as well as the annual **MSD Solutions Index Pledge Community Report** corroborate the current findings. These findings also align with **participatory ergonomics** literature demonstrating that worker involvement enhances intervention effectiveness, adoption and sustainability (Burgess-Limerick, 2018; Hansen et al., 2024), and echo recommendations from the MSD Solutions Lab emphasizing frontline worker engagement as critical to successful technology implementation.

Limitations

Limitations of this study include that the survey employed a general set of questions that were applied uniformly across all technology types, despite meaningful differences in how each technology functions and is used in practice. As a result, important nuances specific to particular technologies may not have been fully captured. Relatedly, technology groups, most notably digital twins, had relatively small sample sizes, limiting the strength and generalizability of conclusions for those categories. Additionally, qualitative responses suggested that some participants may have misunderstood and, as a result, misidentified certain technologies, particularly computer vision and digital twins, and it was not possible to verify respondents' actual use of these technologies aside from their responses in the survey. Although a standardized definition was provided, future studies should incorporate clearer examples or context-specific descriptions to ensure respondents accurately recognize and differentiate the technologies they use. Future research should also employ technology-specific study designs; recruit samples from organizations when their use of MSD prevention technologies is known; include more tailored measures to better capture the unique benefits, challenges and implementation needs associated with each MSD prevention technology; and recruit more diverse and representative samples to address potential bias associated with an online, convenience sample survey, particularly given that the present sample consisted entirely of English-speaking respondents and was predominantly white.

Practical Applications

Taken together, these findings offer several actionable insights for employers, safety professionals and technology developers seeking to more effectively implement MSD prevention technologies in the workplace.

Match technology to the goal:

- Use **exoskeletons** or **robots and cobots** when reducing physical load is essential
- Use **wearables** or **computer vision** to identify high-risk tasks and guide targeted interventions
- Use **XR** or **digital twins** to support training, task simulation and proactive ergonomic design
- Pair technologies that generate insights with concrete, worker-centered changes to translate data into real impact

Treat safety technology as not just an intervention that reduces physical burden but also as a potential psychosocial intervention that can alleviate cognitive burden:

- Ask the following before implementation: How will this affect worker autonomy, workload and perceived monitoring?
- Prioritize technologies that reduce task burden by, for example:
    - Automating physically or cognitively demanding tasks
    - Providing simple, real-time feedback to support decisions
    - Decreasing uncertainty and error risk in daily work

Build trust so that technology does not increase worker stress by being perceived as a surveillance tool:

- Position safety technology as a worker benefit, not as a control tool, by highlighting benefits around reduced fatigue and discomfort
- Clearly state that data will be used for safety improvements, not punitively or to monitor productivity
- Avoid using individual-level data for disciplinary actions
- Explain how technology data will guide task design and redesign and injury prevention
- Minimize intrusive monitoring and allow worker control and opt-out options when possible

When making decisions around technology and implementation, center workers' daily experiences and wellbeing, and measure job satisfaction as a core return on investment metric:

- Prioritize technologies that improve daily work experience, and highlight those benefits to the workforce
- Ask and amplify the following: How will this technology make a worker's day easier or less tiring?

Embed worker participation and voice as a core principle of technology adoption:

- Actively involve workers in the selection, piloting and evaluation of MSD prevention technologies by co-designing pilots, gathering real-time feedback and iterating solutions based on their lived work experiences
- When sourcing technologies, consider whether the solution provider offers training that will be beneficial to frontline workers, whether direct training for the worker or a train-the-trainer model
- Offer clear pathways for workers to bring up concerns and questions, always acknowledge the feedback, and act on it when possible
- Be transparent about how data are used, and involve workers in the process, including providing access to their own data whenever possible
- Utilize tools such as wearable sensors and computer vision to collaboratively assess worker-identified solutions

Conclusion

Emerging technologies are increasingly positioned as promising solutions for preventing work-related MSDs, yet their success ultimately depends on how they are experienced by frontline workers. Our findings demonstrate that MSDs remain widespread and physically and mentally burdensome across frontline roles, reinforcing the need for effective interventions. Workers perceived the greatest physical benefits from technologies that directly reduce physical demands, such as exoskeletons and robots and cobots. At the same time, benefits extend beyond symptom reduction, with other technologies contributing to improved awareness, reduced mental stress and increased job satisfaction.

