Evaluation of the MSD Wearable Study

icare

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Contents

Glossary

Acronym	Full name
DV	Dependent variable
HRP	High-risk posture
MSD	Musculoskeletal disorder
NSW	New South Wales
Q&A	Question and answer
TRIFR	Total recordable injury frequency rate
WHS	Workplace Health and Safety

Terminology	Meaning
Wearables	For the purposes of this evaluation, wearables are devices worn by workers that can reduce or eliminate risk factors associated with musculoskeletal disorders (MSDs). Two types of wearables were evaluated in this study: • **Sensors** that make use of a mobile or satellite connection to transmit data wirelessly to a smartphone, monitor or other device. Sensors are able to measure a range of physiological, biometric and activity data including person's heart rate, perspiration, temperature and muscle activity through the use of a combination of Sensors (such as force / pressure Sensors), inertial measurement units, depth sensing, accelerometers and gyroscopes. • **Assistive Devices** are devices used by workers to augment, enable, assist or enhance motion, posture, or physical tasks.
Calibration period	When explanations were provided to workers on how to use Sensors and Assistive Devices.
Baseline period	When the Sensors were collecting information, but no feedback was given to the workers. This period is only relevant to the Sensors.
Intervention period	When workers did receive feedback from the Sensors and management team or when they were using the Assistive Devices.
Sustained behavioural change	When the Sensors continued to collect information, but no feedback was given to the workers to test if the wearables had resulted in lasting behavioural changes. This period is only relevant to the Sensors.

Executive summary

icare MSD Wearables Study

Wearables have become increasingly recognised for their potential to safeguard workers in the workplace. In the context of this evaluation, wearables are devices that can reduce the risk of work-related Musculoskeletal Disorders (MSDs). Wearables in the form of **Sensors** provide real-time feedback when workers perform potentially hazardous movements and/or postures. This feedback can provide employers with data and insights to improve work design. **Assistive Devices** are another form of wearables in the form of passive or active exoskeletons that can assist workers to perform manual tasks requiring high force and/or sustained postures.

Despite the potential of wearables, studies have focused on reporting the efficacy of wearables in experimental settings but few have demonstrated their impact in work settings. There are also few studies that explore worker acceptance of wearables in the Australian context.

The icare MSD Wearables Study provided an opportunity to address these research gaps through piloting four wearables (two types of Sensors and two types of Assistive Devices) in real-world work settings and measure their impact in supporting employers' continuous improvements in workplace health and safety. The technologies evaluated in this study include:

- **Sensor 1:** Two small wearable Sensors, one worn on the upper back and one on the upper arm, which measure workers' movement and identify 'high-load' movements through a smartphone and App.
- **Sensor 2:** A belt-mounted wearable sensor which recognises awkward or 'high-risk' postures at the low back.
- **Assistive Device 1:** Off-body, tool-holding exoskeleton arm which comprises of a passive, spring-loaded mechanical arm to assist workers hold hand-held tools (weighing up to 19 kg).
- **Assistive Device 2:** On-body, shoulder- and arm- exoskeleton vest which uses a passive, spring loaded system to provide 2.3 kg to 6.8 kg of lift assistance to support the shoulders and arms when performing overhead work tasks.

This study aimed to test two hypotheses:

1. Wearables can improve the identification and analysis of hazardous manual tasks and/or workers most at-risk of injury to facilitate the elimination/reduction of risk factors which increase injury risk of work-related MSDs
2. Wearables can eliminate/reduce workers' exposure to risk factors which increase injury risk of work-related MSDs.

Evaluation of the MSD Wearable Study

Deloitte Access Economics was engaged by icare to design the implementation and evaluate the MSD Wearable Study. While the four piloted devices were used for the evaluation, the purpose of the Study was to assess the effectiveness of wearbles in improving workplace health and safety in general, rather than evaluating individual devices.

The implementation design included identifying the participant sample (identifying high-risk sectors and employers) and an implementation plan for the pilot. An evaluation framework was developed in conjunction with icare in 2018, which guided the sample size and data collection. The pilots were conducted at various times between February 2020 and April 2021. The evaluation has two components – an implementation evaluation and an outcome evaluation. This report presents the findings of both components.

Evaluation findings

Key evaluation findings

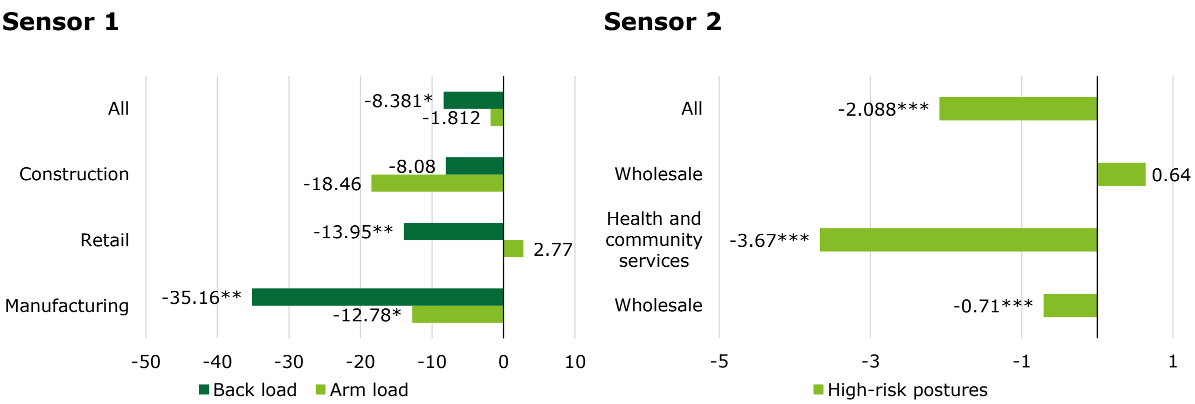
1. Short-term indicators suggest wearables are effective in identifying and reducing high-risk manual tasks in the workplace
2. Wearables should be considered a part of the broader Workplace Health and Safety (WHS) suite of interventions by employers to improve worker safety
3. Employers need to determine whether wearables are fit for purpose and are comfortable for workers before implementing them in their workplace
4. Communication, training and technical support can assist future implementation and scale up.
5. The Study offers insights for consideration by employers to assist in realising the potential benefits of wearables.

Short-term indicators suggest wearables are effective in identifying and reducing high-risk manual tasks[1] in the workplace.

The evaluation found evidence that both types of wearables – Sensors and Assistive Devices – were effective in achieving the two hypotheses considered in the evaluation. The reduction in high-risk movements was supported by survey data from 126 workers across five pilot employers that showed that 73% of workers agreed they are more aware of the safety and potential risks at work.

Quantitative data from both Sensors suggest that the feedback mechanisms in them produced a statistically significantly reduction in 'high-risk postures' or 'high-load counts'.[2] Across the three employers that trialled Sensor 1, there was a statistically significant (at the 10% level) reduction of 8.4 hourly high-load counts on the back. Among those that trialled Sensor 2, there was a statistically significant (at the 1% level) reduction of 2.1 hourly high-risk postures.

Chart i: Changes in average high-load counts and high-risk postures (baseline to intervention) for Sensor 1 (LHS) and Sensor 2 (RHS)



Source: Deloitte Access Economics analysis of device data.

Notes: *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

[1] Classed as 'Sustained and/or Awkward Posture', a risk factor or task characteristic associated with hazardous manual tasks, under the Code of Practice for Hazardous Manual Tasks.

[2] 'High load counts' for the arms and back were measured by the technology vendor of Sensor 1 using thresholds from the International Organisation for Standardisation (ISO). High load counts for the legs were calculated using the same methodology, however there is no such internationally standardised approach for high impacts on the legs. 'High-risk postures' were determined by the technology vendor of Sensor 1 based on built-in mapping of unsafe biomechanics (e.g. bending, overreaching, twisting instability (foot off ground) or overreaching) that, when recognised by the Sensor, would lead to an alert.

Assistive Devices do not collect quantitative data like the Sensors do. Consultations with workers using the Assistive Devices found the technologies made certain tasks easier such as repetitive drilling in overhead posture and sustained use of hand-held power tools.

Continued monitoring of long-term outcomes from the wearables is needed to determine the impact on work-related MSD injuries and claims. The relatively recent completion of several pilots (in April 2021) means the effect of the wearables on injuries and claims has not yet materialised. Analysis of claims data confirmed that no trend is apparent due to the aforementioned time lag and the small number of workers (342) participating in the study relative to the workforce of the participating organisations. Wearables are likely to lead to reductions in injuries and claims, therefore continued monitoring of the claims data is recommended.

Wearables should be considered a part of the broader WHS suite of interventions by employers to improve worker safety

The optimal use of wearables will not only directly reduce high-risk movements, but also form part of an employer's broader WHS toolkit by assisting identification and reduction of hazards that can contribute to their workers' risks of developing work-related MSDs.

An unintended benefit of this Study for employers' management teams has been the increased focus on the issue of work-related MSDs. This was particularly true for pilots involving Sensors where quantitative data was collected, which enabled management and WHS personnel to proactively engage (through incentives such as reward and recognition programs) with workers to identify and understand contributing factors and then developing interventions to address these issues. For Assistive Devices, workers who experienced reduced physical effort when performing their work tasks communicated with their management team on potentially safer and more efficient ways to perform their job tasks.

The wearables evaluated in this pilot were also able to improve workplace design. Sensors helped improve workplace design by assisting employers during the identification and/or analysis of the manual work tasks, workplace characteristics and processes as well as in the development and implementation (including assessing the effectiveness) of interventions to control risks.

Example of wearables improving workplace design – Employer 2 (Retail)
Key staff who championed the pilot within their organisations said that by using data collected from the Sensors, they were able to identify risk factors in the workplace and potential interventions to reduce high risk movements. One example is the development of a prototype trolley to reduce risk factors (high and repetitive force) associated with handling timber products as well as in the re-design of shelving systems.

Employers need to determine whether wearables are fit for purpose and are comfortable for workers before implementing them in their workplace

Employers demonstrated high interest in adopting wearables in the Study. Consultations with employers revealed that wearables are valuable in reinforcing WHS practices in the businesses and implementing wearables were a signal of commitment to improving worker WHS and general interest in worker wellbeing.

Attitudes of workers on wearables was more mixed – 40% of those surveyed were neutral towards continued use of the wearables and 20% indicated they would not continue use. The consultations suggested that the design of the wearable, especially comfort, was an important factor as to whether workers would continue its use.

In general, the Study found that most workers felt the wearables were generally suitable for their work environment and tasks. This was consistent across the range of industries involved in the pilot such as manufacturing, retail trade, wholesale trade and health and community services. Construction workers wearing the Assistive Devices indicated they were particularly useful for tasks involving repetitive movements with static postures.

1 Introduction

1.1 The role of wearables in reducing musculoskeletal disorders

Musculoskeletal disorders (MSDs) are the most common work-related injury in Australia, making-up 87% of serious claims in 2018-19. This equates to 99,710 claims or 8.2 per 1,000 workers during that financial year.[3] Work-related MSDs made up 31,700 (or 48%) of total reported claims in NSW in 2020-21 for the Nominal Insurer.[4]

These injuries impose a substantial economic burden. Safe Work Australia estimated the economic cost of work-related MSDs sustained in the 2012-13 financial year to be more than $24 billion.[5] Over the five years to 2013-14, 60% of serious workers' compensation claims were made for workplace MSDs. The median work time lost from these injuries rose by 35% between 2000-01 and 2012-13, 6 percentage points higher than the equivalent increase for all serious claims.[6]

The persistently high proportion of serious claims attributable to work-related MSDs is concerning. So, too, is the increasing amount of time taken off work. Addressing these injuries will be critical in achieving the Australian Work Health and Safety Strategy 2012-2022's target of reducing the incidence rate of claims resulting in one or more weeks off work by at least 30%.[7]

However, arresting or reversing these trends is challenging. Work-related MSDs have a diverse and complex aetiology. Risk factors for such injuries often include physical hazards such as heavy loads, poor posture, and task repitition. There are also many contributing organisational and psychosocial factors, including frequenct job rotation, inadequate rest breaks, the quality of supervision and training, and competing cognitive demands, among others.[8]

Interest in wearables for Workplace Health and Safety (WHS) purposes, including the prevention of work-related MSDs, has been growing despite their relatively recent introduction in Australian workplaces. For the purposes of this evaluation, wearables are devices worn by workers that can reduce or eliminate risk factors associated with MSDs. Two types of wearables were evaluated in this study – Sensors and Assistive Devices. Sensors that make use of a mobile or satellite connection to transmit biometric or activity data wirelessly to a smartphone, monitor or other device. Assistive devices are devices used by workers to augment, enable, assist, or enhance motion, posture, or physical tasks.

The value proposition of wearables for WHS purposes lies in their capabilities to contribute and/or complement an employer's risk management efforts. Compared to traditional WHS tools for MSDs – such as observational methods that can be influenced by the asessor's competencies, cannot be objectively conducted and/or might focus only on snapshots of a small sample of workers – wearables offer real-time objective measuring and monitoring with a higher level of accuracy and reliability or provide direct assistance in completing tasks. In combintation with the the potential of assessing risk factors, some wearables can also alert workers by providing immediate biofeedback to alert them to 'unhealthy' work habits (especially when risks have been controlled to acceptable levels) and guide them to healthier, safer working habits.

Businesses and insurers may have a commercial interest in adopting wearables that can assist in reducing Workers Compensation claims, but ultimately such technologies serve a greater purpose – they improve worker wellbeing, create a safer work environment.

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[3] Safe Work Australia (2021), Australian Workers' Compensation Statistics 2018-19, https://www.safeworkaustralia.gov.au/collection/australian-workers-compensation-statistics.
[4] Based on icare Nominal Insurer Workers Compensation claims data FY2020-21.
[5] Safe Work Australia (2015), The cost of work-related injury and illness for Australian employers, workers, and the community: 2012-13. Canberra, Australia.
[6] Safe Work Australia (2016), Statistics on work-related musculoskeletal disorders. Canberra, Australia.
[7] Safe Work Australia (2012), Australian Work Health and Safety Strategy 2012-2022: Healthy, safe, and productive working lives. Canberra, Australia.
[8] Safe Work Australia (2019), Work-related musculoskeletal disorders in Australia, 2019. Canberra, Australia.

The uptake and benefits realisation of such technologies in the workplace depends on a variety of factors such as organisational factors such as the WHS culture, the nature of tasks undertaken by workers and organisational communication and trust in how any data will be used and managed.

Despite the potential of wearables, a review of existing literature has found that many studies have focused on reporting the efficacy of wearables by means of experimental tests and/or simulations but few have demonstrated their application and validation in real contexts.[9] There is also few studies that explore worker acceptance of wearables in the Australian context. This gap in the literature was a factor for icare in undertaking the MSD Wearable Study to build the evidence base in real work contexts and conditions and assess worker acceptance of these wearables.

1.2 The MSD Wearable Study

The MSD Wearable Study was provided with a program budget of $819,724 by icare's Nominal Insurer Workers Compensation Scheme amid growing interest in, and evidence of, the role that wearables could have in the improvement of WHS. In line with icare's purpose to care for the people of NSW, building confidence and trust so our communities can thrive, the Study focused on helping icare's customers better understand if wearables are suitable for consideration as part of their WHS toolkit and how to realise the benefits of such technologies in the workplace. This has focused on the issue of work-related MSDs and the key considerations including enablers and barriers to the successful implementation of wearables to improve WHS outcomes and reduce Workers Compensation claims and premiums.

