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The effectiveness of ergonomic interventions in material handling operations

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Abstract

This study evaluated the effectiveness of ergonomic interventions in material handling operations involving 33 employers and 535 employees from 2012–2017. Outcomes included employee-reported low back/upper extremity pain and safety incidents at baseline, every three months, and annually for up to two years. A total of 32.5% of employees completed at least one survey, while 13.6% completed all nine surveys over two years. Among highly exposed employees (who reported handling >= 50 lbs. > 33% of the time), upper extremity pain frequency and severity were lower among those who reported using the intervention routinely versus those that reported using their body strength alone to handle objects >= 50 lbs. After excluding from analyses one employer that used anti-fatigue mats, low back pain frequency was also significantly lower among highly exposed intervention users. In conclusion, there was some evidence that the interventions were effective in reducing employee-reported pain for highly exposed employees.

1: Introduction:

Work-related musculoskeletal injuries and illnesses associated with biomechanical risk factors such as overexertion, repeated movements, bodily reaction, and awkward body postures accounted for approximately 34% (295,830 of 882,730) of the non-fatal injuries and illnesses involving days away from work in US private industry in 2017 (BLS, 2019). Liberty Mutual has estimated overall direct employees' compensation claim costs to US industry to be $55.4 billion in 2016, with $13.1 billion due to overexertion injuries alone (Liberty Mutual, 2019). This estimate does not include indirect costs (such as lost productivity, overtime and training costs to replace injured workers) which some research suggest are equal to or greater than corresponding direct costs for the same disabling injuries (OSHA 2020; NIOSH 2020; Huang et al. 2009). Musculoskeletal injuries and illnesses also are among those for which patients are most often prescribed opioids both initially and on a long-term basis (Thumala et al. 2018), suggesting an additional worker and societal burden.

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Major public health goals set forth by the US National Institute for Occupational Safety and Health (NIOSH) include reducing work-related musculoskeletal injuries and illnesses in part by assessing the effectiveness of interventions. Although many ergonomic interventions are designed to reduce biomechanical risk factors involved in common tasks such as manual material handling, few high quality quasi-experimental, or randomized controlled trial (RCT) studies have been conducted to determine whether the interventions reduce future pain symptoms and injuries. Recent literature reviews on ergonomic intervention effectiveness, have found that RCTs were largely focused on office-based interventions (van Eerd et al. 2016; Driessen et al. 2010) or on specific occupations such as dental care practitioners (Mulimani et al. 2018).

Most ergonomic intervention effectiveness studies in industries such as manufacturing and construction have used quasi-experimental designs (e.g. pre- and post- intervention studies without control groups or randomization). A systematic review found that studies which have investigated the effectiveness of ergonomic engineering interventions alone have typically used short-term workload assessments as outcomes rather than reported pain symptoms or incidents and have been mixed in quality and findings (van der Molen et al. 2005). The engineering interventions tested have typically included material handling devices or other workstation changes evaluated in laboratory experiments (Resnick and Chaffin 1997; Mirka et al. 2002) or limited field trials (Bongers et al. 2001; Devereux et al. 1997; McGlothlin et al. 1996). Relatively few studies have involved longer-term field trials of patient handling equipment (Collins et al. 2004; Li et al. 2004), material handling equipment (Van der Molen et al. 2010; Marras et al. 2000; Vink et al. 1997) or other worksite engineering changes (Luijsterburg et al. 2005). Two systematic reviews identified several studies that have examined the combined effect of ergonomic programs that include engineering, administrative, and work practice interventions and involve both management and employees in the improvement process (Tompa et al. 2009; Sultan-Taïeb et al. 2017). Tompa found strong economic evidence for ergonomic program intervention effectiveness at a firm level in certain industries (manufacturing and warehousing), moderate evidence in others (administrative support health care sectors), and limited or insufficient evidence in other sectors. Sultan-Taïeb by contrast found evidence for program effectiveness among studies largely in the healthcare sector.

There is a need to conduct additional research that examines the effectiveness of ergonomic engineering interventions such as material handling equipment especially in high-risk industries. A partnership between the Ohio Bureau of Workers' Compensation (OHBWC) and the NIOSH Center for Workers' Compensation Studies (CWCS) has been conducting a series of such studies. In 1999, the OHBWC developed a safety intervention grant program through which it awards insured employers grants to purchase engineering interventions to reduce safety hazards. Two previous studies (Park et al. 2009; Fujishiro et al. 2005) found that the program could reduce workers' compensation claims for impacted employees for select industries. More recently, a large OHBWC-NIOSH study (Wurzelbacher et al. 2014) evaluated the program from 2003–2009 for 468 employers for intervention effectiveness. Overall, the study determined that the program did significantly reduce workers' compensation claim frequencies in nine of ten industry sectors, and for three of four intervention types (i.e., ergonomic, safety, and multi-purpose). In summary, claim

frequency per 100 employees was reduced by 66% (95%CI: 42–81%), while cost per employee was reduced by 81% (95%CI: 73–88%), and cost per claim reduced by 30% (95%CI: 13–44%).

In a subsequent study, researchers evaluated 153 OHBWC safety intervention grant case study reports completed by employers in the construction industry between 2003 and 2016 (Lowe et al. 2020). Employers prepared these reports one year after implementation of interventions as a requirement of the program. Reports covered various elements related to interventions including cost-benefit analyses, and changes in quality, productivity, safety hazards, and ergonomic-related risk factors. The review indicated variability in the quality of the case study reporting and that interventions ranged in effectiveness in reducing ergonomic-related exposures and safety risks. Nearly all case studies reported some risk reduction. The authors identified 17 high-quality case studies, with the most complete information, that were also ranked highly in terms of quantified reduction in risk factors. The equipment in these case studies included electrical cable feeding/pulling systems, concrete sawing equipment, skid steer attachments for concrete breaking, and boom lifts.

In summary, earlier studies found that the OHBWC sponsored intervention program reduced workers' compensation claims (Wurzelbacher et al. 2014; Park et al. 2009; Fujishiro et al. 2005) and reduced some ergonomic and safety risk factors (Lowe et al. 2020). However, other studies have shown that employees underreport injuries and pain symptoms (Azaroff et al. 2013; Lipscomb et al. 2009; Scherzer and Wolfe, 2008; Fan et al. 2006; Azaroff et al. 2002; Rosenman et al. 2000; Biddle et al. 1998).