By centering frontline worker perspectives, this report complements prior research and highlights the importance of human-centered implementation. MSD prevention technologies should not be viewed as stand-alone solutions but as components of integrated approaches that prioritize worker wellbeing. Technologies are more likely to deliver meaningful benefits when they match task demands, are supported by pilot studies and success stories showing data driven improvements, are integrated into broader ergonomic and organizational strategies, and include adequate training for workers. Elevating worker voice in the selection and implementation of emerging technologies will be critical to realizing their full potential for reducing injuries.

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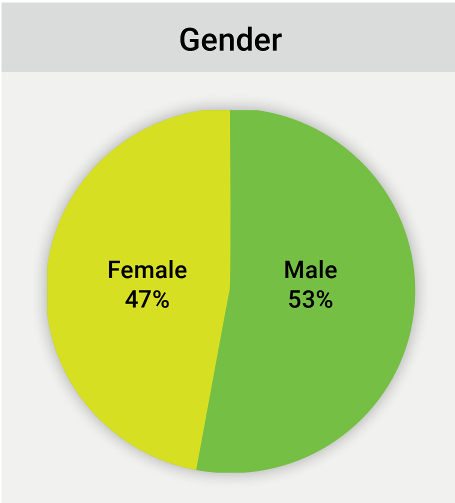
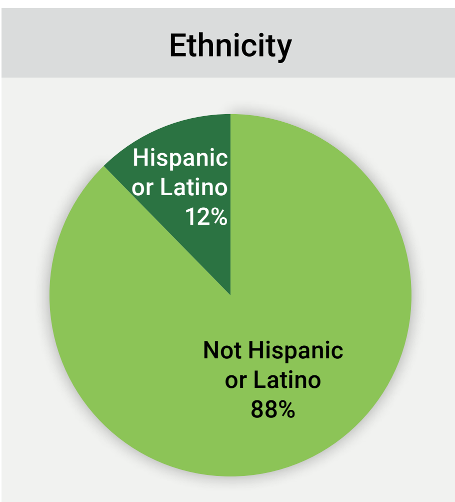
Statistical Output – Pearson Correlations of Participatory Organizational Factors and Perceptions of MSD Prevention Technologies

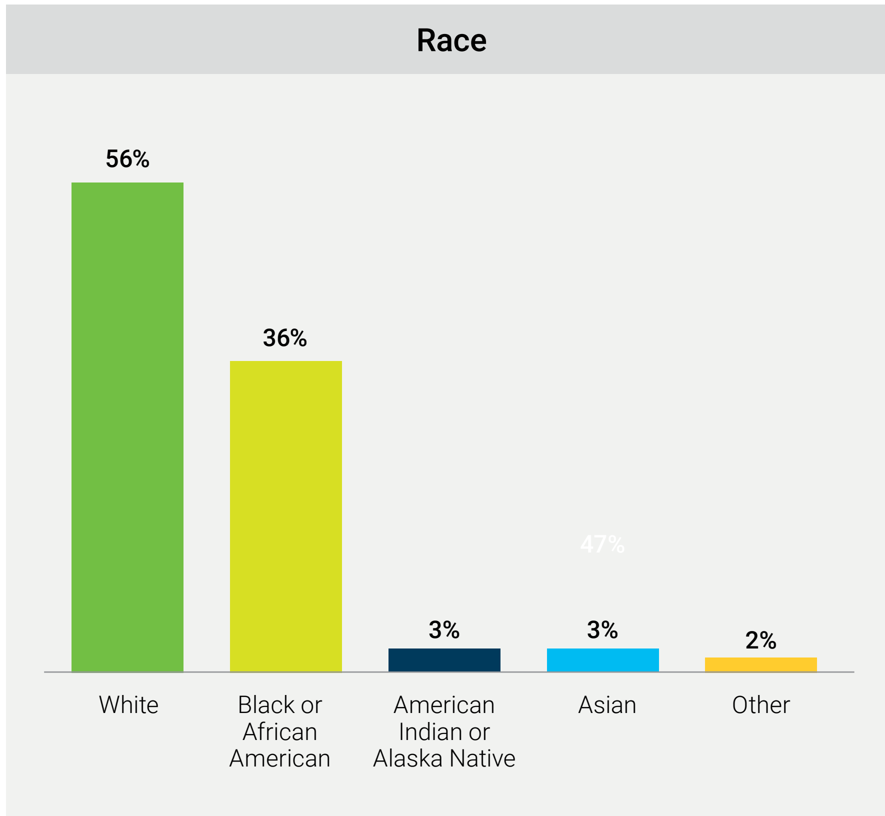
	Comfort bringing concerns to leadership	Comfort suggesting improvements	Involvement in decision making	Chance to practice/give feedback	Concern about injuries	Awareness of ergonomic risk factors	Posture quality	Mental stress	Job satisfaction
Comfort bringing concerns to leadership									
Comfort suggesting improvements	.613**								
Involvement in decision making	.401**	.373**							
Chance to practice/ give feedback	.451**	.454**	.368**						
Concern about injuries	.226**	.270**	.191**	.280**					
Awareness of ergonomic risk factors	.247**	.221**	.137**	.347**	.417**				
Posture quality	.316**	.318**	.254**	.337**	.454**	.402**			
Mental stress	-.107*	-.207**	-.127*	-.147**	-.224**	-.150**	-.304**		
Job satisfaction	.214**	.229**	.216**	.253**	.346**	.196**	.386**	-.410**	