Deloitte Access Economics was engaged by icare to design the implementation and evaluate the MSD Wearable Study. The focus was on deploying and testing the efficacy of wearables with actual employer organisations and in real work contexts and conditions.

A program logic was developed to articulate how use of wearables are organised to achieve intended outcomes outlined in the theory of change. Key evaluation questions and the subsequent data requirements for undertaking the evaluation are derived from this. The evaluation then provides an opportunity to test this theory, and ultimately provides feedback on the strength of the underlying logic of the program or policy, where intended outcomes are realised, or alternatively fail to materialise.

The program logic for the MSD Wearable Study is presented in Appendix A.

The MSD Wearable Study has provided an opportunity to pilot two types of wearables – Sensors and Assistive Devices – in real work contexts and conditions. The technologies piloted are outlined in Table 1.1 below. Refer to Appendix B for a detailed description of the piloted wearables. While the wearables assessed in this evaluation have been previously used in Australian workplaces in a limited capacity, the wearables still represent an innovative way for businesses to prevent work-related MSD injuries and improve the health and wellbeing of workers. While this evaluation covers four wearables, there are several different brands that employers can select from.

[9] Griffith University (2018), Rehabilitation Innovation Service Evaluation. Wearable Technology: A review of wearable technologies for the prevention of work-related musculoskeletal injury. Gold Coast, Australia.

Table 1.1: Technologies included in the MSD Wearable Study

Category	Evaluation design	Description of technology
Sensor	For the two Sensors, each pilot involved the following periods: a calibration period to establish and set-up the pilot, a baseline period where the wearables were collecting information, but no feedback was given to the workers; an intervention period where workers did receive feedback from the device and management team and a sustained change period where the wearables continued to collect information, but no feedback was given to the workers to test if the wearables have resulted in behavioural changes.	**Sensor 1** Two small wearable Sensors, one worn on the upper back and one on the upper arm, measure workers' movement and identify 'high-load' movements through a smartphone and App, which uses algorithms to determine changes to movement ranges (angles) and acceleration. The smartphone, via the App, provides workers with real-time vibrational and/or sound feedback when 'high-load' movements are performed. Data on workers' movements is stored on the smartphone and uploaded to a cloud-based, web platform to provide analytics and insights.
		Sensor 2 A belt-mounted wearable sensor which recognises awkward or 'high-risk' postures at the low back by using algorithms to determine changes to postural angles, acceleration, and height. It provides workers with real-time vibrational feedback when 'high-risk' postures are performed. Data on workers' postures is collected from the wearables and uploaded onto a cloud-based, web dashboard to provide analytics and insights.
Assistive Device	For the two Assistive Devices, the pilots involved a calibration period where workers undertook training on how to use the devices and set-up the pilot and an intervention period where workers used the devices.	**Assistive device 1** Off-body, tool-holding exoskeleton arm which comprises a passive, spring-loaded mechanical arm to assist workers hold hand-held tools (weighing up to 19kg) when working on various work platforms, most typically aerial work platforms and scaffolding. It transfers the load of the tools to the arm's base. By providing lift assistance, it reduces the workers' muscular effort when performing manual tasks which may involve a combination of different task characteristics like repetitive or sustained force, repetitive movement and/or sustained or awkward postures.
		Assistive Device 2 On-body, shoulder- and arm-exoskeleton vest which uses a passive, spring loaded system to provide 2.3 kg to 6.8 kg of lift assistance to support the shoulders and arms when performing overhead work tasks. It transfers the weight of the workers' shoulders and arms to the body's core. By providing lift assistance, it reduces the workers' muscular effort when performing manual tasks which may involve a combination of different task characteristics like repetitive or sustained force, repetitive movement and/or sustained or awkward postures.

Source: icare and Deloitte (2021)

The four different technologies were piloted by six employers from a range of industries and business size. These employers were selected based on several criteria during the implementation design phase, including operating in industries with a high frequency of MSD claims.

For confidentiality purposes, the employers included in the study are not be named but described consistently throughout the document with consistent labels shown in the Table 1.2. Table 1.2 also details the technology and high-level details around each of the pilots. Further detail on each pilot is available in Section 2.2.

Table 1.2: Pilot employers characteristics

Employer name	Industry	Wearable piloted	Number of pilot sites	Number of workers included in study[10]	Length of pilot in weeks
Employer 1	Manufacturing	Sensor 1	1	31	32
Employer 2	Retail trade	Sensor 1	7	50	10
Employer 3	Wholesale	Sensor 2	3	93	39
Employer 4	Health and community services	Sensor 2	10	142	45
Employer 5	Wholesale	Sensor 2	1	22	27
Employer 6	Construction	Assistive Device 1 and 2 and Sensor 1	1 for Assistive Device 1 and Sensor 1 2 for Assistive Device 2 and Sensor 1	17	19

Source: icare and Deloitte (2021)

The pilot design, including the research approach, has leveraged research study best practice for pilots that are testing transformative innovations where there is limited evidence and a high number of unknowns. This can be contrasted to other incremental improvements that build upon existing and well-evidenced technologies.

It should be noted that all pilots in the MSD Wearable Study began or partly took place during COVID-19 outbreak. The pandemic did affect the implementation and timing of the pilot as some pilots did not received face to face technical support and briefings from the technology vendors at the start of the pilot, variations in the nature of work for some pilots and one employer (not included in the above) was unable to take part in the study due to suspension of operations. The impact of COVID-19 is described in Section 2.3. and throughout the evaluation findings where the impact of COVID-19 was material.

[10] The number of workers presented includes only those that trialled the technology during the entire pilot period. For several pilots, there were some workers that did not complete the entire pilot period. Data sources were used for these workers where applicable.

1.3 Purpose of the evaluation

The aim of this evaluation is to test the two hypotheses of the MSD Wearable Study:

1. **Hypothesis 1:** Wearables can improve the identification and analysis of hazardous manual tasks and/or workers most at-risk of injury to facilitate the elimination / reduction of risk factors which increase injury risk of work-related MSDs
2. **Hypothesis 2:** Wearables can eliminate / reduce workers' exposure to risk factors which increase injury risk of work-related MSDs.

Assessing these hypotheses has required the development of an evaluation framework, detailed in Chapter 2 to provide comprehensive assessment of the pilot against these hypotheses.

In assessing the technologies against these hypotheses, the evaluation seeks to identify whether the respective technologies were effective and identify the critical success factors for implementing the technologies. Developing a understanding of these success factors and barriers is necessary to replicating any outcomes in other sites or increasing the scale of the workers using the technology.

1.4 Structure of this report

The remainder of the report is structured as follows:

- Chapter 2 outlines the methodology used for this evaluation including the Evaluation Framework as well as data collected to answer the evaluation questions
- Chapter 3 assesses how effective the implementation of the pilots were for employers and workers
- Chapter 4 examines the outcomes associated with the use of technologies for workers and the replicability of the technologies to other contexts.
- Chapter 5 explores a case study of one pilot employer identifying the factors leading to succesful implemention of wearables
- Chapter 6 summaries the key findings of the evaluation and provides considerations for potential employers wanting to trial wearables or scale up their use.

2 Methodology

2.1 Evaluation framework

The Evaluation Framework for the icare MSD Wearable Study was developed in March 2019. The document provides guidance and structure on how the results of the study should be measured and assessed. The Evaluation Framework has been co-designed with the icare project team.

Key evaluation questions have been influenced by the program logic to outline the key lines of inquiry that the evaluation of the MSD Wearable Study will address while retaining flexibility to assess any unforeseen implications from the study. Using the NSW Government Program Evaluation Guidelines as a foundation, evaluation questions have been developed under four domains identified in Table 2.1.[11]

Table 2.1: Key evaluation questions

	Domain	Key evaluation questions
Implementation	Adoption & Feasibility	I1. Is the technology safe, acceptable, and feasible? I2. What are the barriers and enablers to successful adoption and utilisation? I3. To what extent do employers have to adapt in order to implement / incorporate wearables?
	Appropriateness	I4. How well designed was the pilot? I5. Are the wearables fit-for-purpose?
Outcome	Effectiveness & Impact	O1. To what extent do the wearables deliver the desired outcomes? O2. What are the cultural, social, environment, and design factors that increase or impact on effectiveness? O3. To what extent are outcomes sustainable in the longer term?
	Scalability & Replicability	O4. To what degree are the wearables scalable and replicable? O5. What are the key learnings from the pilot that can translate into future programs?

Source: icare and Deloitte (2021)

The evaluation domains that relate to **implementation** of the pilot include:

- **Adoption & Feasibility** – The extent to which the wearables have been adopted by employers and workers, including the willingness to adopt and barriers to utilisation.
- **Appropriateness** – The extent to which the program is evidence-based and the wearables are fit-for-purpose.

The evaluation domains that relate to the **outcomes** of the pilot include:

- **Effectiveness & Impact** – The extent to which the wearables deliver expected outcomes and the key factors that will affect outcomes such as cultural, social, and environmental factors.
- **Scalability & Replicability** – The degree to which the wearables and the outcomes generated can be scaled to new industries, employers and conditions and the key learnings to inform future programs.

[11] NSW Premier and Cabinet, NSW Government Program Evaluation Guidelines, January 2016.

2.2 Data collection

The Evaluation Framework provides the data requirements and methodology for carrying out the evaluation. This evaluation has sought to combine several data sources and apply experimental methods to provide evaluation findings that are evidence-based and practical to inform future programs. The data sources and associated performance indicators used to answer each key evaluation question are outlined in Table C.1 and Table C.2 in Appendix C.

Table 2.2 presents the sample sizes for each of the key data sources used in this evaluation. The worker surveys (conducted at the end of the pilot) and the consultations represent qualitative data sources, while the device data is a quantitative source. There were 126 worker surveys, 31 consultation transcripts, and 426 unique workers' device data analysed. The consultations were conducted with a range of stakeholders, including an icare pilot manager, employer pilot managers, technology vendors, and workers.

Table 2.2: Sample sizes for key data sources

Pilot group	Worker survey	Consultation	Device data
Employer	**126**	**31**	**426**
1 (Manufacturing)	14	7	27
2 (Retail trade)	35	1	50
3 (Wholesale)	41	8	106
4 (Health and community services)	26	8	199
5 (Wholesale)	0	2	27
6 (Construction)	10	4	17
Not applicable	0	1	0
Stakeholder group	**126**	**31**	**426**
icare pilot manager	0	1	0
Employer pilot manager	0	7	0
Technology vendor	0	3	0
Worker	126	22	426
Wearable device	**126**	**31**	**426**
Sensor 1	59	12	94
Sensor 2	67	18	332
Assistive Device 1 and 2	10	4	0
Not applicable	0	1	0

Note: Components may not sum to total due to multiple wearables being piloted by the same employer.

Further details around the data sources and their use can be found in Appendix C, Appendix D, and the Evaluation Framework document.

2.3 Data limitations

There were several data limitations associated with this evaluation.

No assessment of long-term outcomes

This evaluation considered the short-term outcomes given that four out of the six pilots concluded in April 2021. Longer-term outcomes are unlikely to be captured at this stage of evaluation.

Adhering to pilot requirements

Technology vendors and pilot employers were asked to adhere to the pilot design which was different to their usual implementation process. For example, some pilots required workers to wear a device for up to 8 months to enable data collection for evaluation purposes. This is a longer period than the 2-3 months typically recommended by the vendors.

Disruptions due to COVID-19

This evaluation took place during the COVID-19 economic and health restrictions. All pilot employers included in the analysis for this evaluation remained open and continued work. One additional pilot employer was prevented from participating due to disruptions to their industry.

For the participating employers, COVID-19 restrictions diminished the quality of the technical support that could be provided by the technology vendors. The study had to pause for 3 months during the first lockdown of Greater Sydney between March and June 2020. One participating employer had to delay the start of their pilot due to the impact on their operations and workforce, while another two employers had to shorten the duration of their pilots. These challenges delays in resolving issues with wearables and had an impact on the amount of data collected.

Technical issues with wearables

During two of the pilots, some of the Sensors experienced technical issues for a range of reasons. This included incomplete software environments, incompatible mobiles and operating systems, incorrect firmware, general wear and tear, and some instances of human error (e.g. jamming the chargers into the wearables causing failure). As a result, there were instances whereby the wearables did not record data and/or provide feedback to workers and thus these data were not included in the final analysis.

There is also the possibility of false positive alerts to workers with the Sensors i.e. where a worker received an alert even if not undertaking a high-risk posture or a high-load movement. While undesirable, this was assumed to occur throughout the pilot with a similar frequency and unlikely to bias the findings towards being more effective. However, it is noted that a high degree of false positives could impact the effectiveness of the wearables by causing workers to ignore the alerts.

No separate analysis of acceptability and effectiveness each wearable device

While the two types of Sensors were trialled independently in different industries, the Assistive Devices which were only trialled in combination with Sensor 1. This may lead to the evaluation of the Assistive Devices to capture the combined effects of using the two wearables, particularly in the end of pilot worker surveys. The use of interviews with participants did enable an exclusive focus on Assistive Devices.

Varied participation in pilot by employer limiting some industry comparisons

The participation rate by employer varied significantly from around 10 to 158 workers. Where data were insufficient to make conclusions, this has been highlighted. These inconclusive results for an employer mean that some of the results for a particular industry are not available and limits the ability to make cross-industry comparisons.

3 Implementation evaluation

This section of the report presents the evaluation findings relating to the implementation aspects of the MSD Wearable Study. This includes the safety, acceptability, and feasibility of the technologies themselves, as well as the key barriers and enablers of their successful adoption and utilisation. It also concerns the suitability of the Study's design and whether the wearables were fit-for-purpose.

Table 3.1 summarises the relevant evaluation questions and high-level findings relating to the Study's implementation.