The specific aims of the current study were to understand how the funded interventions affected employee-reported symptoms and safety incidents. This study targeted heavy material handling tasks because overexertion associated with these types of tasks remains a leading cause of injury (BLS, 2019; Liberty Mutual 2019) despite some prior research that indicates ergonomic material handling equipment can reduce biomechanical risk factors for musculoskeletal disorders (Lowe et al. 2020; Mirka et al. 2002; Bongers et al. 2001; Marras et al. 2000;) and workers' compensation claims (Wurzelbacher et al. 2014; Park et al. 2009; Fujishiro et al. 2005; Marras et al. 2000) or other worksite engineering changes (Luijsterburg et al. 2005).

2: Methods

2.1: Study Design

This study evaluated the effectiveness of ergonomic interventions in material handling operations using a prospective, quasi-experimental design involving 33 employers and 535 employees at baseline from 2012–2017. The study population included volunteer employees working at OHBWC-insured employers who volunteered to participate in a research study with OHBWC and NIOSH. OHBWC insures all employers with 1 to 499 employees in the state of Ohio. Employers with 500 or more employees can self-insure if fiscally able to do so.

This study utilized a randomized multiple baseline design in which all employers eventually received an intervention, but at different times. Researchers admitted employers to the study on a rolling basis from January 2012 through September 2014. Upon program application acceptance, employers were matched to other participant employers based on industry type, type of affected task, number of affected employees, prior loss history (experience modification rating), and proposed intervention. After matching, researchers randomly assigned employers to different intervention implementation schedules. Schedule A received the intervention immediately, and Schedule B received the intervention six months later. Researchers matched 26 employers (13 pairs) based on the above criteria. The remaining seven employers were not able to be matched, but were still randomized to receive the intervention according to one of the above schedules. Participating employers were not restricted from receiving additional OHBWC-sponsored services that they would otherwise choose and could freely engage in other safety/health practices.

2.2: Recruitment

NIOSH coordinated with the OHBWC to recruit employers to participate in this study using an informational flyer that was advertised on the OHBWC website and sent by NIOSH via postal mail to employers in targeted industries that involved heavy material handling. A main incentive to participate was that OHBWC provided 3:1 funding (up to $40k per employer) and that employers could receive certain equipment that was otherwise unavailable through the safety intervention grant program since the equipment (such as powered hand trucks) had been placed on a moratorium list. At the time, OHBWC was trying to ensure that employers from a diverse set of industries were utilizing the safety intervention grant program for a wide variety of interventions and had limited the availability of some of the more common types of equipment available.

Participation by individual employees was voluntary. Participating employers provided a contact list for all individuals performing material handling tasks directly impacted by the intervention, such as delivery, installation, and receiving operations. NIOSH emailed or postal mailed the flyer directly to all prospective employee recruits or called recruits if no email address was available. There was no random sampling of impacted employees. Additional flyers were also placed at each employer. If an employer agreed to participate, but no individual employees wished to participate by answering surveys, the employer was still provided the intervention. This protocol was followed to reduce the chance of employer coercion for individual employee participation in order to receive the intervention. Each employee participant was fully informed of the potential risks and benefits of participation and completed informed consent forms.

2.3: Data Collection

Pre- and post-intervention metrics included affected employee-reported low back/upper extremity pain symptoms collected at baseline, every three months, and annually for up to two years using online or paper surveys. Online surveys were only available from 2012–2013 such that all surveys eventually were completed in paper form. Participant employees were given time in their normal workday to complete all surveys. Participants were mailed a $5 debit card upon completion of each survey data collection (up to a total of $45 for

the entire study). Participants were sent surveys two weeks prior to the expected collection date. Emails and phone call prompts were used to maximize response rates. If no response was returned within six weeks of the scheduled data collection date, the participant was considered withdrawn from the study. Participant employees who withdrew were contacted to conduct exit interviews.

2.4: Independent Variables

2.4.1: Intervention: The interventions were implemented as part of the OHBWC safety intervention grant program with a special NIOSH research collaboration to target activities involving heavy material handling. Employers worked with OHBWC ergonomics consultants to identify at-risk workgroups and choose equipment for implementation based on the specific needs of that workplace. This process may have involved employee participation, but it was not required as part of the research study.

Interventions included a variety of equipment designed to improve material handling ergonomics and safety during delivery, installation, receiving, and other processes in construction, manufacturing, health care, and services. Specific example interventions included stair-climbing/powered hand trucks, powered truck lift gates, lift tables, and cranes/hoists. One employer used funds to install anti-fatigue mats. The total initial cost for these interventions for the 33 participating employers was $834,529 ($556,353 provided by OHBWC). Participating employers also provided regular scheduled maintenance for interventions as indicated by the manufacturer. Participating employers encouraged the use of the intervention but did not require their use. Affected employees were provided training by participating employers in the safe use of the intervention as outlined by the manufacturer.

2.4.2: Individual: Two types of individual exposure surveys (employee-reported general work environment and health, and employee-reported specific job tasks and intervention use) were administered to employees directly impacted by the ergonomic interventions throughout the course of the study as outlined below:

Employee-reported general work environment and health: Surveys were administered to each employee up to three times (at baseline and every twelve months for up to two years) to collect self-reported data on co-variate health and work conditions. This survey was a subset of data collected for a past large musculoskeletal epidemiologic study (Burt et al. 2011). See Table A1 (Example Survey) and Table A2 (Survey Outcome Scoring) in the Appendix for more information.

Employee-reported exposure and intervention use: A second set of surveys were administered to each employee up to nine times (at baseline and every three months for up to two years) at the same time the pain symptom surveys (described below) were administered. This set of surveys was designed by NIOSH specifically for this study. Employees were asked to rate the distribution of their workload among tasks expected to be impacted by the intervention and those tasks where no impact was expected. As a specific example, employees were asked how often on

average they handled objects or stacked loads over 100 lbs. (such as appliances, large electronics equipment) in the last three months. Employees were then asked corresponding questions about their usage of the interventions for specific tasks. For example, employees were asked how often the new safety grant equipment was used to handle objects or stacked loads over 100 lbs. See Table 1, Table A1 (Example Survey), and Table A2 (Survey Outcome Scoring) in the Appendix for more information.