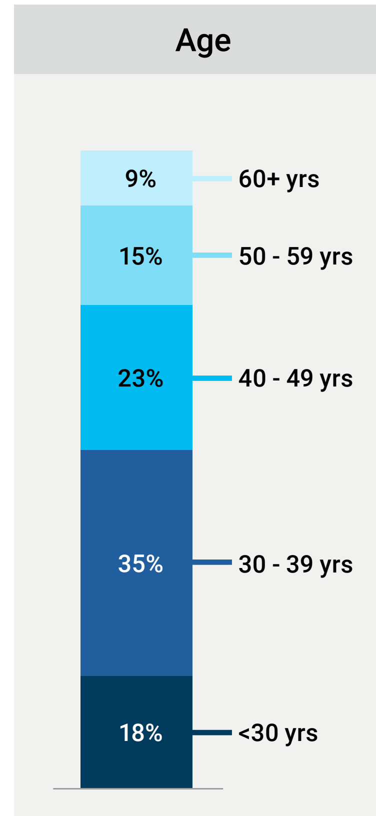
* Correlation is significant at the .05 level (2-tailed). ** Correlation is significant at the .01 level (2-tailed).

Demographics

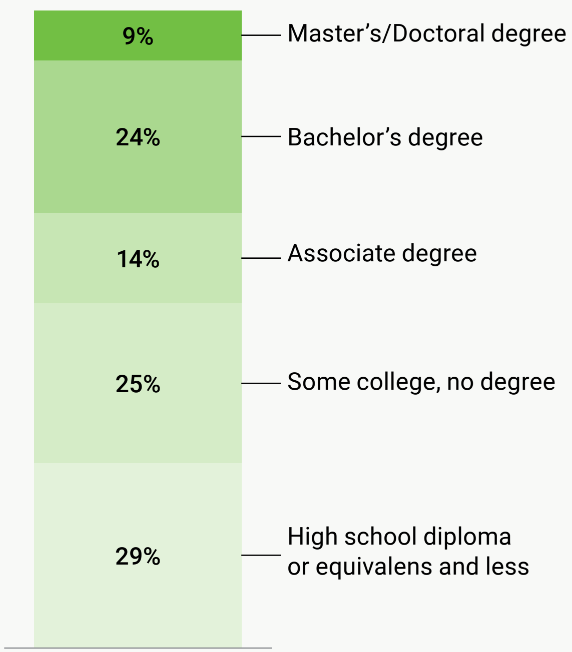




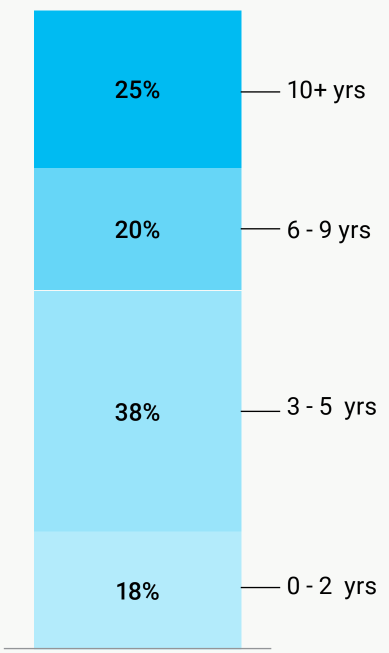


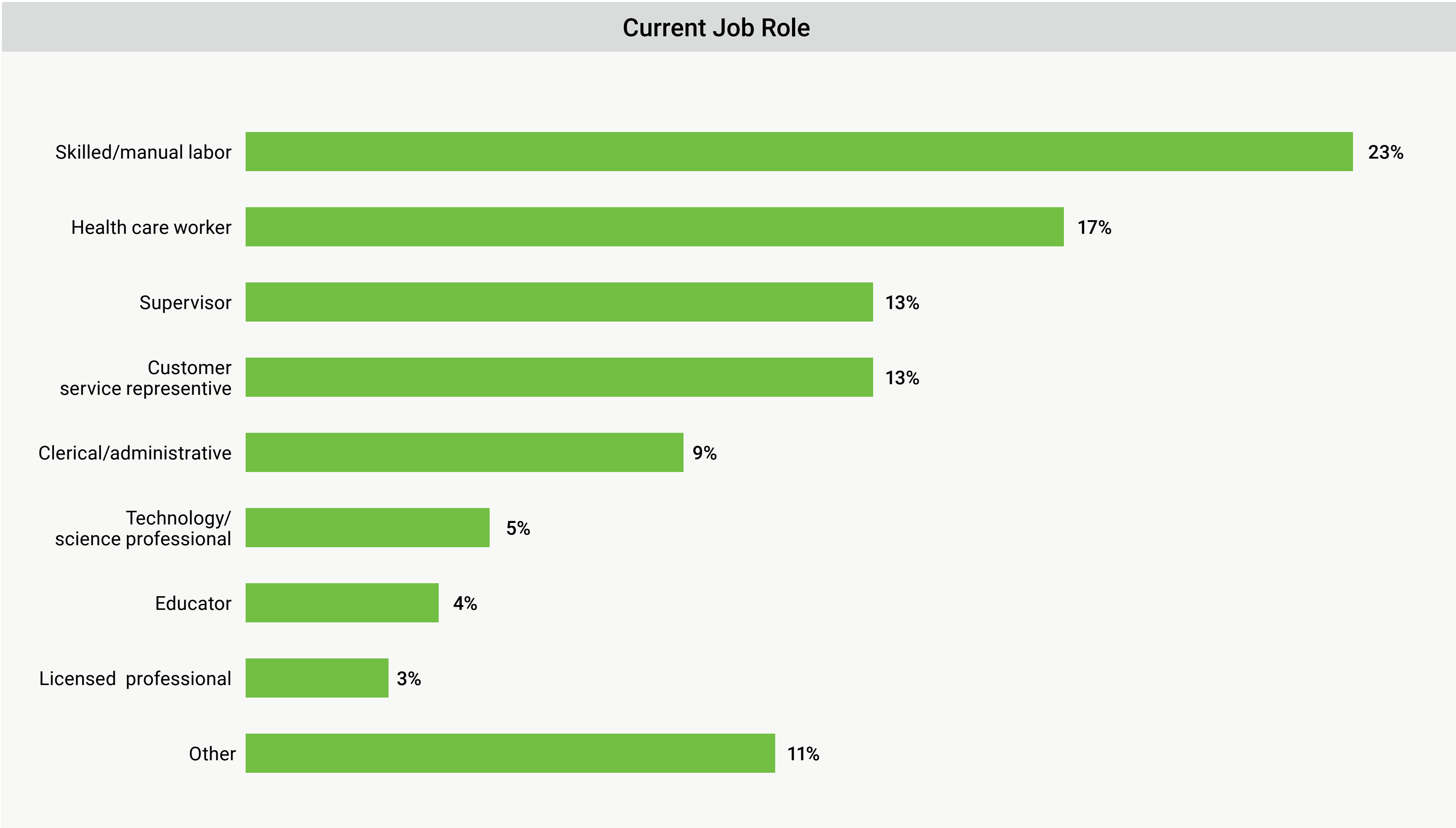


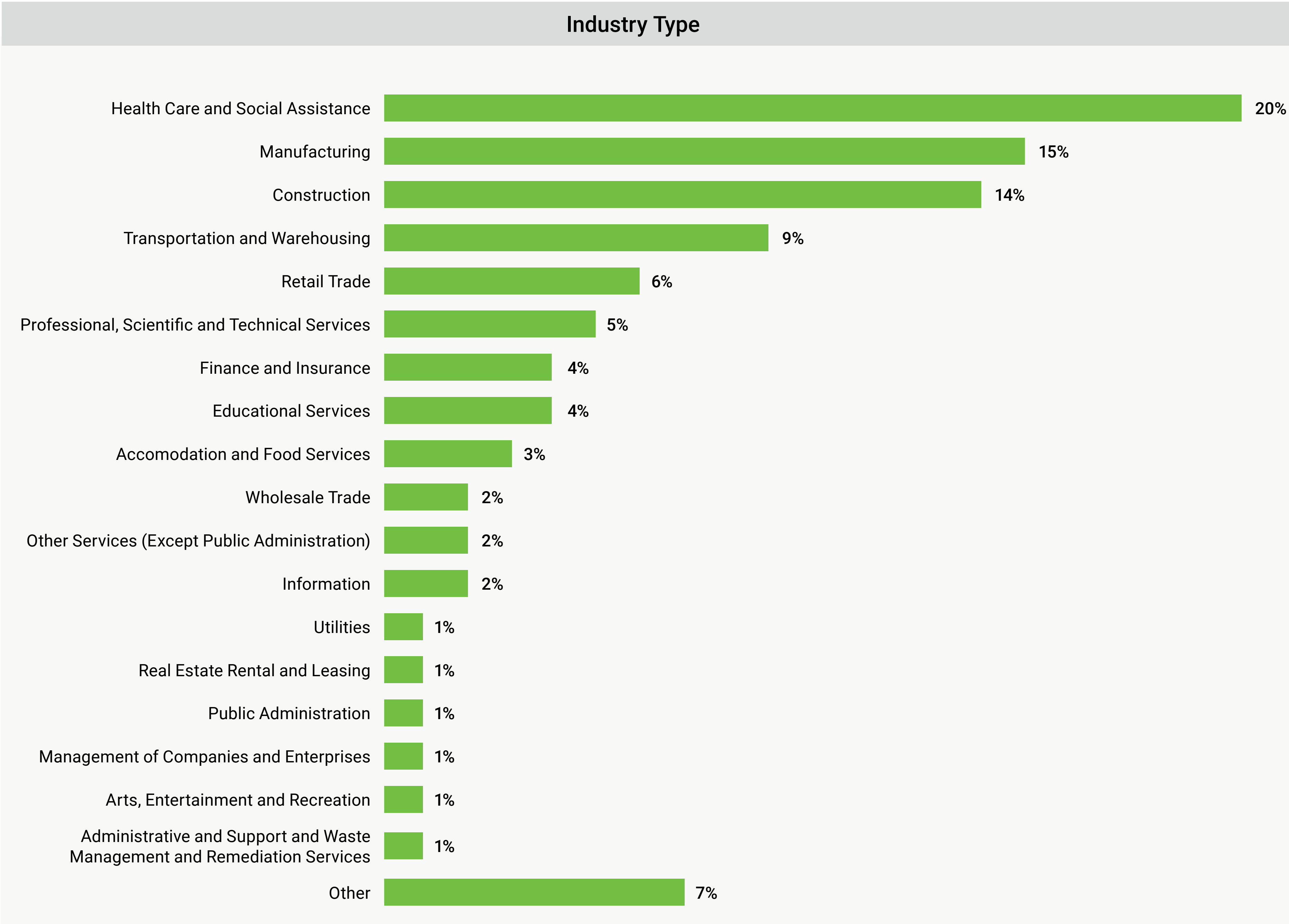
Level of Education



Length of Time in Current Position




Current Job Role
Skilled/manual labor
23%
Health care worker
17%
Supervisor
13%
Customer service representive
13%
Clerical/administrative
9%
Technology/ science professional
5%
Educator
4%
Licensed professional
3%
Other
11%


Industry Type
Health Care and Social Assistance
20%
Manufacturing
15%
Construction
14%
Transportation and Warehousing
9%
Retail Trade
6%
Professional, Scientific and Technical Services
5%
Finance and Insurance
4%
Educational Services
4%
Accomodation and Food Services
3%
Wholesale Trade
2%
Other Services (Except Public Administration)
2%
Information
2%
Utilities
1%
Real Estate Rental and Leasing
1%
Public Administration
1%
Management of Companies and Enterprises
1%
Arts, Entertainment and Recreation
1%
Administrative and Support and Waste Management and Remediation Services
1%
Other
7%