Table 3.1: Key implementation findings for the MSD Wearable Study

Evaluation domain	Evaluation question	Key findings
Adoption and feasibility	I1: Is the technology safe, acceptable, and feasible?	• Most workers endorsed or were indifferent towards the use of the wearables. • Factors relating to worker beliefs and experiences that affected technology acceptance included the level of understanding of the wearable, how their data will be used and managed and the design of the wearables. • Some workers found certain design features of the wearables could be improved, to increase safety and overall willingness to use the device. For example Sensor 2 has a metal clasp that attaches the device to the user, and some workers found it to cause skin irritation due to the rubbing of the clasp on skin, whilst Assistive Device 1 could be made more robust to ensure they do not detach from the safety latch-and-release mechanism and, potentially, cause injury.
	I2: What are the barriers and enablers to successful adoption and utilisation?	• Enablers included the ease of use of the wearables, the provision of rewards and recognition, integration into work, and organisational factors such as active leadership and management, a strong WHS culture, enabling company policies, and engaged and experienced pilot managers. • Barriers included certain design and performance features of the wearables, technical issues, and organisational factors such as insufficient communication and support. • The Sensors presented some technical difficulties, particularly with mobile phone compatibility, pairing, and navigation through the application to commence and end sessions. Technical issues for the Assistive Devices were not widespread. • A barrier for Assistive Devices was the time it took to obtain them from the storage and put them on. This led to some workers feeing it was more efficient to complete the task without assistance. This was particularly true for tasks involving lighter objects.
	I3: To what extent do employers have to adapt in order to	• The implementation of the wearables required the provision of resources to enable clear communication with workers, training and support for both workers and assigned pilot (change) managers and allocation of management

	implement/incorporate wearables?	resources to action insights and develop interventions in response to the insights. • In some cases, employers had to make cultural adaptations to motivate workers to adopt and engage with new technologies.
Appropriateness	I4: How well designed was the pilot?	• The key factors influencing the success of the pilot were: clear communication regarding the purpose of the pilot, active leadership, a pilot co-designed with consultations with workers, adequate and timely support, and the level of information/feedback workers received of their progress. • A lack of clarity around the purpose of the pilot e.g. whether the wearables were used to monitor work performance, compromised workers' overall experience using the wearables. • Active leadership was a key factor of success, and entailed commitment from senior management. • Consultations with workers would be beneficial early, during the design of the pilot to mitigate preventable barriers from workers' perspectives. • Training, feedback, and support during the pilot was important for workers who wanted more information on the use of the wearables and how they were progressing throughout the pilot. • Most workers received timely support when their wearables experienced technical issues, but some felt they had insufficient support during the pilot. This may have been partly due to the impact of COVID-19.
	I5: Are the wearables fit-for-purpose?	• Overall, the wearables were fit for the purposes of increasing the awareness of high-risk movements, causing behaviour changes both at the workplace and at home, and aiding with high-risk or high injury tasks. This varied by industry, roles and tasks.

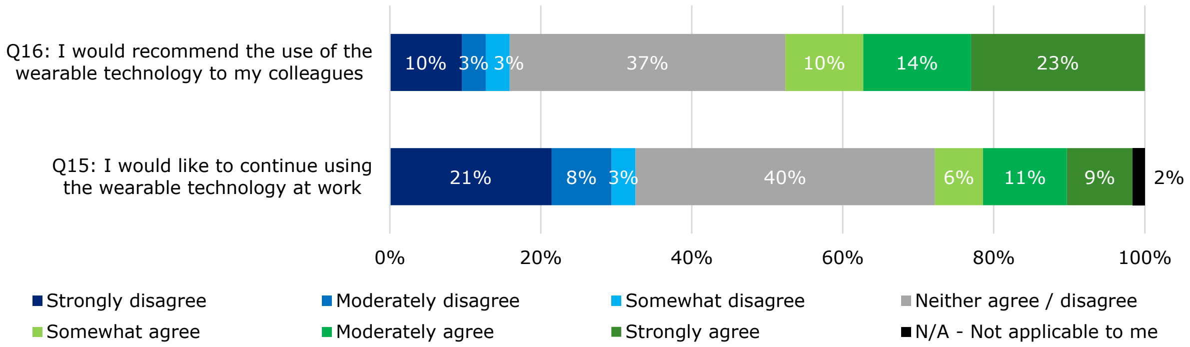
3.1 Adoption and feasibility

3.1.1 Indicator 1: Is the technology safe, acceptable, and feasible?

Chart 3.1 shows that most workers neither agreed or disagreed with continuing to use the wearables or recommending their use to colleagues. This is based on the analysis from all employers for whom survey data was collected.

Nearly half of the participating workers agreed when asked whether they would recommend the use of the wearable. Fewer workers (26%) stated that they would like to keep using the wearables themselves. When considering the continued personal use of the wearables, a significant proportion of workers strongly disagreed. The most common response from workers was neither agree nor disagree to both questions. Recognising that the Study involved the use of technologies not widely used in Australia, it may be expected that there would be a significant amount of uncertainty among workers towards their future use.

Chart 3.1: Pilot participants' endorsement of the wearables

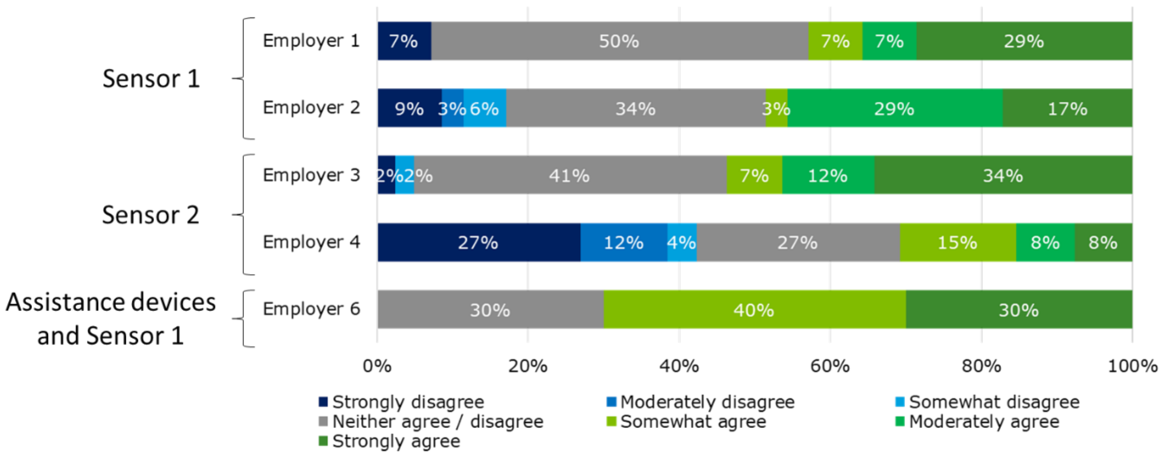


Source: Deloitte Access Economics analysis of worker survey data.

Chart 3.2 shows significant variation in worker endorsement of the technology between employers and does not appear related to the type of wearables used. This suggests that the more critical factor may be the design or implementation of the pilot. Employer 3 (Wholesale) and Employer 6 (Construction) were most likely to recommend the use of the wearable to colleagues. Employer 4 (Health and community services was the least likely to recommend the technologies. This may be partially attributable to a high proportion (almost half) of the wearables used by Employer 4 (Health and community services) experiencing technical issues and inadequate training and support.

Employer 5 (Wholesale) is not included in Chart 3.2 as no surveys were completed (due to conflicts with operational requirements) by workers after the study.

Chart 3.2: Worker endorsement of the wearables to colleagues, by employer



Source: Deloitte Access Economics analysis of worker survey data.

Consultations revealed that understanding the WHS benefits from using the wearables were key for adoption and feasibility. Most workers found the wearables were safe overall, however; it was noted that Sensor 2 caused skin irritations for some workers due to the pressure exerted by the metal clasps, and that some thought Assistive Device 1 could be made more robust to ensure they do not detach from the safety latch and release mechanism, and potentially injure someone while working.

For employers, the key factors that affected the adoption and feasibility of the wearables were benefits from using the wearables along with consideration of costs of implementation and advancing a workplace culture that welcomes innovation and change. While employers were largely positive about the benefits on workplace safety, there were some instances where the adoption still relied on providing incentives to embrace new technologies.

3.1.2 Indicator 2: What are the barriers and enablers to successful adoption and utilisation?

The enablers to the successful adoption and utilisation of the wearables related to the following key features of the wearables and how they were implemented: ease of use, the provision of rewards and recognition and the integration of the wearables into work, and organisational factors. Barriers included certain design features of the wearables, technical issues, and organisation factors such as insufficient communication, management and commitment behaviours. These features are described below:

Design and ease of use

Both the Sensors and Assistive Devices were found to be relatively easy to use with only some relatively minor complaints around the design features of some of the wearables. The Study involved workers from a range of industries and found most felt the wearables were generally suitable for their work environment and tasks.

Workers wearing the Sensors reported they were applicable to a variety of roles from ones involving dynamic body movements like lifting and walking to static body movements like driving and sitting.

For workers, a design enabler of Sensor 2 was its small and manoeuvrable design. Most workers stated the device was easy to use and comfortable, with many forgetting the device was on due to its seamless compatibility with their body movements. This did lead to an unintended consequence of workers forgetting to wear or take off the device.

Employers involved with the Sensors noted in consultations that the provision of data through dashboard was user friendly and amenable to be used for actionable insights. For Employer 2 (Retail), this enabled 'Team Talks' to discuss store-level data insights with workers. These were conducted in either the yard or the lunchroom in the form of an open conversation among all participating members of the team.

Some participants reported on a high frequency of feedback from Sensor 2 when performing tasks they did not consider to be high-risk, such as walking or answering a telephone call. This made users question the validity of the sensor. Less common barriers for the Sensor 2 included pressure induced discomfort on the skin when the device was not worn over a belt.

Construction workers wearing the Assistive Devices indicated they were particularly useful for specific tasks involving repetitive movements with static postures such as drilling in overhead positions, and anything involving high or sustained force such as the use of hand-held power tools.

However, the design of Assistive Device 1 also led to concerns from some workers who felt it would be better to perform the tasks without the wearable, because the time cost of putting it on and manoeuvring it outweighed the benefits offered by the wearable. This was particularly true for tasks with lighter weights. There was also a time cost associated with retrieving these wearables from storage, where they were kept for fear of them being lost or stolen if left on the work platform.

Provision of rewards and recognition

Reward and recognition were found to be effective for encouraging ongoing participation in the Study. These incentives included gift cards, free lunches, and program rewards and recognition within the organisation.

Workers using the Sensors benefited from additional incentives and engagement in the form of performance-based challenges, enabled by the data provided through the Sensors. A public graph and leader board was used to create a sense of competition alongside discussion of how high achievers were getting their results, enabling others to learn. The points system built into the Sensor 2 was used in one instance to recognise how well workers were identifying solutions to problems in movement as indicated by the wearables.

Integration into work

Some difficulties were experienced in integrating both the Sensors and Assistive Devices in work within the six pilots. While most of these issues were able to be mitigated for the Sensors through minor interventions, this was not the case for Assistive Devices as they would require changes to design and work process planning.

For the Sensors, consultations with workers revealed that a common barrier faced was remembering to wear it before starting a shift and/or taking it off at the end. This resulted in lower utilisation and compromised data collection. Some participants addressed this by placing their device in a frequented location, such as sign-on stations, for a visual reminder. Pilot managers also played a role in reminding workers to use the wearable, through reminders at pre-start meetings, by placing posters and stickers near the workers' lockers and by using reward incentives for workers who demonstrated consistent utilisation.

The Assistive Devices did face some issues when integrating into workplace processes. Workers suggested Assistive Device 2 needed to provide stronger lift assistance on the arm, and was too warm to wear in hot and humid work environments such as underground tunnels. Workers also reported it was incompatible with their safety harness when using boom lifts. Workers wearing Assistive Device 1 found that it limited the ability to perform some movements such as swings, and required planning the work schedule of tasks to be more effective. Tasks that were compatible with the device did not occur in a predictable and frequent manner to enable the workers to use the wearable continuously.

Technical issues

The wearables also presented technical difficulties in some cases which impacted user experience and utilisation. For the Sensors, these were to do with incomplete software environments, incompatible mobiles and operating systems, incorrect firmware, data upload faults, and some instances of human error (e.g. jamming the chargers into the wearables causing failure). No technical issues were reported specifically for the Assistive Devices.

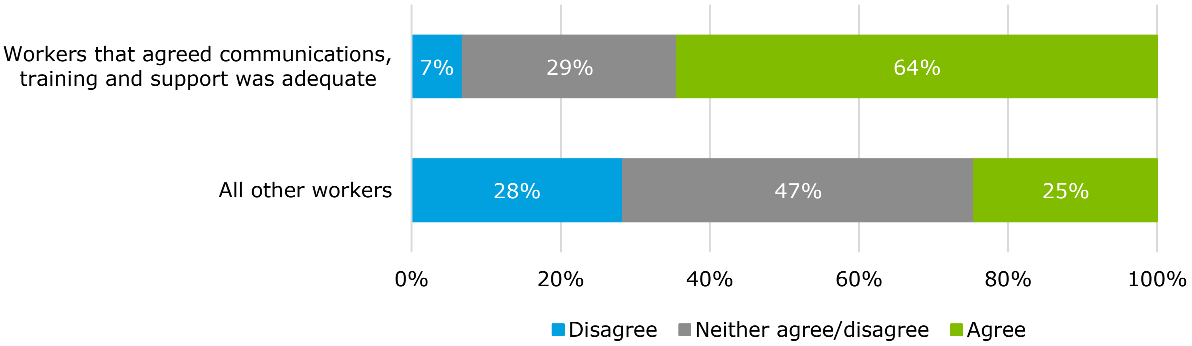
Organisational factors

Characteristics of the pilot managers, such as level of interest and involvement in the pilot, and the role they held within the organisation (in safety or in operation) affected their level of communication with the workers, which in turn impacted the workers' engagement with the pilot. Management's behaviours such as whether supervisors actively participated in the pilot and clearly communicated information also had an impact on the adoption and utilisation of the technologies. A strong WHS culture enabled these behaviours.

Understanding the purpose of the wearables and the utilisation of the data provided by the Sensors also influenced the experience of end users. By providing consistent feedback to the workers on how the data assists WHS objectives, workers are made aware of the importance of risk mitigation at workplaces. Participants also enjoyed additional features such as step tracking. Similarly, significant enablers for the adoption of Assistive Device 1 and 2 were their perceived contribution to mitigating risks and injuries at the workplace.

Chart 3.3 demonstrates that the importance of communication for participating workers when deciding to recommend using the wearable. When the communications, training, and support received was considered adequate, nearly two thirds of respondents agreed that they would recommend their device to colleagues, which dropped to just 25% for all other respondents.

Chart 3.3: Likelihood of recommending the wearables to colleagues, by the quality of communications, training, and support received



Source: Deloitte Access Economics analysis of worker survey data.

3.1.3 Indicator 3: To what extent do employers have to adapt in order to implement/incorporate wearables?

Consultations with employers indicated the introduction of the wearables required provision of resources to enable clear communication with workers throughout the pilot on the purpose of the study and logistics on when the study would take place. Employers also noted the study required training and support for both workers and assigned pilot (change) managers and time for managers to action insights and develop interventions in response to the insights developed from the use of the wearables.

Some participants also stated that they foresaw future changes in workflow processes once high-risk tasks were identified by the wearables. For example, changing the location of palettes to reduce how many times workers have to reach out for items. These workplace design adaptations indicate the willingness of employers to take up the technologies in the longer term, because of the overall effect they have on workplace safety and claims reductions.

However, in some cases, cultural adaptations to motivate workers to adopt and engage with new technology might need to be considered further going forward. Pilot managers indicate that workers can be apprehensive about the introduction of new workplace interventions, especially if they have previously been a part of unsuccessful trials.

3.2 Appropriateness

3.2.1 Indicator 4: How well designed was the pilot?

The key factors influencing the success of the pilot were: clear communication regarding the purpose of the pilot, active leadership, a pilot co-designed with consultations with workers, training and support, and the level of information/feedback workers received of their progress.

Clarity of communication

Clear communication at key stages of the pilot was important to encourage engagement from workers. One key stage is during the introduction of the wearables, where the purpose of the wearables needed to be clear. For example, several participants stated that Sensor 2 was perceived as a performance management tool that tracked work performance. Clearer communication around the WHS objectives of the wearables and re-iteration to the workers on how the data can be used or not be used could have helped to alleviate performance management concerns and improved adoption.