The above survey data were then categorized based on the frequency of exposure and intervention use into four comparison groups of employee surveys that were used for the analysis:

- *Least Exposed (Group 1):* Employee reported handling < 50 lbs. < 33% of the time.
- *Highly Exposed Intervention User (Group 2):* Employee reported handling >= 50 lbs. > 33% of the time AND reported using the sponsored intervention routinely > 33% of the time during tasks where >= 50 lbs. were handled.
- *Highly Exposed Other (Group 3):* Employee reported handling >= 50 lbs. > 33% of the time, but did NOT report using the sponsored intervention routinely > 33% of the time during tasks where >= 50 lbs. were handled. The employee may have reported using other equipment to aid material handling during tasks where >= 50 lbs. were handled.
- *Highly Exposed Body User (Group 4):* Employee reported handling >= 50 lbs. > 33% of the time, but did NOT report using the sponsored intervention routinely > 33% of the time during tasks where >= 50 lbs. were handled, and instead reported using their body strength alone > 33 % of the time during tasks where >= 50 lbs. were handled.

Note that individual employee participants were placed into one of the above groups based on their responses at the time of each data collection, but that individuals over time may have been placed into more than one group. The category of >= 50 lbs. was chosen to represent the highest level of risk, based on the NIOSH lifting equation that recommends employees never lift more than 51 lbs. (NIOSH, 1994).The choice of "> 33% of the time" to designate "routine" intervention use was chosen as a cut-point to create comparison groups (Groups 2 versus 4) of roughly equivalent size. The original survey included responses to a categorical question where reported intervention usage responses included: 1 = Never (0% of the time), 2= Occasional (1–33% of the time), 3= Frequent (34–66% of the time), 4= Regular (67–100% of the time), and Not applicable (safety grant equipment not in place yet). See Table 1, Table A1 (Example Survey), and Table A2 (Survey Outcome Scoring) for more information.

2.5: Dependent Variables

2.5.1: Low Back Pain—Employee-reported low back pain was assessed with two surveys, both provided in the Appendix. The first survey was based on a modified Nordic discomfort assessment tool (Kuorinka et al. 1987) that was administered to each employee

up to three times (at baseline and every twelve months for up to two years). This survey included the following main outcome measure:

Annual Low Back Symptom Frequency > 0	Measured whether there was any employee-reported low back pain [every day for a week (7 days) or more) in the past 12 months] on the modified Nordic assessment survey modules.

The second survey was the North American Spine Society (NASS) Lumbar Spine Outcome Assessment Instrument, that was administered to each employee up to nine times (at baseline and every three months for up to two years). The NASS instrument has been found to have acceptability, high re-test reliability, internal reliability, and validity for low back pain and disability in multiple language translations (Bosković et al. 2009; Schluessmann et al. 2009; Schneider et al. 2007; Sigl et al. 2006; Weigl et al. 2006; Schaeren et al. 2005; Padua et al. 2001; Schochat et al. 2000; Pose et al. 1999; Daltroy et al. 1996). This survey included the following main outcome measures:

NASS-Pain Frequency > 0	Measured whether there was any employee-reported low back pain or associated leg pain in the past week on the NASS-Pain survey modules.
NASS-Pain Severity Scaled	Measured the level of employee-reported low back pain or associated leg pain in the past week on the NASS-Pain survey modules.
NASS-Neuro Frequency > 0	Measured whether there was any employee-reported low back pain or associated leg pain in the past week on the NASS-Neuro survey modules.
NASS-Neuro Severity Scaled	Measured the level of employee-reported low back pain or associated leg pain in the past week on the NASS-Neuro survey modules.

2.5.2: Upper Extremity Pain—Employee-reported upper extremity pain was assessed with two surveys, both provided in the Appendix. The first survey was based on a modified Nordic discomfort assessment tool (Kuorinka et al. 1987) that was administered to each employee up to three times (at baseline and every twelve months for up to two years). This survey included the following main outcome measure:

Annual Upper Extremity Symptom Frequency > 0	Measured whether there was any employee-reported upper extremity pain [more than 3 times or lasting a week (7 days) or longer in the past 12 months] on the modified Nordic assessment survey modules.

The second survey used the Quick Disabilities of the Arm, Shoulder, and Hand (DASH) Outcome Measure with Work Module Option (Beaton et. al. 2001), that was administered to each employee up to nine times (at baseline and every three months for up to two years). The DASH outcome has been found to have acceptability, high re-test reliability, internal reliability, and validity for shoulder/arm pain and disability (Adams et. al. 2005; Beaton et. al. 2005; Gay et. al. 2003; Solway et. al. 2002; Beaton et. al. 2001a,b; Atroshi et. al. 2000; Hudak et. al. 1996). These instruments were jointly developed by the Institute for Work and Health (IWH) and the American Academy of Orthopaedic Surgeons (AAOS). This survey included the following main outcome measures:

DASH Disability Frequency > 0	Measured whether there was any employee-reported upper extremity pain in the last week on the DASH-Disability survey modules.
DASH-Disability Severity	Measured the level of employee-reported upper extremity pain in the last week on the DASH-Disability survey modules.
DASH-Work Frequency > 0	Measured whether there was any employee-reported upper extremity pain in the last week on the DASH-Work survey modules.
DASH-Work Severity	Measured the level of employee-reported upper extremity pain in the last week on the DASH-Work survey modules.

2.5.3: Safety Incidents—Employee-reported safety incidents were assessed using a survey that was administered to each employee up to nine times (collected at baseline and every three months for up to two years). This survey was designed by NIOSH specifically for this study. See the Appendix for more information. This survey included the following main outcome measures:

Any Safety Events Frequency > 0	Measured whether there were any employee-reported safety related incidents at work within the last 3 months.
Material Handling Task-related Safety Events Frequency > 0	Measured whether there were any employee-reported safety related incidents at work associated with specific material handling tasks within the last 3 months.

2.6: Statistical Analysis

Poisson, two-part, and linear regression models with repeated measures were used to evaluate changes over time (pre- and post-intervention) in the frequency and severity of employee-reported employee low back pain, upper extremity pain, and safety incidents. One employer was excluded from analyses since they only reported seasonal work, averaging nine months per year. Comparisons over time were restricted to employees who completed all nine surveys. Regression models were used to compare Highly Exposed Intervention Users (Group 2) versus Highly Exposed Body Users (Group 4) based on reported exposures and intervention usage among all employees who completed any surveys. All analyses were conducted using SAS 9.4 (SAS Institute, Inc., Cary, NC).