Active leadership

Pilot managers noted that active leadership was as important during the design of the pilot as it was during the implementation. This entailed commitment from relevant senior stakeholder within the organisations – such as the Operations Manager, General Manager, or WHS committee leaders – to establish new workplace safety strategies, or advance existing ones. A part of this was to have pilot managers on site to support the implementation process.

Voice of a Pilot manager:

"Where people participated more, the managers were very involved."

Co-designed implementation

Employers noted that successful introduction of the wearables required co-designed approaches with workers and other stakeholders. One example was Employer 2 (Retail), whose consultation with store manager led to them introducing a strong rewards and recognition program for involvement in using the device. This feature was recognised as contributing to higher worker participation in the study throughout the pilot.

Training and support

Consultations with pilot managers and workers highlighted the importance of timely provision of technical support. This was necessary so that the user experience remains positive, and users remain engaged. One example of effective risk management is arranging with vendors to have spare wearables on site in case faults occur for the wearables in use. The icare pilot manager recognised the need to get this right the first time to prevent disengagement from workers in future trials. An instance of disengagement occurred when workers sought support for skin irritation caused by the Sensor 2 increases as the support provided was inadequate and slow, resulting in the participants dropping out of the trial.

Overall, most participants indicated that the replacement service for faulty wearables was relatively prompt. Where not prompt, COVID-19 could have played a role in delaying support. Workers also stated that while the wearables were mostly easy to navigate, user training before using the wearables was useful and they could have benefited from more of it.

Pilot managers highlighted the importance of having support from vendors and icare, both on-site and off-site. Having support made it easier for pilot managers to troubleshoot with workers when they presented with device faults, and helped them understand and explain features of the wearables. Support from vendors also helped deliver a smooth implementation, despite the uncertainties caused by the COVID-19 pandemic.

Voice of a Pilot manager:

"[We] were able to successfully roll out [the] pilot over the pandemic, despite being unsure how it would be done at many times. We always had the advantage of having someone from [the technology vendor] available which provided much needed support."

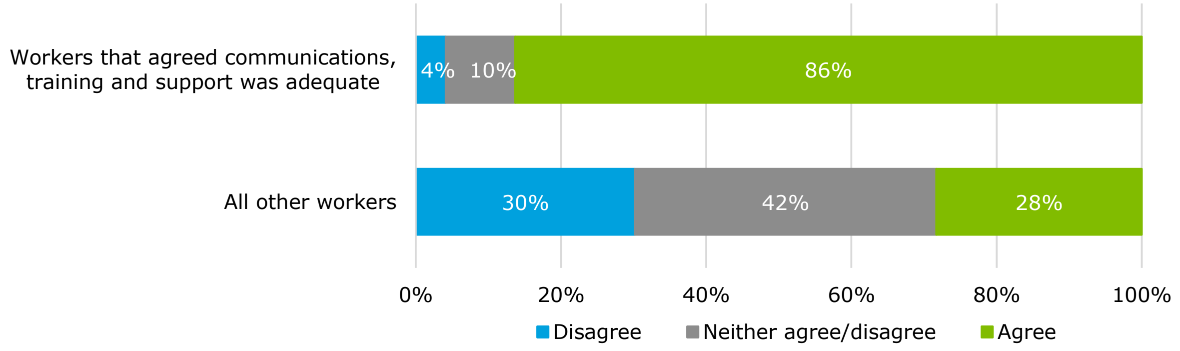
Information/Feedback on progress

Pilot managers identified that receiving feedback on how participants were progressing with mitigating high-risk movements at an individual level as well as collectively as a site was particularly important for the Sensors. Many workers were interested in this, and stated that a visual depiction of the trends around high-risks postures would be a useful motivator for behavioural change, if delivered fortnightly or monthly.

Chart 3.4 demonstrates how important clear communication, ongoing support, and adequate training were to the workers. Among those who at least agreed that the communications, training, and support they received was adequate, 47% strongly agreed that their overall experience with the pilot was positive. A further 40% either agreed or moderately agreed.

This was in stark contrast to those who didn't receive adequate communications, training, and support, among whom the sentiment was much more mixed. While 28% of these respondents at least agreed that they had a positive experience, 30% also disagreed. A much larger share (42%) neither agreed nor disagreed. Notwithstanding the extenuating circumstances of COVID-19 that affected the pilot rollout at some participating employers, this shows that the pilot could have benefited from more standardised training and a greater level of ongoing support for workers.

Chart 3.4: Likelihood of having a positive experience in the pilot, by the quality of communications, training, and support received



Source: Deloitte Access Economics analysis of worker survey data.

3.2.2 Indicator 5: Are the wearables fit-for-purpose?

Overall, the wearables were fit for the purposes of increasing the awareness of high-risk movements, causing behaviour changes both at the workplace and at home, and aiding with high-risk or high injury tasks. Some employers found the wearables to be fit-for-purpose over the duration of the pilot, as they realised the benefits.

Voice of a Pilot manager:

'At the beginning the owners were reluctant as they thought it would take up too much time, take the workers' focus away from their jobs. Over time they saw how it worked.'

How fit-for-purpose the wearables were also differed depended on the nature of the tasks within an industry.

Within the organisations involved in the pilot, the findings for Sensor users was that they were applicable to a variety of roles from dynamic body movements like lifting and walking through to static working postures like sitting. Further, Sensor 2 particularly useful to identify tasks that were associated with repetitive bending at the back, where workers stated they were unaware of these task characteristics were considered hazardous. Pilot managers were more sceptical of the application of the Sensors in office-based roles, where they were seen as being less useful.

Voice of a Pilot manager (regarding Sensors):

"I am not sure about the office environment. In the manufacturing and the manual labour, it is definitely fit for purpose."

The findings for the Assistive Devices were more task dependent than were the Sensors. Workers wearing Assistive Device 1 and Assistive Device 2 (which were both paired with Sensor 1) indicated the wearables were particularly useful for tasks such as drilling using powered tools in tunnel construction environment, and aided well in tasks involving high loads overhead, because of their ability to provide lift assistance.

The usability of the wearables went beyond the individuals who wore the technology – pilot managers identified that the data from the device could be useful to identify risks at the workplace and implement broad changes. Examples of this include moving pallets that workers frequently interact with from a high shelf to a low shelf to reduce injury risk, or understand workflow demands.

Pilot managers also stated that the wearables helped workers understand movements they did not think were classified as high-risk, changing the way they performed their tasks.

Voice of a Pilot manager:

"[The wearables] helped participants understand their movements in a way they didn't expect to. Resulted in people changing the way they moved."

For this Study, the wearables were targeted at industries identified as high-risk. To determine how fit-for-purpose the wearables are, selection criteria should identify overarching industries which can benefit from the wearables, but focus on tasks and roles completed by workers within each industry. Employers could also benefit from undertaking reviews of technological developments in wearables to keep up to date with the types of solutions available, and the outcomes of similar trials that take place locally or internationally.

4 Outcome evaluation

The section of the report covers the aspects of the evaluation that relate to the study's outcomes. This primarily concerns the effectiveness and impact of the wearables, and the extent to which they are scalable and replicable for future broader use. Table 4.1 summarises the relevant evaluation questions and high-level findings relating to the Study's implementation.

Table 4.1: Evaluation of the Study's outcomes

Evaluation domain	Evaluation question	Key findings
Effectiveness and impact	Q1: To what extent do the wearables deliver the desired outcomes?	• The expected short-to-medium-term outcomes from the wearables were increased safety awareness, impacts on task efficacy, and improved physical wellbeing. • For the Sensors, there were statistically significant reductions in the number of hourly alerts received for high-risk postures and high load movements on the arms and back. • Sensors assisted workplaces to identify risk factors in workplace processes and assisted in design of interventions to remove or reduce these risk factors. • While there was no quantitative data provided by the Assistive Devices, consultations revealed they were considered helpful in assisting workers perform certain work tasks, but working conditions needed to be suitable (repetition of the same task involving heavy load) to realise the benefits. • The positive short-term indicators are likely to lead to longer-term outcomes of reductions in injuries and claims, but no conclusive evidence of these outcomes is currently available given the short gap between the completion of the study and this evaluation.
	O2: What are the cultural, social, environmental, and design factors that increase or impact on effectiveness?	**Cultural and social** • Workers who were more engaged with the wearables generally had a supervisor and/or management who was active in the pilot. These supervisors thought creatively about emerging issues with the wearables and provided effective communication and encouragement for their use, such as providing a budget to create incentives. **Environmental** • Most workers found the wearables to be compatible with their work, but some stated they could not be used with certain workwear without causing discomfort. • The installation of docking stations for the Sensors in areas with high foot traffic was effective at reducing the number of times people forgot to wear the device. **Design** • The design of the Assistive Devices made it incompatible with some tasks, such as those performed on elevator work platforms which required harnesses to be worn.

	O3: To what extent are outcomes sustainable in the longer term?	• The outcomes from using the Sensors and Assistive Devices are likely to be sustainable in the longer term, however there are some learnings that could be used when replicating the use of wearables outside of a pilot scenario • Reductions in high-risk postures (Sensor 2) observed during the intervention phase were more likely to be sustained than reductions in movements with high loads (Sensor 1). • A few participants noted that the interest in the Sensors dropped during the pilot. This was partially due to the positive behavioural changes that occurred – meaning that users received less notifications – but also because the novelty of the device diminished over time. • Some workers suggested using Sensors in shorter bursts, for example during peak operational periods to remind workers to be aware of the potential high-risk postures could improve sustainable use. • Some employers suggested using the wearables in alternative ways to expand the potential WHS benefits that could be derived from the wearables e.g. to help onboard new workers by assessing their movements and assisting them adjust to the new job demands.
Scalability and replicability	O4: To what degree are the wearables scalable and replicable?	• Scalability and replicability to other businesses and across industries depends on the technology and the job roles/tasks within the industries. • Employers reported the wearables were able to reduce risks and injuries related to high-risk movements, increase awareness of workplace safety and improve decision making. The employer using the Assistive Device was pleased with the positive results and requested to continue using the technology after the pilot ended. • Key factors influencing the suitability of the wearables for organisations include the nature of the roles and tasks within the organisation, the WHS culture, worker interest, and the capacity of management to engage. • When scaling and replicating the wearables, an effective approach would consider which roles would benefit from the wearables, rather than industries, given the wide-ranging functions within each industry.
	O5: What are the key learnings from the pilot that can translate into future programs?	• Key learnings that emerged from the pilot were the need for a staggered implementation, active leadership, early consultation with workers, and enabling organisational factors that maintain engagement throughout the program.

4.1 Effectiveness and impact

4.1.1 Indicator 1: To what extent do the wearables deliver the desired outcomes?

The expected short-to-medium-term outcomes from the wearables were increased safety awareness, impacts on task efficacy, and improved physical wellbeing.

Safety awareness

One of the primary outcomes achieved through the pilot was an improved awareness of MSD risks among workers. Workers stated during consultations that the Sensor had improved their own safety awareness. Consultations with workers trialling the Assistive Devices found the use of the wearables changed the way workers performed their tasks, and were used to start broader conversations about adjusting work processes to increase WHS.

Voice of a worker:

"[I was] swinging up on the shovel and jamming into the concrete and I realised how many times I was doing that. Using the Sensor made switch to my other arms to avoid doing that too much to reduce the high load alerts."

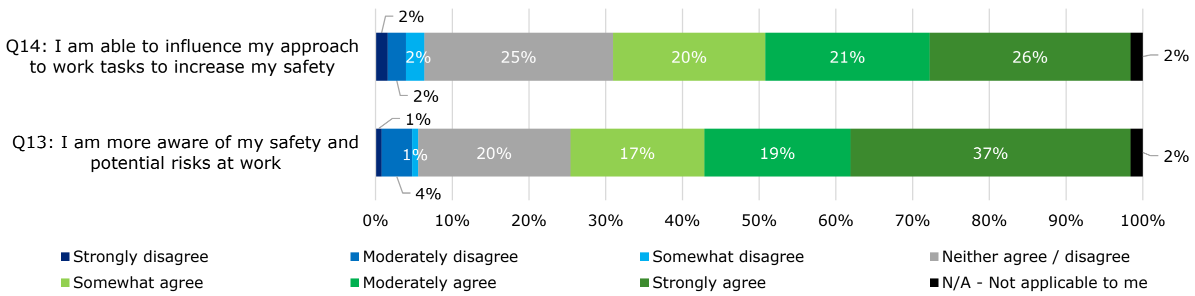
Pilot managers stated that the wearables enabled employers to increase workplace safety in multiple ways. In the case of Sensors, the wearables helped identify the tasks that incurred high-risk postures, the frequency with which workers performed these tasks, which workers performed these tasks the most, and workplace design factors that contributed to the risky movements.

Voice of a Pilot manager:

"Wearable tech allows you to observe workflow demands & the impact of that on [the] workforce where you would only normally be able to observe maybe sales data. Managers can then look at making changes & reviewing them objectively with the tech in 1-2 weeks to see if the changes are effective."

These positive changes were also evident in the end-of-pilot survey data. Chart 4.1 shows that, when aggregated across employers, 37% of respondents strongly agreed that they are more aware of their own safety and potential risks while at work, while just 6% disagreed on any level. The majority of workers also agreed that they can influence their approach to work tasks to increase their safety after using the wearable.

Chart 4.1: Study participants' perspectives on safety and risk awareness and mitigation



Source: Deloitte Access Economics analysis of worker survey data.

The responses to these two survey questions varied by employer and wearable device. While 100% of participants from Employer 6 (Construction) agreed that they were more aware of their safety and potential risks at work, just 36% of respondents from Employer 1 (Manufacturing) gave this response. Meanwhile, 80% of participants from Employer 2 (Retail trade) and 78% of participants from Employer 3 (Wholesale) agreed that they were more able to influence their approach to work tasks to improve their safety.

Pilot managers presented positive results about the role of the Sensors in increasing workplace awareness of MSD risks. The data from the wearables highlighted trends in high-risk work processes or time periods such as stock take. Analysis of the data led to additional training or personalised conversations with workers to avoid these postures and the testing of alternative methods for completing tasks. The pilot managers recognised the importance of having a measurement of high-risk movements from the Sensors in starting these conversations with workers.

Impact on tasks

The impact of the wearable on task efficiency and efficacy was more mixed and depended on the technology and the task.

Users of Sensors stated that the notifications slowed down tasks as avoiding notifications required taking more care to ensure the right posture was maintained. There were also situations in which the task could not be performed in an alternative way, resulting in notifications being dismissed.

Workers reported Assistive Device 1 and 2 made tasks physically easier to perform on average and more efficient when completing repetitive tasks. However, some workers reported that there were occasions where it would be quicker to perform the task without the Assistive Device due to the time required for set up being a barrier. Consultation with the icare pilot manager noted meant the benefit of Assistive Devices increased significantly on the repetitive high load movements. This potentially would require redesign of work task sequencing to maximise the effect of Assistive Devices.

Physical wellbeing

The wearables supported workers' physical wellbeing by either alerting them to high-risk postures and movements (Sensors) or improving their ability to complete tasks requiring repeated heavy lifting (Assistive Devices).

In the case of Sensors, pilot managers noticed workers felt less pain and fatigue as they reduced the number of risky movements they were making.

Voice of a Pilot manager:

"Several people feeling less fatigued at the end of the day as they were handling the product."

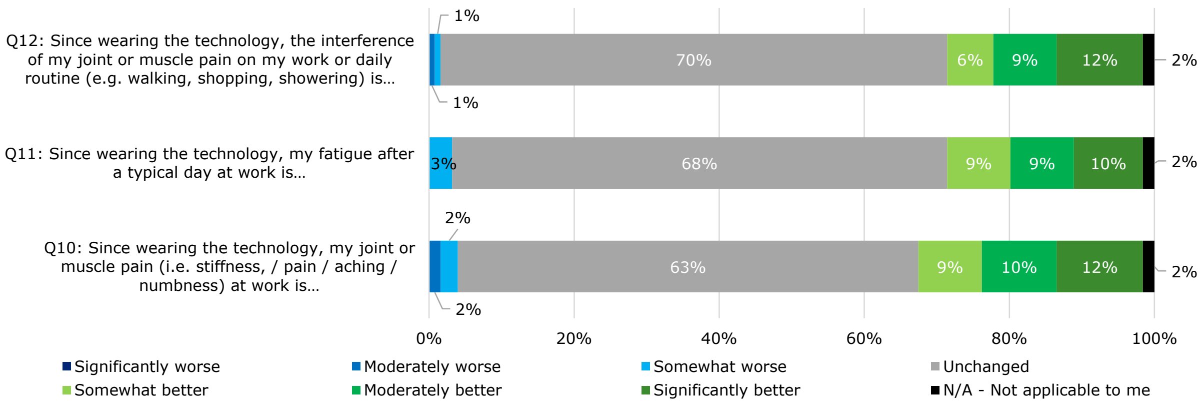
In the case of Assistive Devices, the wearables increased the overall safety at the workplace and made certain tasks (e.g. drilling) easier to perform, resulting in better health outcomes.

Voice of a Worker:

"I am comfortable to use it, I used to have a sore back and sore arm, I don't have those things now."

Chart 4.2 shows that most workers were unable to identify specific changes in their pain or fatigue levels within the timeframe of the study. When aggregated across all participating employers, 70% of respondents stated joint or muscle pain after work was unchanged. Similarly, 68% and 63% of respondents found that their fatigue after a day of work and their pain during work was unchanged, respectively. Consultations did reveal that some worker reported improvements in their joint and muscle pain or their general fatigue experienced after a shift. This was particularly true for users of the Assistive Devices.

Chart 4.2: Changes in joint and muscle pain, fatigue after work, and interference with work tasks



Source: Deloitte Access Economics analysis of worker survey data.

Another key measure of the effectiveness of the wearables is whether they were able to directly or indirectly lead to a reduction of a worker's exposure to force, postures and/or movements that would directly stress the body. As gradual wear and tear is the more common mechanism to develop work-related MSDs, reducing these exposures could lead to more workers experiencing improvements in their level of bodily pain or fatigue over time, and potentially reduce the risks of suffering from a work-related MSD injury and the associated costs to claims and insurance premiums.

Use of Sensor 1 was associated with the following statistically significant reductions in high load movements during the intervention phase of the pilot:

- There was a statistically significant (at the 10% level) reduction in **high arm load counts** per hour among the workers at Employer 1 (Manufacturing) using Sensor 1. Before the intervention period, these workers averaged 27.2 alerts of this nature per hour. This fell by an average of 12.8 during the intervention period. This represents a reduction of nearly 47% in the number of high arm load alerts per hour.
- There was also a statistically significant reduction in **high back loads counts** per hour for users at Employer 1 (Manufacturing) and Employer 2 (Retail). From baseline averages of 63.0 and 52.2 respectively, high back load counts per hour among these workers fell by an average of 35.2 and 13.9. This represents a reduction of 55% and 29% respectively. The results were significant at the 5% level.
- No results for high impact counts on the leg were statistically significant.

Sensor 2 was also associated with a statistically significant reduction in high-risk postures among workers at two of the three participating employers during the intervention phase.

- **Hourly high-risk postures** among device users at Employer 4 (Health and community services) fell by an average of 3.7 during the intervention period. This represents a 36% reduction in hourly high-risk postures from the baseline average of 10.2. This result was significant at the 1% level.
- The rate of **high-risk postures per hour** also fell by 0.7 during the intervention period among workers at Employer 3 (Wholesale). This represents a 15% reduction from the baseline average of 4.7 per hour. This result was also significant at the 1% level.

These results are summarised in Table 4.2. Detailed outputs are available in Appendix A.

Table 4.2: Changes in high load movements and high-risk postures, baseline to intervention

Device / employer	Hourly alert measure	Sample size (N)	Baseline mean	Intervention mean	Attributed change
Sensor 1					
Employer 1	Arm load	242	27.18	15.75	**-12.78***
Employer 1	Back load	240	62.99	31.25	**-35.16****
Employer 1	Leg load	174	1.10	1.12	-0.51
Employer 2	Arm load	1,248	16.54	18.51	2.77
Employer 2	Back load	1,246	51.47	36.35	**-13.95****
Employer 2	Leg load	1,033	0.99	0.94	-0.09
Sensor 2					
Employer 3	High-risk postures	5,470	4.67	3.65	**-0.71*****
Employer 4	High-risk postures	4,322	10.21	6.77	**-3.67*****
Employer 5	High-risk postures	794	5.34	4.96	0.64
Assistive Device 1 and 2					
Employer 6	Arm load	74	68.94	23.39	-18.46
Employer 6	Back load	74	45.12	33.11	-8.08
Employer 6	Leg load	61	0.82	0.61	-0.06

Source: Deloitte Access Economics analysis of device data.

The analysis showed that there was minimal sustained behavioural change in high-risk postures/movements across the participating employers who used the Sensors. This suggests that workers may revert to baseline behaviours in the absence of device feedback, but the results may also be driven by the smaller volumes of data. It should be noted that Employer 6 (Construction) did not collect any data during the sustained behaviour phase of the pilot.

There were a few exceptions where the changes observed in the intervention phase remained statistically significant during the sustained behavioural change phase.

- **High back load counts** were 20.1 lower per hour in the sustained behavioural change phase than the baseline phase among workers at Employer 2 (Retail). This represents a reduction of 36% from the baseline average of 51.5 hourly high back load counts, and the result remained significant at the 5% level.
- Reductions observed during the intervention phase remained statistically significant during the sustained behavioural change phase for Employer 3 (Wholesale) and Employer 4 (Health and community services). Hourly **high-risk postures** were 0.4 and 3.3 lower during this phase than they were in the baseline phase among workers at Employer 3 (Wholesale) and Employer 4 (Health and community services), respectively. These represent sustained reductions of 9% and 33%, results which were statistically significant at the 1% level and 5% level, respectively.

These results are summarised in Table 4.3. Refer to Appendix A for detailed regression outputs.

Table 4.3: Changes in high load movements and high-risk postures, baseline to sustained change

Device / employer	Hourly alert measure	Sample size (N)	Baseline mean	Sustained change mean	Attributed change
Sensor 1					
Employer 1	Arm load	80	27.18	30.18	2.54
Employer 1	Back load	83	62.99	41.47	-20.67
Employer 1	Leg load	56	1.10	1.29	0.35
Employer 2	Arm load	582	16.54	18.10	2.54
Employer 2	Back load	576	51.47	33.21	**-20.06****
Employer 2	Leg load	462	0.99	0.89	-0.04
Sensor 2					
Employer 3	High-risk postures	1,016	4.67	2.58	**-0.41****
Employer 4	High-risk postures	3,905	10.21	7.97	**-3.34*****
Employer 5	High-risk postures	826	5.34	3.16	-0.71

Source: Deloitte Access Economics analysis of device data.

The analysis across both phases was more mixed for Employer 5 (Wholesale) and Employer 6 (Construction). Employer 5 (Wholesale) had piloted Sensor 2, while Employer 6 (Construction) piloted Assistive Device 1 and 2. Several factors affected the implementation of the pilot and ongoing efficacy of the wearables.

- **Employer 5 (Wholesale)** was forced to delay the start of their pilot and reduce its duration due to the impact of COVID-19 on their operations. This meant there was less time available to focus on implementation and adoption which translated into poorer commitment among workers. Due to conflicting operational priorities which resulted in a lower level of investment of time and attention from the management team, it created a difficult environment for workers to realise the potential benefits from the device.
- **Employer 6 (Construction)** was also required to delay the commencement of the pilot as it was coinciding with the Christmas break to minimise the risk of potential disruption to workers' engagement with the wearables. This delay in the calibration phase meant that the baseline phase had to be shortened, again affecting workers' familiarity with the device. This employer also had to reduce the number of pilot sites piloting Assistive Device 2 from two to one and the condensed timeframes proved too challenging to find a replacement site. This, coupled with the shortened duration of their pilot, resulted in a smaller sample of participating workers and total days spent using the device.

Potential longer-term outcomes

The ability of both the Sensors and the Assistive Devices in reducing the high-risk moments in the short-term are expected to translate to longer-term outcomes such as lower work-related MSD injuries.

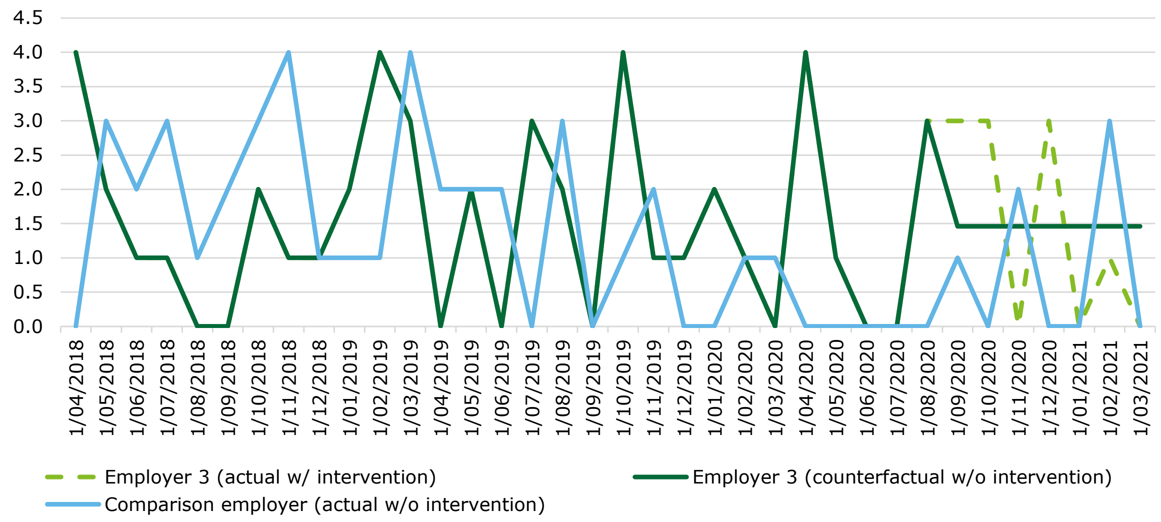
Feedback from the Sensors are would reduce the number of high load movements and high-risk postures made by workers in the short-term. The regression analysis showed this to be true. By reducing exposure to repetitive movement and/or awkward postures in this way, a longer-term outcome that could be expected is a reduction in the number of work-related injuries and associated economic and human costs.

The use of Assistive Devices is expected to directly lead to a reduction in MSD injuries over the longer-term by removing the risks of completing repetitive, heavy tasks by those workers wearing the wearables.

Workers Compensation claims data for the six participating employers were analysed to determine if any evidence of such a trend had emerged. Each of the pilot employers was assigned a comparison employer that operated in the same industry and was of a similar business size. Only claims for either 'traumatic joint/ligament and muscle/tendon injury' or 'musculoskeletal and connective tissue disorders' were considered relevant if the mechanism of injury was 'body stressing'.

Chart 4.3 presents three years' worth of data for claims of this nature for Employer 3 (Wholesale) and its comparator. The broken green line shows the actual number of claims that were recorded during the intervention and sustained change phases of the pilot. The darker green shows the same series up until the end of the baseline phase, at which point a monthly average of the baseline and one-year prior was applied to establish a counterfactual.

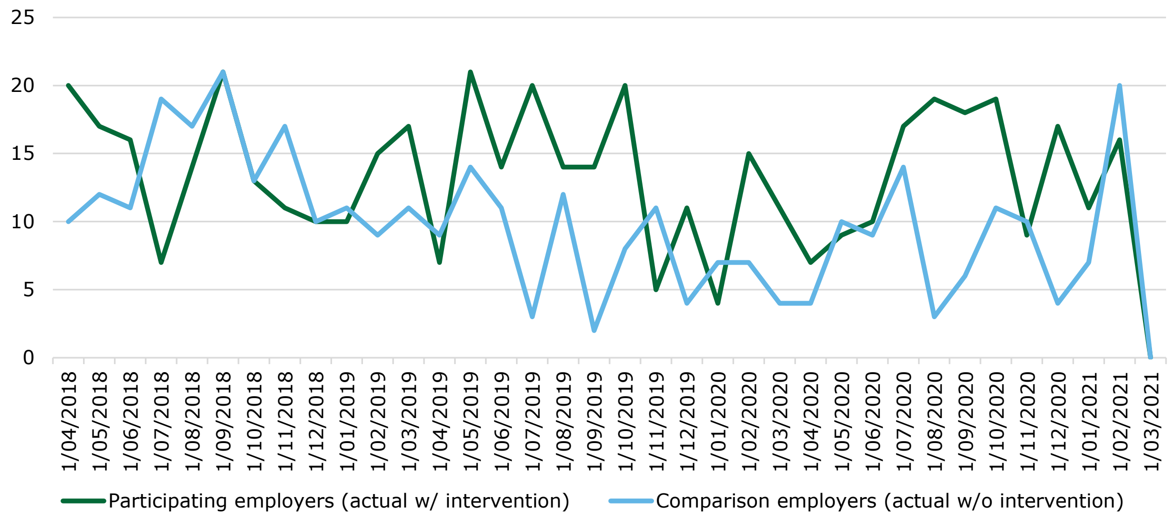
Chart 4.3: Monthly work-related MSD claims for Employer 3 and its comparator



Source: Deloitte Access Economics analysis of injury claims data.

Both data series exhibit a high level of volatility month-to-month but do appear to be correlated. This suggests there could be specific time periods with higher numbers of claims on average. Nonetheless, the volatility of the data makes it difficult to establish a clear trend that may be attributable to the wearables. While there is some evidence from the last two months of the claims' data that a downward trend may be emerging, it is too brief to be attributed to the wearables themselves and could simply be random variation. Chart 4.4 demonstrates that the significant noise in the data remains when the monthly data is aggregated to include all participating employers and their comparators.

Chart 4.4: Aggregated monthly work-related MSD claims



Source: Deloitte Access Economics analysis of injury claims data.

It was unlikely that an attributable reduction in work-related MSD claims would have emerged at this stage for three reasons.