2.7: Human Subjects Review

This study was approved by the NIOSH Institutional Review Board.

3: Results

3.1: Participant Demographics and Intervention Summaries

Table 2 provides a summary of participating employer industries, intervention types, impacted workgroup sizes, and number of completed surveys. Overall, there were seven different major industry groups represented, with most in construction, manufacturing, and services (except public safety). All employers had at least one employee submit a consent form to participate. For two employers, no employee surveys were ever completed. The mean impacted workgroup size was 16.2 employees, ranging from 1–50 employees. Among

affected employees at baseline, 32.5% (174/535) completed at least one survey, 19.4% (104/535) completed at least five surveys over one year, while 13.6% (73/535) completed all nine surveys over two years. The vast majority (95%,165/174) of participating employees were male. Total employer size (based on a count of all employees, not just those impacted by the interventions) ranged from 1 to 572 (mean = 64). Employer union status was not determined.

3.2: Pain Baseline Comparison

Table 3 provides a baseline summary for reported employee demographics, symptoms, and job exposures. A majority reported at least some low back pain (NASS-Pain Frequency > 0, 67%) and upper extremity pain (DASH-Disability Frequency > 0, 55%) at baseline. The severity of reported low back pain was higher than reported upper extremity pain throughout the study. The table also compares Schedules A and B (intervention implementation) at baseline and shows that the two Schedules were generally not significantly different, though some differences were still notable. All the reported symptom outcome scores were higher in Schedule B and Schedule B participant employees tended to be older. Schedule B was higher than Schedule A in NASS-Pain frequency and score as well as Annual Low Back Symptom Frequency. There were no significant differences in baseline reported symptoms among employees who eventually completed nine surveys versus those that withdrew over the course of the study.

3.3: Pain Time Trends

Table 4 presents employee-reported upper extremity/low back pain symptom frequency and severity trends over time. There were no significant trends in reported pain over time without controlling for reported exposure or intervention usage. The proportion of participant employees who were symptomatic (score > 0) decreased over time for four of six outcomes (Annual Upper Extremity Symptoms, Annual Low Back Symptoms, NASS-Neuro, and DASH-Disability) but increased for two outcomes (DASH-Work, NASS-Pain). Table 4 also depicts that the cumulative raw scores for Schedule A and B employees increased over time for three of four scored outcomes. There were no significant differences between symptoms reported for Schedule A and B employers.

3.4: Pain, Exposure, and Intervention Usage Relationship

Among all employee surveys, an average of 39% reported routine intervention use (defined to be > 33% of the time) during tasks where >= 50 lbs. were handled, with some fluctuations over time (data not shown). Among highly exposed employees (who reported handling >= 50 lbs. > 33% of the time), an average of 18% reported routine intervention use, with a slightly greater proportion reporting routine use early in the study. An average of 37% of employees reported high exposures (handling >= 50 lbs. > 33% of the time) for the study, with a greater proportion reporting high exposures in the beginning of the study (50%) versus the end (30%).

Table 5 displays employee-reported symptom outcomes by exposure and intervention usage groups. For five of six symptom outcomes (all except Annual Upper Extremity Symptoms), the percent of participant employees who were symptomatic (score > 0) and mean symptom

scores were lowest with the Least Exposed (Group 1). For all symptom outcomes, the percent of participants who were symptomatic and mean symptom scores were lower among Highly Exposed Intervention Users (Group 2) versus Highly Exposed Body Users (Group 4). Highly Exposed Intervention Users had significantly lower upper extremity mean symptom score outcomes (DASH-Work, DASH-Disability) and a lower frequency of upper extremity pain (Annual Upper Extremity Symptoms) than Highly Exposed Body Users (Group 4). After restricting analyses to only material handling equipment (excluding anti-fatigue mats), Highly Exposed Intervention Users had significantly lower reported low back pain frequency (NASS Pain > 0 and Annual Low Back Symptoms) than Highly Exposed Body Users (Group 4).

3.5: Safety Incidents Time Trends

Table 6 depicts the employee-reported frequency of safety incidents. There were no significant trends over time without controlling for reported exposure or intervention usage. There were no significant differences between Schedules A and B.

3.6: Safety Incidents, Exposure, and Intervention Usage Relationship

Table 7 presents employee-reported incidents by exposure and intervention usage groups. Reported safety incident frequencies were lowest with the Least Exposed (Group 1). For material handling related safety incidents, reported incident frequencies were lower among Highly Exposed Intervention Users (Group 2) versus Highly Exposed Body Users (Group 4), though the differences were not significant.

4: Discussion

4.1: Pain

A number of employee participants in this study were symptomatic for low back and/or upper extremity pain. A majority reported at least some low back and upper extremity pain at baseline. The severity of reported low back pain was higher than reported upper extremity pain throughout the study. The level of low back pain (NASS-Pain, 21.3) was higher at baseline than that reported (15.5) in a study of warehouse employees (Ferguson et al. 2008). The level of upper extremity pain (DASH-Disability, 2.3) at baseline was lower than Hunsaker et al. 2002 reported would be expected for the general population (10.1).

Although the DASH and NASS surveys were chosen for use in this study based on their demonstrated reliability and validity, researchers designed both surveys for use among patients recovering from injury, and not necessarily among working populations involving heavy material handling. A survivor effect may have contributed to the fact that DASH scores were relatively low. Although the current study collected the DASH and NASS surveys every three months, the symptom reporting timeframe for each survey was within the last week, so it is possible that employees did not report all episodic symptoms. The annual low back and upper extremity symptom surveys did ask participants to report all symptoms within the last year, but these surveys could have been more prone to recall bias.

This study had mixed results for reported back and upper extremity pain symptoms over time without controlling for reported exposure or intervention use. Although trends were not significant, fewer study participants were likely to report symptoms over the study period, but when participants did report symptoms, the symptoms were likely to be more severe over time. This was not due to a few highly-symptomatic individuals who tended to become worse over time. Upper extremity symptoms were generally low and skewed towards lower symptom severity while low back symptoms were higher and more normally distributed for severity (data not shown). These results are generally consistent with prior studies that have tracked musculoskeletal symptoms for the same individual over time and have shown that symptoms often persist or grow worse, especially among employees performing manually intensive tasks (Oakman et al. 2016; Neupane et al. 2015; Neupane et al. 2013).