- The relatively short timeframe of the study means that changes during the intervention phase cannot be observed for long enough to rule out the possibility of random variation.
- With only a short amount of time having elapsed since the completion of the study, injuries that occurred among comparison workers in recent months may not have materialised as recorded claims yet.
- The timing of the intervention phase varied between employers, meaning that a consistent break in the trend cannot be observed in aggregated data. This made it difficult to overcome the small sample sizes for any one employer and the number of claims in their whole workforce.

If a longer intervention were to be conducted and the timing of this phase was to be aligned across participating employers or all workers participated in the study, a material change may be observable in aggregated data. It is also likely that a longer period between the pilot and the analysis would be beneficial as there are often time delays in injuries being recorded as claims.

4.1.2 Indicator 2: What are the cultural, social, environmental, and design factors that increase or impact on effectiveness?

Cultural and social factors

Consultations with the icare pilot manager indicated that active supervisors or management was a key factor to maintain engagement with using wearables and their effectiveness. These leaders were key to addressing any issues with the wearables – such as technical faults and providing clear communication about the importance the wearables and using incentives to encourage ongoing feedback to workers on the use of the wearables

Beyond active leadership, consultations suggested a well-established existing culture of WHS was useful supporting the adoption of the wearables. One employer noted that previous engagement with workers on WHS initiatives made the introduction of wearables a continuation of broader policies and a signal to workers of commitment to their safety. Conversely, some workers indicated hesitation to using the wearables because of the potential to track performance. It was noted that this hesitation could be mitigated with clearer and ongoing communication about the WHS objectives and potential benefits of the wearables on workers’ health and safety.

Environmental factors

Most workers found the wearables to be compatible with their work tasks. However, some workers stated they could not be used with certain workwear without causing discomfort. The icare pilot manager and worker consultations noted that the sequencing of tasks required frequently putting on the wearable and taking it off for other tasks. The lack of nearby storage facilities concerned workers about theft of the expensive equipment. Redesign of work task sequencing could be used to mitigate this issue.

A key environmental factor that would have enhanced the effectiveness of Sensor 2 is the installation of docking stations in a location with high foot traffic. This would help workers remember to equip and unequip the device at the start and end of their work shifts, which would improve utilisation.

Design factors

Workers commented on two key design features of the wearables that impacted on their effectiveness – compatibility with tasks or work attire requirements and device comfort. Across all the wearables, workers reported that they were, on average, compatible and suitable for the tasks they performed.

There was negative feedback received about issues with the design of the wearables. Participants who were not able to mount Sensor 2 onto a belt also commented on the design of the clasp as being protruding and uncomfortable on the skin, with one participant stating they took the device off during long shifts because of the marks it left. There was no design issues noted about Sensor 1.

There was also feedback on the design of Assistive Device 1 and 2, suggesting it could be made more robust to enhance the effectiveness on high loads, and to ensure they do not detach unsafely when in use. Some participants also stated that Assistive Device 2 was not compatible with certain work apparel. For example, workers could not wear Assistive Device on elevated work platforms which required safety harnesses to be worn. There was also some discomfort resulting from Assistive Device 2 from heating on the back from prolonged use.

4.1.3 Indicator 3: To what extent are outcomes sustainable in the longer term?

Continued monitoring will be required to assess whether the reduction in risky postures and load translates into longer term outcomes – such as reduction in work-related MSD injuries and claims. This will require a significant share of the workforce using the wearables to have a large enough impact on the injuries and claims data.

Improved outcomes over the longer term could be assisted by developments in wearables. Improvements or new innovations in wearables could make them more appropriate for certain workplaces or more effective in monitoring outcomes. Employers seeking to use wearables should undertake a market scan for wearables that are most appropriate to their circumstances.

In terms of workers' perspectives on maintaining sustainable outcomes, a few noted that the interest for the device dropped over the lifecycle of the pilot, specifically for the Sensor 2. While this was partly a result of positive behavioural changes that resulted in less frequent notifications, it was also a product of diminishing novelty of the device.

Some pilot managers and workers suggested using Sensors in short bursts so workers are reminded of high-risk postures, but do not lose interest in maintaining good postures. This would help ensure the sustainable use of the wearables and prevent relapse into risky movements. A pilot manager suggested the device be used as part of an onboarding process whereby a new worker is made aware of the risks of their role.

Voice of a Pilot manager:

"I don't think it's something that should be worn 100% of the time. I believe it's something that should be used in training new people starting new jobs…when you're able to track [high-risk postures] in a new way, their movements & so on."

4.2 Scalability and replicability

4.2.1 **Indicator 4: To what degree are the wearables scalable and replicable?**

The Study was one of the first assessments of worker acceptance of wearables in the workplace. Consultations with workers from all employers indicated they would be advocates for the rollout of the wearables they piloted to other employers in their industries, either in the current state the wearables are in, or after receiving more feedback about their long-term impacts.

Scalability and replicability to other businesses and across industries also depends on the technology and nature of work being completed. Sensor 1 and Sensor 2 was trialled in a variety of job roles/tasks that involved repetitive movement and sustained and/or awkward postures and could be applicable to several industries. The replicability of benefits for Assistive Devices is relatively more task specific, with greater applicability repeated movements involving heavy objects, such as repetitive drilling tasks in overhead postures and carry heavy loads. When scaling and replicating the wearables, an effective approach would be to consider which roles and tasks would benefit from the wearables, rather than industries, given the wide-ranging functions within each industry.

During the consultation with the icare pilot manager, it was recognised that staggered implementation of wearables to greater numbers of workers could assist in the successful introduction of the technology. The staggered implementation could assist in identifying and addressing any emerging issues with the wearables. This was particularly relevant for one pilot that saw a large number of technical faults with the wearables that led to a reduction in usage by workers. If the issue had been contained to a smaller number of workers, the effect on the rollout may have been minimised.

Using the wearables also requires a well-established WHS culture to encourage adoption. The WHS culture can support the introduction and trialling of innovative solutions such as wearables. For Employer 2 (Retail), this existing culture was referenced as a key driver for the quick and widespread adoption of the wearables.

Key personnel or management with the right capabilities to support the use of technology is a key factor in replicating the more successful pilots in the Study. For all the wearables, pilot managers required a proactive interest in addressing WHS issues. For the Sensors, a level of data literacy was useful to maximise the potential benefits from the wearables while Assistive Devices would have benefited from pilot managers with a more organisational focus to redesign workflow sequencing to facilitate longer, uninterrupted time using the device.

4.2.2 **Indicator 5: What are the key learnings from the pilot that could translate into future programs?**

Workers who participated in the study indicated they would be advocates for the rollout of the wearables to other employers and industries. Yet there are key learnings in the deployment of wearables in the workplace that should be considered. These include the need for a staggered implementation, active leadership, early consultation with workers, and enabling organisational factors that maintain engagement throughout the program.

A staggered implementation would enable employers to better manage and support program participants, with smaller cohorts to manage. By implementing the wearables by cohorts, employers have the opportunity to iterate on the learnings from each cohort, before moving onto the next one. Active leadership played a significant role in the success of the pilot, where leaders who were engaged and had the right skillset to effectively communicate the benefits of the program saw better engagement from the participants. Other enabling factors to consider for future programs include ongoing communication and support during key stages of the program, and worker perks to maintain enthusiasm throughout the trial.

5 Case study: Employer 2

Success factors when piloting wearables for workplace injury reduction.

5.1.1 Background and context

The following case study explores a best-in-class introduction of wearables for prevention of work-related MSD into a workplace. It is an output of a pilot project which formed part of a study, commissioned by icare, to investigate the efficacy of wearables in reducing the risk of work-related MSD injuries/claims. The study spanned five high-risk industries, across multiple workplaces and sites, between 2020 and 2021 and was undertaken in association with Deloitte.

Existing literature in the field of wearables for the prevention of work-related MSD prevention is limited and has focussed on wearables, device data and health outcomes. This case study is intended to complement the existing evidence base and will focus on the successful management strategies and interventions that enabled successful adoption, usage, and efficacy as part of the study.

The purpose of the case study is to outline how Employer 2 successfully piloted Sensor 1 across seven retail and trade stores in NSW. The pilot involved 49 voluntary participants who completed a 12-week trial of the device. Participants undertook tasks including timberyard labour, administration, forklift operation and driving. Sensor 2 is used to monitor upper body movements and alert users of potentially high-risk postures and movements, such as bending, twisting, and overreaching. Feedback or alerts are received via a mobile phone, which is used to pair the back and arm wearable Sensors, which also collects device data and produces insights, notifications, and training content. Employer 2 also had access to an analytical dashboard which collates the data collected from the participants and enables Employer 2 to analyse and develop actionable insights.

The case study focuses on:

- The decisions and behaviours made by the employer that led to successful outcomes. These success factors include, but are not limited to, a high cadence of communication between workers and management, provision of rewards and recognition to motivate workers, and personalised training and support throughout the study.
- The measures of success related to the project's delivery specific to Employer 2's performance. Notable measures include uplifting worker perceptions of management; improved worker engagement and adherence to WHS processes and practices; and reductions in exposure to risk factors such sustained and/or awkward postures, reported accidents and injuries, and injury claims.

The findings are intended to be used by other organisations looking to leverage wearables to prevent work-related MSD claims. This best-in-class example of how to introduce wearables into the workplace demonstrates how to effectively implement wearables, and how they can be used to complement existing WHS strategy and initiatives.

5.1.2 Success factors

Employer 2 used several management strategies and interventions that were aligned to and supported their WHS strategy. These, along with the pilot design and implementation guidance provided by icare and the technology vendor, led to the successful introduction of Sensor 2.

The key practices included were disclosed by members of Employer 2's team during evaluation interviews as part of the MSD Wearable Study. They reflect views and attitudes from across the organisation including WHS management, operations, store management, and worker participants.

The findings can be categorised into five key implementation factors, each of which was reported by interviewees as being integral to the successful adoption, usage, and efficacy of the study.

Worker-led, enabled by decision makers and leaders with connection to organisational strategy and WHS initiatives:
The study was enthusiastically adopted by Employer 2 and leveraged as part of its existing WHS program of work. This program focuses on preventative policies and practices to reduce workplace injuries. They also responded to feedback from workers on what they would like to see regarding WHS at the organisation. Employer 2 believed it had a mature WHS program, was familiar with the concept of wearables and had undertaken previous pilots using different wearables.

Employer 2's WHS champion saw the wearables as an opportunity to embed, reinforce, and improve upon existing WHS practices that were being rolled out across their sites. The wearables informed and reinforced a culture of behaviour change and ground-up improvements driven by data across different sites, including at an individual worker level. The wearables were described as "empowering" store management to make changes to their stores using the device data and interactions with team members.

"The organisation wanted to invest in making genuine change; engineering changes to stores, reducing hazards to then focus on driving sales. The program was not just about the gimmick of new technologies."

Participation rates at Employer 2 remained consistently higher than other pilots throughout the study. Worker participation was voluntary, and some individuals who were not initially involved in the pilot later put their hand up to take part. This worker retention was attributed to the level of capital investment made in the necessary items to embed the technology and the clear engagement from the executive.

High quality, regular, multi-level communications, and engagement:
Employer 2 introduced a thorough communication and engagement plan their pilot, anchored to the intention of consulting across the workplace. The focus on consulting ensured the broader organisation remained engaged in leveraging the technology, enabling buy in and benefit realisation. The communication and engagement plan included early stage conversations between store managers and workers and flyers in store lunchrooms to generate initial interest.

Once a reasonable representation of workers had shown interest in involvement in the pilot, a face-to-face briefing for potential participants was facilitated by the technology vendor. This was supported by the store manager, operations management and WHS leaders. The session focused on 'setting the scene' and providing an end-to-end walkthrough of the pilot. This included a demonstration of how to use the technology, a discussion of privacy issues and data security protocols, the benefits of participation, the opt out process, and concluded with Q&A. The session had the right intent from the start and trust across workers was high.

Store managers involved in the pilot recognised that their role was to engage and motivate the workforce to participate and maintain involvement throughout. Pleasingly, there was a low opt out/dropout rate across the pilot at Employer 2. Additional communication and engagement included weekly store-by-store challenges with a public graph and leader board to create a sense of competition. There was discussion of how high achievers were getting their results, enabling others to learn.

Individual coaching conversations took place with individuals for whom there had been a higher than average number of high load movements recorded. These conversations focused on discussing the data and working with the individual to identify the root cause of these movements and assist the individual with injury prevention strategies. There was hands-on support from the technology vendor to ensure technology was working, troubleshooting took place when needed and when issues arose there was a swift resolution (e.g. a two day turn around for any fixes or new wearables required).

There was also a working group of WHS management, operations and store management, and workers, as well as icare and the technology vendor. The working group had a weekly call to share learnings, scale practices that were working well and to support stores requiring it or to resolve issues that arose. Recording data early enabled the pilot to deliver targeted interventions across the workplace. These impacted the experiences of participants and provided evidence of the impact of their involvement at an individual, store, and organisation-wide level.

"The weekly team catch-ups showed value in getting the [wearables data] to corporate from the workers. The learnings were shared across all pillars of the business."

Workers spoke favourably of the communication processes throughout (e.g. the initial demonstration of Sensor 2 and the hands-on workshop). Because of this, most workers understood the intention of the pilot and what was expected of participants.

"One example of a useful topic discussed in these meetings was when we looked at the top three high load movements across stores in contrast to the equipment held by each store and this informed if new equipment may be needed. Specific to store X was the purchase of a new adjustable height trolly that better supported workers to put things in and out of pigeonholes. Data was also used to track the impact of the new equipment in store, which results did improve."

Individuals empowered to act to improve safety, supported by rewards and recognition

Employer 2 used 'Team Talks' to discuss store-level data insights. These were conducted in either the yard or the lunchroom in the form of an open conversation among all participating members of the store team. The sessions focused on areas of concern (e.g. an exceeding number of high load movements in a certain area) and aimed to identify what had been driving the results.

Through these discussions, team members were empowered to identify potentially new risk factors and/or discuss aspects of their job tasks that were contributing to these high load movements (e.g. jumping off the forklift without three-point process) and the safest operating procedures would be highlighted amongst the team. Data would then be monitored in the weeks that followed, and there would generally be a noticeable reduction in the alerts. Pleasingly, individuals were speaking up about their own results and being open to sharing and committed to changing behaviour.

"[In doing coaching] I saw what their form is, where it is [in the yard], then I'd ask them and say "Hey, what were you doing today?" to understand what actually happened."

Employer 2 also introduced recognition and rewards. These were initiated by workers and store management, and they served the dual purpose of building accountability as well as driving engagement. Both goals were realised with store managers engaging in the pilot's coaching sessions and 50 participants volunteering to complete the pilot – 135% of the required audience. The recognition and rewards consisted of weekly store-by-store leader boards showcasing individual performances and individual coaching conversations. Gift cards and raffle tickets were provided to all participants as a thank you, and a lucky draw was awarded to one participant at the completion of the study.

WHS management, and operations and store managers received recognition from across the organisation for their innovative approach to WHS. Management was praised for their hands-on approach and for sharing learnings with other functional areas to scale the impact. They frequently engaged (both physically and virtually) with workers to provide support and swiftly responded to insights from device data. This included investment in new equipment, and in the design and delivery of training modules.

Personalised and timely training and coaching with an emphasis on continuous improvement

The pilot introduced new training and development opportunities for Employer 2 which were successfully leveraged during the program. The data captured by Sensor 2 was communicated across multiple levels at the organisation.