Although this study included a minor RCT design component (where employers were randomized to receive the intervention at different times, with one receiving the intervention immediately and the other six months later), Schedules A and B employees were different at baseline as all reported symptom scores were higher in Schedule B and Schedule B employees tended to be older. Originally, the study plan was to offset interventions by a year, but this offset duration was reduced to six months based on feedback during initial focus groups with OHBWC consultants to improve employer study participation. This relatively short offset between implementation schedules did not afford sufficient time or number of survey measurements for meaningful differences to develop between schedule groups. As a result, there were also no significant differences between intervention implementation Schedules A and B in terms of reported symptoms over time.

The relationship between reported symptoms and reported exposures and intervention usage was clearer. Among highly exposed participants (defined a priori to be those who reported handling >= 50 lbs. > 33% of the time), reported symptom frequency and mean symptom severity were lower among those who reported using the sponsored intervention versus those that reported using their body strength alone to handle objects >= 50 lbs. These differences were significant for upper extremity symptom frequency (Annual Upper Extremity Symptoms) and for upper extremity mean symptom severity outcomes (DASH-Work, DASH-Disability). After restricting analyses to only material handling equipment interventions (excluding anti-fatigue mats), low back pain frequency (NASS Pain > 0 and Annual Low Back Symptoms) were also significantly lower among highly exposed participant intervention users compared to those who reported using their body strength alone to handle objects >= 50 lbs.

This provides some evidence that the interventions when used did reduce self-reported symptoms among the most heavily exposed employees. These findings are similar to the relatively few prior studies that measured the impact of engineering controls on reported symptoms among non-office employees, including bricklayers (Bongers et al. 2001; Luijsterburg et al. 2005) and healthcare employees (Li et al. 2004). Other studies indicated mixed or no changes in reported symptoms after ergonomic engineering intervention among delivery drivers (Devereux et al. 1997; McGlothlin et al. 1996), other construction employees (Vink et al. 1997; Van der Molen et al. 2010), and manufacturing employees (Johansson et al. 1993).

4.2: Safety Incidents

This study found no significant change in reported frequency of incidents over time without controlling for reported exposures or intervention use. Differences between intervention implementation schedules were not significantly different, likely due the relatively short six month offset between the schedules for employers receiving interventions. There were also no significant relationships between reported incident frequency and reported exposures and intervention usage. This was not unexpected, given that employers chose the interventions primarily to reduce biomechanical risk factors during material handling tasks rather than safety-related hazards.

4.3: Limitations

This is one of the largest prospective, multi-site quasi-experimental studies to assess the impact of ergonomic engineering interventions on reported pain symptoms and safety incidents in non-office work environments. However, there are a number of limitations associated with this research, including potential employer/employee selection bias, low employee participation rates, the use of employee-reported measures, and lack of control of other concurrent organizational interventions. Employers had to choose to participate in the overall intervention program, so results may not be generalizable beyond this study population. Once employers agreed to participate, employee participation in the surveys was still voluntary. Survey participation rates among affected employees at baseline were low, as only 19.4% completed at least five surveys over one year, while 13.6% completed all nine surveys over two years. There is no way to ascertain whether participating or non-participating employees from the study differed in terms of their pain levels, safety incidents, work exposures or intervention usage. Although exit interviews were attempted with employees who withdrew from the study, very few withdrawn employees responded. These few interviews indicated that the employees most often left the study because they left their current employer, and the decision was not due to musculoskeletal symptoms or safety concerns. Furthermore, baseline reported symptoms among employees who eventually completed nine surveys were not significantly different from those that withdrew over the course of the study. This provides some support that findings are still valid despite participant employee attrition. The reliability and validity of self-reported measures in general may be questioned, but this specific study used multiple measures of low back and upper extremity pain, including two validated measures (NASS, DASH) and nine repeated measures over a two-year period to address concerns. Finally, employers were free to engage in other interventions. It is possible that there were systematic differences between employers in terms of overarching safety/ergonomic programs which integrate such elements as management commitment, employee participation, hazard identification, hazard control, training, and evaluation (NIOSH, 1997). Such differences could also have impacted reported symptoms and safety incidents.

5: Conclusions

This study evaluated the effectiveness of a variety of ergonomic interventions in material handling operations in a number of employers and industries including construction, manufacturing, and services. Interventions included largely material handling equipment

such as powered hand trucks and lift tables. Outcomes included employee-reported low back/upper extremity pain and safety incidents at baseline, every three months, and annually for up to two years. Although survey participation rates among affected employees at baseline were low, employees reported fewer symptoms while using the equipment for heavy material handling. Specifically, 32.5% of employees completed at least one survey, while 13.6% completed all nine surveys over two years. Among highly exposed employees (who reported handling >= 50 lbs. > 33% of the time), upper extremity pain symptom frequency and severity were lower among those who reported using the interventions routinely (> 33% of the time) versus those that reported using their body strength alone routinely to handle objects >= 50 lbs. After excluding from analyses one employer that used anti-fatigue mats, low back pain frequency was also significantly lower among highly exposed routine intervention users. In conclusion, there was some evidence that the insurer-supported material handling engineering interventions were effective in reducing self-reported pain symptoms for highly exposed employees. This study is consistent with prior research that has indicated that ergonomic material handling equipment can reduce biomechanical risk factors for work-related musculoskeletal disorders and workers' compensation claims. These findings are also consistent with other research that has indicated that integrated safety/ergonomic programs can reduce injuries, as the use of such material handling equipment can represent important aspects of overall hazard control within these systems.