Data and insights from the pilot were communicated through multiple channels. This included a dashboard, reports, working group meetings, phone conversations, emails, videos, and site talks. The insights were used to share participant behaviours, alignment (or misalignment) with safe practices, trends over time, and both inter- and intra-store comparisons.

"This pilot really worked as it was hands on and practical, not a flyer or handout that was just left for you to interpret yourself and action."

"We've had people really think twice about their movements now."

Coaching sessions led to store practices evolving and behaviours to standard operating practices (SOPs) changing:

"You can see when they're actually picking timber off the shelves and stuff like that; they're not rushing, they're standing the right way - how they're supposed to - and bending down when they need, too."

Workers used the accompanying mobile application to view their personal data and were also provided regular app-based quizzes to reinforce personalised education and training. Notifications would be activated if quiz completion had not taken place. Individual technical assessments were also conducted more frequently, targeted at the individuals who were at the greatest risk. Device data was used to inform which task and movements should be the focus of the assessment, with individual device data then monitored following assessment to see if there had been behavioural change that results.

Workers noted that they saw a place for having individual or store-based targets and goals specific to high load movement reduction and tracking against these. They also noted that it would be good to have wearables available for new workers over a series of months so they can see how they are performing and for coaching to be put in place early if there is anything needing to be corrected.

Participative management that utilised data to action change:
Employer 2 made significant investment in leveraging the data gathered by the wearables, turning it into actionable insights to implement across the organisation. WHS and operations management worked with store managers and workers to develop and design new handling practices. They also invested in equipment to reduce the number of high-risk incidents reported. This ground-up approach aligned with the organisation's WHS approach and was new to the organisation.

"We had the backing to consult with our workers around what equipment will assist in high load movements or make their job more efficient. [We were] able to tailor our investments and build our own equipment from the ground up."

As discussed by the WHS Champion, this utilisation of the insights impressed the fact that the wearables were not generating "data for data's sake" but rather tangible changes were being made to improve the safety of the teams.

Store managers and workers valued the regular presence of WHS and operations leaders on-site. These visits were made to discuss insights, discuss root causes, and provide awareness of resources available to drive improved practices. Multiple workers noted that the study was not done to them but instead very much with them. They felt their voices were heard and suggestions were taken onboard and, where appropriate, led to decisions to change equipment or practices.

Some store managers participated in the pilot which enabled them to show leadership in WHS and use personal examples in conversations with team members demonstrating vulnerability and that they were learning and changing too.

"Store Managers and Assistant Mangers need to be part of the study as a participant not just watching their team's data and performance to make it impactful."

5.1.3 Measures of success

The effective rollout of Sensor 2 by Employer 2 is evidenced by several successful outcomes. Measures include both lead and lag indicators that outline the effectiveness of different aspects of the pilots roll out, as well as the wearables themselves. The outcomes may be consulted as a list of opportunities and goals for organisations looking to trial wearables in other workplaces.

Employer 2 reported the following list of benefits from participation in the pilot:

Table 5.1: Benefits from Employer 2's participation in the pilot

Successful outcome	Examples of behaviour
Significant improvement in worker perceptions of management and engagement.	*"Leaders are coming from the heart – pushed to make sure they achieved the outcomes."*
Significant reduction in incidents TRIFR.	*"People [are] thinking of what they're doing now, it's a lot safer."*
Improved workplace safety practices.	Increased WHS focus in store: "Empowered leaders to make changes [and remove risks]." Training life cycle: "For new workers, I think it should be mandated that they wear it for three months to really see their bad habits, and then show them the [right] ways." Continual improvement coaching: "[We should be using] it randomly - not sticking with it. Use them around the network, have targets, then come back with the next target after three months, and then tackle that." Safer stores: "We came up with different trolleys for different stores to […] fulfil the needs of each store" Improved technical reviews: "People saw value in doing coaching and [technique reviews] where a leader watches the participant to do their job. That was a new concept in the smaller locations."
Reduction in high load movements recorded by Sensor 2.	29% reduction in hourly counts of risky "high back load" alerts, vs prior state. 121% reduction in hourly counts of risky "high leg load" alerts, vs prior state.

Voice of WHS Management:

"MSD risk is our main risk; our awareness was already high, but a change of habits [has] occurred."

Voice of a Store Leader:

"For me, [the best aspect] was the positive [relationship] between the workers and myself and it really broke it down to a level of informal - but very positive - and very results driven conversations. That's why we got the engagement from the guys. […] It was good that way because it's very hard to get guys - especially yardies - to really open up and say "hey I'm doing something wrong", you know it's hard for a lot of people to be able to do."

Voice of a Worker:

"For me it was more that I'd like to lessen the impact and risk of myself getting hurt. There are a lot of older guys here who've been here for a while that have been doing the wrong procedures for a while. And you can obviously see that, and their backs are playing up. I want to lessen the risk of any kind of injury like that as much as possible - so this was great for me to be aware of and to know what to do, from the data."

Employer 2 delivered a best-in-class study on the impacts of wearables with their workforce by employer effective project delivery methodologies. The success factors and measures of success highlighted in this case study provide a range of leverageable opportunities for other organisations interested in introducing wearables.

Employer 2's use of wearables was purpose-driven by an engaged leadership team and fostered their new ground-up approach to WHS. Encouraged by recognition and rewards; workers maintained high engagement with the wearables. This provided rich user data that was leveraged to deliver new safety focussed features across the workforce. Outputs such as specialist trolleys and tailored manual handling training reinforced the value of the wearables to the broader business, solidifying ongoing engagement.

Top tips for the effective delivery of a wearables study of this nature:

1. Leverage wearables as part of the organisation's broader WHS strategy to connect the purpose to the bigger picture.
2. Apply wearables that solve for specific and targeted behaviours to maximise worker participation and injury reduction.
3. Attain senior leadership buy in to drive sponsorship and appropriate investment.
4. Listen to and engage workers in design, implementation, and evaluation to promote adoption and effectiveness.
5. Communicate personalised wearable data insights and trends regularly by functions and individuals.
6. Use device data to identify and fix factors that are making a task unsafe in the workplace and monitor and communicate the impacts.
7. Use device data to inform training requirements to focus on the areas that matter most.
8. Use wearables at different times of the worker lifecycle to address different needs (e.g. onboarding, rectifying risky postures, change of roles).
9. Incentivise engagement with recognition and rewards to build momentum and to showcase positive role models.

6 Conclusions

6.1 Evaluation findings

This evaluation contributes to the evidence base regarding wearables and their potential role in the prevention of work-related MSDs. The evidence on the impact of wearables is mostly restricted to experimental settings and few studies have considered worker acceptance of using these innovative technologies. This study has aimed to fill these gaps in the evidence base to support potential employers considering their use. It has done so by assessing four wearables in real work contexts and conditions.

The analysis contained in this evaluation has supported the two initial hypotheses originally set out for this evaluation. All four wearables improved identification high-risk tasks or workers and effectively eliminated or reduced risk factors which could increase injury risk of work-related MSDs.

The two Sensors were found to have statistically significant reductions in high-risk movement. Assistive Devices were effective in supporting workers by reducing the force required to perform certain tasks that may be hazardous. Employers for both Sensors and Assistive Devices noted that the use of wearables were used to identify or start conversations about improving workplace design, processes, and practices to increase safety. The findings from the evaluation emphasise the important role wearables can have as part of an employer's broader WHS toolkit.

The data collected by Sensors also provides scope to personalise safety interventions. The evaluation found several examples where training and information sessions were targeted at specific worker types or areas of the participating businesses based on the available data. This level of personalisation in safety messaging can help to uplift effectiveness and achieve greater

Across the wearables, consultations with workers and post pilot surveys indicated interest in ongoing use of wearables.

Yet the introduction of wearables alone may not be sufficient to bring about risk reductions. Broader organisational factors have a significant bearing on whether desired outcomes are achieved. Active involvement of management, effective communication, training for workers, and technical support are all key enablers required to realise the benefits from the wearables.

There were several limitations associated with this evaluation. This evaluation took place during the COVID-19, which diminished the quality of the technical support that could be provided by the technology vendors. During two of the pilots, some of the Sensors experienced technical issues for a range of reasons that led to instances whereby the wearables did not record data and/or provide feedback to workers. More broadly, the study focused on changes to high-risk movements and risk factors with some changes to the physical work environment. The study did not focus on psychosocial hazards such as extent of work or organisation of work.

6.2 Considerations for adoption or scaling up use of wearables

For businesses considering use of the wearables to reduce work-related MSDs, there are a number of important considerations to ensure their introduction is effective. There is no one size fits all approach to using or implementing wearables, but the below questions can be useful as a starting point.

1. **Would the common tasks in my workplace benefit from the use of wearables?** Sensors were found to be useful in a range of manual tasks that are broadly applicable to a range of tasks, workplaces and industries. The Assistive Devices were trialled in the construction industry and were found to be most beneficial for repeated heavy lifting. Considering workflow sequencing will be required to maximise the benefits from these wearables.
2. **How does the wearables fit into my broader WHS culture and strategies?** Wearables alone will not eliminate work-related MDSs. Thinking holistically about the role of wearables in

supporting other initiatives or considering how using wearables could be seen as a tangible action to implement a strategy could support adoption by workers.

3. **Have you listened to an internal perspective?** Before investing in wearables, consider consulting with workers to identify issues and the requirements of the solution. Clear and early communication will assist in creating transparency in motivation for considering wearables and may lead to improvements in their implementation.
4. **Who is the relevant expert?** Wearables are an innovative technology solution with fast paced developments in features and capabilities. Getting outside assistance to understanding the market and current capabilities will be necessary to ensure selecting a solution that is the best fit for the business and workers.
5. **How can I design the rollout to maximise use of the wearables?** Staggered implementation could allow for any lessons learnt before widening the use of wearables to additional workers or units within the business. Early trials and allowing time for testing wearables and calibration may result in more positive experiences for workers and implementing any required solution before an issue escalates.
6. **Does my team have enough time and the right capabilities?** Introducing wearables can require significant upfront investment of supervisors and manager, this is particularly true for businesses without prior experience with wearables. Early experiences with the wearables may influence ongoing perceptions about them and having training and technical support available could encourage positive experiences. Ensuring managers have the right capabilities – such as data analysis for Sensors or work flow organisation for Assistive Devices – could assist with maximising the benefits from using the wearables.

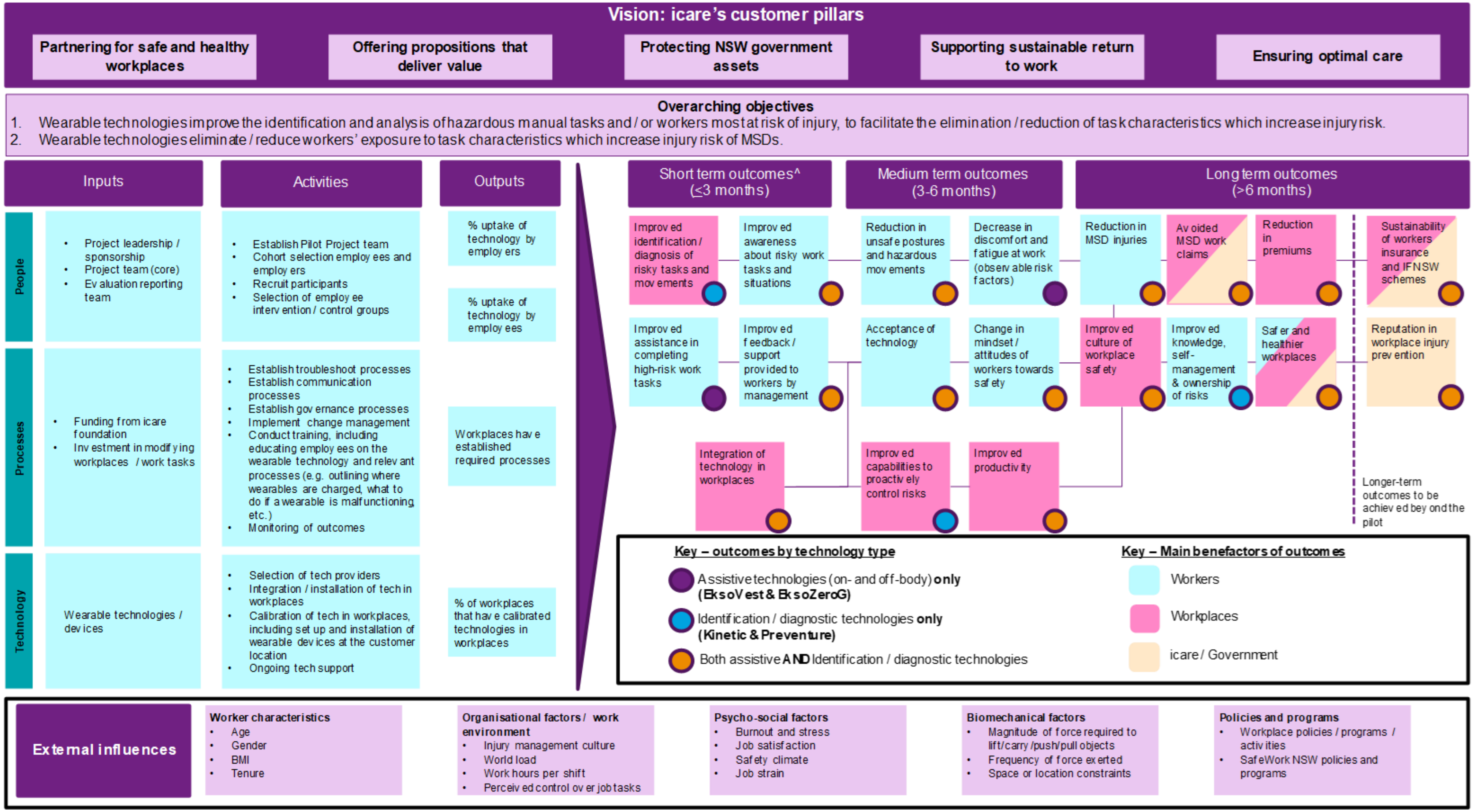
Appendix A : Program logic

The program logic for the MSD Wearable Study was developed using a combination of existing icare documentation, findings from the literature and stakeholder input, including an Evaluation Design Workshop with representatives from icare. Figure 5.1 provides the program logic. The program logic covers longer-term outcomes of the program that may not necessarily be achieved as part of the pilot project.

The program logic is organised into the following key categories:

- **Vision** – the broader, organisation-wide vision of icare, expressed in terms of icare's five customer pillars.
- **Objectives** – the overarching goals and aims of the program.
- **Inputs** – describe the funding and other non-financial resources that have been allocated to the program.
- **Activities** – describe the activities and processes involved in delivering outputs.
- **Outputs** – describe the services, deliverables or units of delivery generated by the program.
- **Outcomes** – the impacts or consequences of the outputs defined in accordance with the program objectives over the short, medium and long-term, defined as a change in state.
- **External influences** – factors that are outside the control of the program that can affect the achievement of outcomes.