Appendix

Table A1:

Example Survey

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
H1_1	H1 (Low back pain)_NASS Pain and Disability	1a. In the past week, how often have you suffered low back and/or buttock pain?	0= None of the time; 1= A little of the time; 2= Some of the time; 3= A good bit of the time; 4= Most of the time; 5= All of the time;	Baseline, every 3 months
H1_2	H1 (Low back pain)_NASS Pain and Disability	1b. How bothersome has the low back and/or buttock pain been?	0= Not at all bothersome; 1= Slightly bothersome; 2= Somewhat bothersome; 3= Moderately bothersome; 4= Very bothersome; 5= Extremely bothersome	Baseline, every 3 months
H1_3	H1 (Low back pain)_NASS Neuro	2a. In the past week, how often have you suffered leg pain?	0= None of the time; 1= A little of the time; 2= Some of the time; 3= A good bit of the time; 4= Most of the time; 5= All of the time;	Baseline, every 3 months
H1_4	H1 (Low back pain)_NASS Neuro	2b. How bothersome has the leg pain been?	0= Not at all bothersome; 1= Slightly bothersome; 2= Somewhat bothersome; 3= Moderately bothersome; 4= Very bothersome; 5= Extremely bothersome	Baseline, every 3 months

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
H1_5	H1 (Low back pain)_NASS Neuro	3a. In the past week, how often have you suffered numbness or tingling in leg and/or foot?	0= None of the time; 1= A little of the time; 2= Some of the time; 3= A good bit of the time; 4= Most of the time; 5= All of the time;	Baseline, every 3 months
H1_6	H1 (Low back pain)_NASS Neuro	3b. How bothersome has the numbness or tingling in leg and/or foot been?	0= Not at all bothersome; 1= Slightly bothersome; 2= Somewhat bothersome; 3= Moderately bothersome; 4= Very bothersome; 5= Extremely bothersome	Baseline, every 3 months
H1_7	H1 (Low back pain)_NASS Neuro	4a. In the past week, how often have you suffered weakness in leg and/or foot?	0= None of the time; 1= A little of the time; 2= Some of the time; 3= A good bit of the time; 4= Most of the time; 5= All of the time;	Baseline, every 3 months
H1_8	H1 (Low back pain)_NASS Neuro	4b. How bothersome has the weakness in leg and/or foot been?	0= Not at all bothersome; 1= Slightly bothersome; 2= Somewhat bothersome; 3= Moderately bothersome; 4= Very bothersome; 5= Extremely bothersome	Baseline, every 3 months
H1_9	H1 (Low back pain)_NASS Pain and Disability	5. In the past week, how has pain affected you when you get dressed?	0= I can dress myself without pain.; 1= I can dress myself without increasing pain.; 2= I can dress myself but pain increases.; 3= I can dress myself but with significant pain.; 4= I can dress myself but with very severe pain.; 5= I cannot dress myself due to pain.;	Baseline, every 3 months
H1_10	H1 (Low back pain)_NASS Pain and Disability	6. In the past week, how has pain affected you when you lift something?	0= I can lift heavy objects without pain.; 1= I can lift heavy objects but it is painful.; 2= Pain prevents me from lifting heavy objects off the floor, but I can lift heavy objects if they are on a table.; 3= Pain prevents me from lifting heavy objects off the floor, but I can lift light to medium objects if they are on a table.; 4= I can only lift light objects due to pain.; 5= I cannot lift anything due to pain.	Baseline, every 3 months
H1_11	H1 (Low back pain)_NASS Pain and Disability	7. In the past week, how has pain affected you when you are walking and running?	0= I can walk or run without pain.; 1= I can walk comfortably, but running is painful.;2= Pain prevents me from walking more than 1 hour.; 3= Pain prevents me from walking more than 30 minutes.;4= Pain prevents me from walking more than 10 minutes.; 5= I am unable to walk or can walk only a few steps at a time.;	Baseline, every 3 months

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
H1_12	H1 (Low back pain)_NASS Pain and Disability	8. In the past week, how has pain affected you when you are sitting?	0= I can sit in any chair as long as I like.; 1= I can only sit in a special chair for as long as I like.; 2= Pain prevents me from sitting more than 1 hour.; 3= Pain prevents me from sitting more than 30 minutes.; 4= Pain prevents me from sitting more than 10 minutes.; 5= Pain prevents me from sitting at all.;	Baseline, every 3 months
H1_13	H1 (Low back pain)_NASS Pain and Disability	9. In the past week, how has pain affected you when you are standing?	0= I can stand as long as I want.; 1= I can stand as long as I want but it gives me pain.; 2= Pain prevents me from standing more than 1 hour.; 3= Pain prevents me from standing more than 30 minutes.; 4= Pain prevents me from standing more than 10 minutes.; 5= Pain prevents me from standing at all.;	Baseline, every 3 months
H1_14	H1 (Low back pain)_NASS Pain and Disability	10. In the past week, how has pain affected you when you sleep?	0= I sleep well.; 1= Pain occasionally interrupts my sleep.; 2= Pain interrupts my sleep half of the time.; 3= Pain often interrupts my sleep.; 4= Pain always interrupts my sleep.; 5= I never sleep well.;	Baseline, every 3 months
H1_15	H1 (Low back pain)_NASS Pain and Disability	11. In the past week, how has pain affected your social and recreational life?	0= My social and recreational life is unchanged.; 1= My social and recreational life is unchanged, but it increases pain.; 2= My social and recreational life is unchanged, but it severely increases pain.; 3= Pain has restricted my social and recreational life.; 4= Pain has severely restricted my social and recreational life.; 5= I have essentially no social and recreational life because of pain.;	Baseline, every 3 months
H1_16	H1 (Low back pain)_NASS Pain and Disability	12. In the past week, how has pain affected your traveling?	0= I can travel anywhere.; 1= I can travel anywhere but it gives me pain.; 2= Pain is bad but I can manage to travel over 2 hours.; 3= Pain restricts me to trip of less than 1 hour.; 4= Pain restricts me to trip of less than 30 minutes.; 5= Pain prevents me from traveling.;	Baseline, every 3 months
H1_17	H1 (Low back pain)_NASS Pain and Disability	13. In the past week, how has pain affected your sex life?	0= My sex life is unchanged.; 1= My sex life is unchanged, but causes some pain.; 2= My sex life is nearly unchanged, but it is very painful.; 3= My sex life is severely restricted	Baseline, every 3 months