Figure 6.1: Program logic



Appendix B : Detailed description of piloted wearables

Table B.1: Wearables piloted in the MSD Wearable Study

Wearable device	Body part	Task characteristics	Main purpose	Output
Sensor 1	Back, arms and legs	Repetitive movement (range and quality) Sustained and/or awkward posture High or sudden force (to legs)	Continuous monitoring Task-specific assessment Data analytics and insights to inform potential ergonomic / work design	Unit of measure: High load count[12] Data on workers' movements and postures made with high loads on the back, upper arms and/or legs are either collected continuously during work shifts or point-in-time (including video recording of worker) performance of specific work tasks. Data is uploaded to a cloud-based, web dashboard.
Sensor 2	Low back	Repetitive movement Sustained and/or awkward posture	Continuous monitoring Data analytics and insights to inform potential ergonomic / work design	Unit of measure: High-risk posture Data on workers' movements and postures are collected continuously during work shifts. Data is uploaded to a cloud-based, web dashboard.
Assistive Device 1	Upper body	Repetitive or sustained force High or sudden force Sustained and/or awkward posture	Reduce muscular effort	Unit of measure: All data collection focused on workers' perception of, and experiences with, the wearables. No quantitative data regarding muscle activity and/or metabolic cost was collected.
Assistive Device 2	Upper body	Repetitive or sustained force Repetitive movement Sustained and/or awkward posture	Reduce muscular effort Reduce	Unit of measure: All data collection focused on workers' perception of, and experiences with, the wearables. No quantitative data regarding muscle activity and/or metabolic cost was collected

[12] High load counts for the arms and back were calculated using thresholds from the International Organisation for Standardisation (ISO). These thresholds were used to program when alerts would be received, and these alerts were summed across the duration of a worker's shift. High load counts for the legs were calculated using the same methodology, however there is no such internationally standardised approach for high impacts on the legs. High-risk postures were determined based on built-in mapping of unsafe biomechanics (e.g. bending, overreaching, twisting) that, when recognised by Sensor 2, lead to an alert.

Appendix C : Evaluation framework

Table C.1: Implementation evaluation indicator framework

Key evaluation question	Indicators	Data sources
Adoption & Feasibility		
I1. Is the technology safe, acceptable and feasible?	• Perspectives on the safety of the wearables • Perspectives on the willingness to wear the wearables and participate in the pilot	• Consultation with pilot managers • Consultation with workers • worker survey
	• % of employers in the pilot that implemented the wearables • % of workers within a workplace who participated • % utilisation of wearables	• Quantitative data from wearables
I2. What are the barriers and enablers to successful adoption and utilisation?	• Perspectives on the key barriers and enablers faced by workers and employers in implementing the wearables	• Consultation with pilot managers • Consultation with workers • Consultation with icare pilot manager
I3. To what extent do employers and workplaces have to adapt in order to implement / incorporate wearables?	• Reported processes introduced to implement the pilot • Reported changes in process or environment to integrate the wearables into day-to-day work	• Consultation with pilot managers • Consultation with workers • Consultation with technology vendors
Appropriateness		
I4. How well designed was the pilot?	• Perspectives on the appropriateness of pilot design and alignment with evidence and best practice • Documented evidence on the application of wearables in workplaces	• Consultation with pilot managers • Consultation with icare pilot manager • Existing documentation, reports, and studies on workplace MSD injury prevention
I5. Are the wearables fit-for-purpose?	• Reported use of wearables categorised by task, role, employer and industry • Perspectives on what tasks, roles, employers and industries are best suited to each wearable	• Consultation with pilot managers • Consultation with workers

Source: icare and Deloitte (2021)

Table C.2Outcome evaluation indicator framework

Key evaluation question	Indicators	Data sources
Effectiveness & Impact		
O1. To what extent do the wearables deliver the desired outcomes?	• Perspectives on changes in awareness of MSD risks by workers and employer management • Perspectives on the acceptance of the wearables by workers and willingness to advocate use of the wearables as an injury prevention intervention • Perspectives on changes in wellbeing at work including fatigue and comfort during and after shifts • Perspectives on the change in mindset by workers and culture across employers in terms of safety and injury prevention • Reported additional interventions introduced to enhance effectiveness of the wearables and an employer's approach to injury prevention	• Consultation with pilot managers • Consultation with workers • Consultation with icare pilot manager • Worker survey
	• % change in number or growth rate of hazardous movements	• Quantitative data from wearables
	• % change in number or growth rate of MSD injuries	• Consultation with pilot managers • Consultation with workers • Consultation with icare pilot manager
	• % change in number or growth rate of MSD claims	• Claims data
O2. What are the cultural, social, environment, and design factors that increase or impact on effectiveness?	• Perspectives on the key factors that influenced or impacted the expected outcomes	• Consultation with pilot managers • Consultation with workers • Consultation with icare pilot manager
O3. To what extent are outcomes sustainable in the longer term?	• Perspectives on the support ongoing utilisation of the wearables • Perspectives on the factors that will enable or hinder sustainability of outcomes in the longer term	• Consultation with pilot managers • Consultation with workers • Consultation with technology vendors • Consultation with icare pilot manager

Key evaluation question	Indicators	Data sources
Scalability & Replicability		
O4. To what degree are the wearables scalable and replicable?	• Perspectives on the feasibility of rolling out the wearables to a larger number of employers and workers, under the same conditions • Perspectives on the extent to which outcomes can be achieved if the wearables were implemented under new conditions, including other industries, employers or work settings	• Consultation with pilot managers • Consultation with technology vendors • Consultation with icare pilot manager
O5. What are the key learnings from the pilot that could translate into future programs?	• Perspectives on the lessons learned from the pilot including what worked well and recommendations for future programs • Perspectives on unintended consequences from the pilot in terms of positive and / or negative experiences in implementation or achievement of outcomes	• Consultation with pilot managers • Consultation with technology vendors • Consultation with icare pilot manager

Source: icare and Deloitte (2021)

Appendix D : Data collection and analysis

This section describes each of the data sources listed in Table 2.2 and Table 2.3 in further detail, including outlining methods for collection in which the data will be collected.

The evaluation has identified themes and findings across data sources. This involves comparison of the emerging themes, particularly from the primary sources data with themes identified in existing documentation. This comparison would seek to identify areas of alignment and differences in the themes.

Strong alignment across data sources would suggest confidence in a particular finding. Where there is divergence, further investigation may need to be undertaken in order to determine what might be driving these anomalies. Five additional semi-structured interviews will be completed by Deloitte to explore such anomalies if they arise. These interviews will be determined and scheduled at the end of the pilot and during the evaluation and reporting stage.

Table 6.1: Data sources

Data source	Key evaluation questions	Description of data and analysis undertaken
Quantitative data from wearables	I1, O1	Quantitative data collected from wearables (Sensor 1, Sensor 2, Assistive Device 1, and Assistive Device 2) will be used to measure changes in the number of hazardous movements and high-risk postures during the pilot. The pilot has been designed using an approach in which workers received a device, and alerts for hazardous movements and high-risk postures were initially turned off (Baseline). Alerts were then turned on (Intervention) after this initial period and then turned off again to observe any change in behaviours (Sustained Change). Regression analysis was used to analyse the trend in the number of hazardous movements and high-risk postures being made by workers across the different phases of the pilot. Data collected by the wearables included the user's occupation, shift durations, location, steps taken, and the number of alerts received. The evaluation of the MSD Wearable Study analysed these data from each technology and measured changes in: • Sensor 1: high load movements (Sensor 1 data), claims (icare data) and worker self-reported wellbeing (survey and consultations) • Sensor 2: high-risk postures (Sensor 2 data), claims (icare data) and worker self-reported wellbeing (survey and consultations) • Assistive Device 1 (to be used with Sensor 1): high load movements (Sensor 1 data), claims (icare data) and worker self-reported wellbeing (survey and consultations) • Assistive Device 2: claims (icare data) and worker self-reported wellbeing (survey and consultations).

		The purpose of the analysis was to determine whether there was a statistically significant reduction in any of these alerts during the intervention and sustained change phases of the study, after controlling for other factors that may be associated with the number of alerts.
Consultations with: • pilot managers • Workers • technology vendors • One case study employer	Consultations has provided evidence against all evaluation questions.	Interviews have been conducted to provide perspectives on the implementation experience (e.g. modifications required, suitability of wearables to tasks or employer environments), factors that impacted effectiveness and learnings from the pilot. Audio files of the interviews with pilot managers, workers and technology vendors have been received. These will be transcribed and analysed using Nvivo. Nvivo is a qualitative analysis software package, will be used to analyse the insights from consultation. Data analysis will be undertaken using thematic analysis where insights are sorted and categorised by themes related to the evaluation questions.
Worker survey	I1, O1	An worker survey will be fielded to participants at the end of the pilot to gauge technology acceptance and effectiveness (i.e. fatigue, discomfort and stress). These surveys were analysis to assess the perspectives of workers on the efficacy of the technology.
Claims data	O1	A reduction in hazardous movements is expected to lead to a reduction in MSD related incidents and hence a reduction in MSD related claims in the long term. As claims data is only available at an employer level, the evaluation will compare work-related MSD claims at the employer who has participated in the pilot (Employer 1) and a control employer who has no involvement in the pilot (Employer 2)
Case study	Case study consultations has provided evidence against all evaluation questions.	Consultation were conducted between the 29th June and 13th July from a wide variety of perspectives from the employer The aim of these consultations were to identify the factors of success in implementing the pilot for the employer.

Appendix E : Detailed regression outputs

Table E.1: Sensor 1 regression output – DV = Armcount_rate

Dependent variable			Armcount_rate		
Independent variables	**Employer 1**	**Employer 2**	**Employer 6**	**All**	**Pooled**
Occupation_type	38.406***	6.328	0.186	7.522	3.961
	(9.768)	(3.882)	(26.727)	(8.338)	(6.425)
Intervention	-12.779*	2.856	-9.122	-2.482	-1.812
	(7.403)	(2.974)	(18.432)	(2.837)	(2.301)
Sustained_change	-5.503	2.879	-	-1.516	-
	(10.181)	(3.896)	-	(3.804)	-
Employer 1	-	-	-	-	4.156
	-	-	-	-	(5.221)
Employer 6	-	-	-	-	26.327***
	-	-	-	-	(7.792)
Duration_hours	-3.168***	-0.219*	-3.213	-0.317**	-0.319**
	(0.723)	(0.124)	(2.157)	(0.126)	(0.125)
Steps_rate	0.045***	0.045***	0.207***	0.053***	0.052***
	(0.010)	(0.004)	(0.025)	(0.004)	(0.004)
Constant	0.000	-8.800*	0.000	-0.708	-4.141
	(0.000)	(5.173)	(0.000)	(9.110)	(6.462)
Observations	275	1,504	74	1,853	1,853
Number of ID	24	49	11	84	84

Note: Armcount_rate was calculated as the number of alerts for high loads on the arms during a shift divided by the duration (in hours) of that shift. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level respectively. Standard errors in parentheses.

Table E.2: Sensor 1 regression output – DV = Backcount_rate

Dependent variable			Backcount_rate		
Independent variables	**Employer 1**	**Employer 2**	**Employer 6**	**All**	**Pooled**
	-	(11.789)	-	(14.866)	-
Occupation_type	33.796*	-4.584	41.921*	-6.807	3.858
	(18.709)	(8.757)	(23.840)	(12.042)	(11.405)
Intervention	-35.164**	-13.951**	-8.078	-16.071***	-8.381*
	(13.784)	(6.149)	(5.880)	(5.470)	(4.492)

Sustained_change	-29.202	-19.015**	-	-19.074***	-
	(19.406)	(8.060)	-	(7.344)	-
Employer 1	-	-	-	-	3.582
	-	-	-	-	(9.332)
Employer 6	-	-	-	-	-0.384
	-	-	-	-	(14.196)
Duration_hours	-3.268**	-0.649**	0.106	-0.675***	-0.665***
	(1.405)	(0.255)	(0.745)	(0.244)	(0.245)
Steps_rate	0.154***	0.003	0.043***	0.026***	0.028***
	(0.019)	(0.009)	(0.016)	(0.008)	(0.008)
Constant	0.000	84.998***	0.000	61.501***	35.850***
	(0.000)	(11.403)	(0.000)	(13.616)	(11.708)
Observations	274	1,498	74	1,846	1,846
Number of ID	25	49	11	85	85

Note: Backcount_rate was calculated as the number of alerts for high loads on the back during a shift divided by the duration (in hours) of that shift. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level respectively. Standard errors in parentheses.

Table E.3: Sensor 1 regression output – DV = Legcount_rate

Dependent variable			**Legcount_rate**		
Independent variables	**Employer 1**	**Employer 2**	**Employer 6**	**All**	**Pooled**
Occupation_type	-1.455	0.119	0.451	0.352*	0.116
	(0.922)	(0.146)	(0.552)	(0.183)	(0.165)
Intervention	-0.511	-0.087	-0.060	-0.097	-0.103
	(0.627)	(0.110)	(0.139)	(0.129)	(0.108)
Sustained_change	0.242	-0.029	-	0.091	-
	(0.984)	(0.146)	-	(0.178)	-
Employer 1	-	-	-	-	0.656***
	-	-	-	-	(0.157)
Employer 6	-	-	-	-	-0.185
	-	-	-	-	(0.262)
Duration_hours	-0.054	-0.004	0.001	-0.006	-0.006
	(0.066)	(0.004)	(0.021)	(0.005)	(0.005)
Steps_rate	0.009***	0.002***	0.002***	0.003***	0.003***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.000	-0.101	0.000	-0.303	-0.116
	(0.000)	(0.203)	(0.000)	(0.241)	(0.202)
Observations	192	1,235	61	1,488	1,488

Number of ID	25	48	10	83	83

Note: Legcount_rate was calculated as the number of alerts for high loads on the legs during a shift divided by the duration (in hours) of that shift. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level respectively. Standard errors in parentheses.

Table E.4: Sensor 2 regression output

Dependent variable			HRP_rate		
Independent variables	**Employer 3**	**Employer 4**	**Employer 5**	**All**	**Pooled**
Occupation_type	5.488***	5.526	4.200	3.517	5.547**
	(0.509)	(3.481)	(7.249)	(2.603)	(2.576)
Intervention	-0.707***	-3.665***	-0.635	-2.072***	-2.088***
	(0.135)	(0.265)	(0.511)	(0.148)	(0.148)
Sustained_change	-0.413**	-3.344***	-0.712	-1.756***	-1.775***
	(0.204)	(0.496)	(0.664)	(0.239)	(0.239)
Employer 4	-	-	-	-	-3.690***
	-	-	-	-	(0.900)
Employer 5	-	-	-	-	-1.584
	-	-	-	-	(1.480)
Hours	-0.092***	-0.068	-0.021	-0.081***	-0.081***
	(0.023)	(0.052)	(0.072)	(0.026)	(0.026)
Steps_rate	0.000	0.005***	0.002***	0.004***	0.004***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Constant	0.000	2.334	1.457	1.914	2.162
	(0.000)	(3.399)	(7.144)	(2.581)	(2.517)
Observations	4,805	5,712	920	11,437	11,437
Number of ID	151	92	27	270	270

Note: HRP = High-risk postures. HRP_rate calculated as the number of high-risk postures recorded in one shift divided by the duration (in hours) of the shift. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level respectively. Standard errors in parentheses.

Limitation of our work

General use restriction

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