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
			by pain.; 4= My sex life is nearly absent because of pain.; 5= Pain prevents any sex life at all.;	
H2_18	H2 (DASH)_ DASH disability score (derived)	1. Open a tight or new jar (Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.)	1= no difficulty; 2= mild difficulty; 3= moderate difficulty; 4= severe difficulty; 5= unable;	Baseline, every 3 months
H2_19	H2 (DASH)_ DASH disability score (derived)	2. Do heavy household chores (e.g. wash walls, floors). (Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.)	1= no difficulty; 2= mild difficulty; 3= moderate difficulty; 4= severe difficulty; 5= unable;	Baseline, every 3 months
H2_20	H2 (DASH)_ DASH disability score (derived)	3. Carry a shopping bag or briefcase. (Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.)	1= no difficulty; 2= mild difficulty; 3= moderate difficulty; 4= severe difficulty; 5= unable;	Baseline, every 3 months
H2_21	H2 (DASH)_ DASH disability score (derived)	4. Wash your back. (Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.)	1= no difficulty; 2= mild difficulty; 3= moderate difficulty; 4= severe difficulty; 5= unable;	Baseline, every 3 months
H2_22	H2 (DASH)_ DASH disability score (derived)	5. Use a knife to cut food. (Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.)	1= no difficulty; 2= mild difficulty; 3= moderate difficulty; 4= severe difficulty; 5= unable;	Baseline, every 3 months
H2_23	H2 (DASH)_ DASH disability score (derived)	6. Recreational activities in which you take some force or impact through your arm, shoulder, or hand (e.g. golf, hammering, tennis, etc.). (Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.)	1= no difficulty; 2= mild difficulty; 3= moderate difficulty; 4= severe difficulty; 5= unable;	Baseline, every 3 months
H2_24	H2 (DASH)_ DASH disability score (derived)	7. During the past week, *to what extent* has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours, or groups?	1= not at all; 2= slightly; 3= moderately; 4= quite a bit; 5= extremely;	Baseline, every 3 months
H2_25	H2 (DASH)_ DASH disability score (derived)	8. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder, or hand problem?	1= not limited at all; 2= slightly limited; 3= moderately limited; 4= very limited; 5= unable;	Baseline, every 3 months
H2_26	H2 (DASH)_ DASH disability score (derived)	9. Arm, shoulder or hand pain. [Please rate the severity of the following symptoms in the last week *(circle number).*]	1= none; 2= mild; 3= moderate; 4= severe; 5= extreme;	Baseline, every 3 months
H2_27	H2 (DASH)_ DASH disability score (derived)	10. Tingling (pins and needles) in your arm, shoulder or hand. [Please rate the severity of the following symptoms in the last week *(circle number).*]	1= none; 2= mild; 3= moderate; 4= severe; 5= extreme;	Baseline, every 3 months

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
H2_28	H2 (DASH)_ DASH disability score (derived)	11. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? *(circle number)*	1= no difficulty; 2= mild difficulty; 3= moderate difficulty; 4= severe difficulty; 5= so much difficulty that I can't sleep;	Baseline, every 3 months
H2_30	H2 (DASH) Work Module	1. Using your usual technique for your work? (Please circle the number that best describes your physical ability in the past week. Do you have any difficulty:)	1= no difficulty; 2= mild difficulty; 3= moderate difficulty; 4= severe difficulty; 5= unable;	Baseline, every 3 months
H2_31	H2 (DASH) Work Module	2. Doing your usual work because of amr, shoulder or arm pain? (Please circle the number that best describes your physical ability in the past week. Do you have any difficulty:)	1= no difficulty; 2= mild difficulty; 3= moderate difficulty; 4= severe difficulty; 5= unable;	Baseline, every 3 months
H2_32	H2 (DASH) Work Module	3. Doing your work as well as you would like? (Please circle the number that best describes your physical ability in the past week. Do you have any difficulty:)	1= no difficulty; 2= mild difficulty; 3= moderate difficulty; 4= severe difficulty; 5= unable;	Baseline, every 3 months
H2_33	H2 (DASH) Work Module	4. Spending your usual amount of time doing your work? (Please circle the number that best describes your physical ability in the past week. Do you have any difficulty:)	1= no difficulty; 2= mild difficulty; 3= moderate difficulty; 4= severe difficulty; 5= unable;	Baseline, every 3 months
H3_34	H3 Job Tasks and Safety PART A	1: Handling objects or stacked loads over 100 lbs. If never, please go to question 2 (such as appliances, large electronics equipment)? (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time);	Baseline, every 3 months
H3_35	H3 Job Tasks and Safety PART A	1a. How often was the new Safety Grant equipment used to handle objects over 100 lbs.? (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time); 4= Not applicable (Safety Grant equipment not in place yet);	Baseline, every 3 months
H3_36	H3 Job Tasks and Safety PART A	1b. How often was another tool (such as regular hand truck) used to handle objects over 100 lbs.? (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time);	Baseline, every 3 months
H3_37	H3 Job Tasks and Safety PART A	1c. How often did you use your body strength alone to handle large items? (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time);	Baseline, every 3 months
H3_38	H3 Job Tasks and Safety PART A	2: Handling objects or stacked loads 50–100 lbs. (such as large boxes, shipping containers)?if never, please go to question 3 (PART A: Please rate how often on average you performed the	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time);	Baseline, every 3 months

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
		following tasks in your daily work over the last 3 months.)		
H3_39	H3 Job Tasks and Safety PART A	2a. How often was the new Safety Grant equipment used to handle objects 50–100 lbs.? (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time); 4= Not applicable (Safety Grant equipment not in place yet);	Baseline, every 3 months
H3_40	H3 Job Tasks and Safety PART A	2b. How often was another tool (such as regular hand truck) used to handle objects 50–100 lbs.? (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time);	Baseline, every 3 months
H3_41	H3 Job Tasks and Safety PART A	2c. How often did you use your body strength alone to handle objects 50–100 lbs.? (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time);	Baseline, every 3 months
H3_42	H3 Job Tasks and Safety PART A	3: Handling objects or stacked loads 25–50 lbs. (such as boxes, parts)? (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time);	Baseline, every 3 months
H3_43	H3 Job Tasks and Safety PART A	4: Packing/ unpacking boxes or containers (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time);	Baseline, every 3 months
H3_44	H3 Job Tasks and Safety PART A	5: Performing seated office work- computer use (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time);	Baseline, every 3 months
H3_45	H3 Job Tasks and Safety PART A	6. Performing standing office work- sales or customer service (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time);	Baseline, every 3 months
H3_46	H3 Job Tasks and Safety PART A	7: Driving a vehicle for work (PART A: Please rate how often on average you performed the following tasks in your daily work over the last 3 months.)	0= Never (0% of the time); 1= Occasional (133% of the time); 2= Frequent (34–66% of the time); 3= Regular (67–100% of the time);	Baseline, every 3 months
H3_47	H3 Job Tasks and Safety PART B	Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task. (Screening)	0= no; 1= yes;	Baseline, every 3 months
H3_48	H3 Job Tasks and Safety PART B	1a: Handling objects or stacked loads over 100 lbs. (such as appliances, large electronics equipment)? (PART B: Have you	0= no; 1= yes;	Baseline, every 3 months

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
		had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) (Task Screening)		
H3_49	H3 Job Tasks and Safety PART B	1b: Handling objects or stacked loads over 100 lbs. (such as appliances, large electronics equipment)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Slip, trip or fall	0= no; 1= yes;	Baseline, every 3 months
H3_50	H3 Job Tasks and Safety PART B	1c: Handling objects or stacked loads over 100 lbs. (such as appliances, large electronics equipment)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Cuts or scratches	0= no; 1= yes;	Baseline, every 3 months
H3_51	H3 Job Tasks and Safety PART B	1d: Handling objects or stacked loads over 100 lbs. (such as appliances, large electronics equipment)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Strains or sprains	0= no; 1= yes;	Baseline, every 3 months
H3_52	H3 Job Tasks and Safety PART B	1e: Handling objects or stacked loads over 100 lbs. (such as appliances, large electronics equipment)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Other	0= no; 1= yes;	Baseline, every 3 months
H3_53	H3 Job Tasks and Safety PART B	2a: Handling objects or stacked loads 50–100 lbs. (such as large boxes, shipping containers)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) (Task Screening)	0= no; 1= yes;	Baseline, every 3 months
H3_54	H3 Job Tasks and Safety PART B	2b: Handling objects or stacked loads 50–100 lbs. (such as large boxes, shipping containers)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Slip, trip or fall	0= no; 1= yes;	Baseline, every 3 months
H3_55	H3 Job Tasks and Safety PART B	2c: Handling objects or stacked loads 50–100 lbs. (such as large boxes, shipping containers)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of	0= no; 1= yes;	Baseline, every 3 months

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
		incident occurred for each type of task.) Cuts or scratches		
H3_56	H3 Job Tasks and Safety PART B	2d: Handling objects or stacked loads 50–100 lbs. (such as large boxes, shipping containers)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Strains or sprains	0= no; 1= yes;	Baseline, every 3 months
H3_57	H3 Job Tasks and Safety PART B	2e: Handling objects or stacked loads 50–100 lbs. (such as large boxes, shipping containers)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Other	0= no; 1= yes;	Baseline, every 3 months
H3_58	H3 Job Tasks and Safety PART B	3a: Handling objects or stacked loads 25–50 lbs. (such as boxes, parts)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) (Task Screening)	0= no; 1= yes;	Baseline, every 3 months
H3_59	H3 Job Tasks and Safety PART B	3b: Handling objects or stacked loads 25–50 lbs. (such as boxes, parts)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Slip, trip or fall	0= no; 1= yes;	Baseline, every 3 months
H3_60	H3 Job Tasks and Safety PART B	3c: Handling objects or stacked loads 25–50 lbs. (such as boxes, parts)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Cuts or scratches	0= no; 1= yes;	Baseline, every 3 months
H3_61	H3 Job Tasks and Safety PART B	3d: Handling objects or stacked loads 25–50 lbs. (such as boxes, parts)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Strains or sprains	0= no; 1= yes;	Baseline, every 3 months
H3_62	H3 Job Tasks and Safety PART B	3e: Handling objects or stacked loads 25–50 lbs. (such as boxes, parts)? (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Other	0= no; 1= yes;	Baseline, every 3 months
H3_63	H3 Job Tasks and Safety PART B	4a: Packing/ unpacking boxes or containers (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which	0= no; 1= yes;	Baseline, every 3 months

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
		type of incident occurred for each type of task.) (Task Screening)		
H3_64	H3 Job Tasks and Safety PART B	4b: Packing/ unpacking boxes or containers (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Slip, trip or fall	0= no; 1= yes;	Baseline, every 3 months
H3_65	H3 Job Tasks and Safety PART B	4c: Packing/ unpacking boxes or containers (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Cuts or scratches	0= no; 1= yes;	Baseline, every 3 months
H3_66	H3 Job Tasks and Safety PART B	4d: Packing/ unpacking boxes or containers (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Strains or sprains	0= no; 1= yes;	Baseline, every 3 months
H3_67	H3 Job Tasks and Safety PART B	4e: Packing/ unpacking boxes or containers (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Other	0= no; 1= yes;	Baseline, every 3 months
H3_68	H3 Job Tasks and Safety PART B	5a: Performing seated office work- computer use (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) (Task Screening)	0= no; 1= yes;	Baseline, every 3 months
H3_69	H3 Job Tasks and Safety PART B	5b: Performing seated office work- computer use (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Slip, trip or fall	0= no; 1= yes;	Baseline, every 3 months
H3_70	H3 Job Tasks and Safety PART B	5c: Performing seated office work- computer use (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Cuts or scratches	0= no; 1= yes;	Baseline, every 3 months
H3_71	H3 Job Tasks and Safety PART B	5d: Performing seated office work- computer use (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Strains or sprains	0= no; 1= yes;	Baseline, every 3 months

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
H3_72	H3 Job Tasks and Safety PART B	5e: Performing seated office work- computer use (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Other	0= no; 1= yes;	Baseline, every 3 months
H3_73	H3 Job Tasks and Safety PART B	6a. Performing standing office work- sales or customer service (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) (Task Screening)	0= no; 1= yes;	Baseline, every 3 months
H3_74	H3 Job Tasks and Safety PART B	6b. Performing standing office work- sales or customer service (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Slip, trip or fall	0= no; 1= yes;	Baseline, every 3 months
H3_75	H3 Job Tasks and Safety PART B	6c. Performing standing office work- sales or customer service (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Cuts or scratches	0= no; 1= yes;	Baseline, every 3 months
H3_76	H3 Job Tasks and Safety PART B	6d. Performing standing office work- sales or customer service (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Strains or sprains	0= no; 1= yes;	Baseline, every 3 months
H3_77	H3 Job Tasks and Safety PART B	6e. Performing standing office work- sales or customer service (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Other	0= no; 1= yes;	Baseline, every 3 months
H3_78	H3 Job Tasks and Safety PART B	7a: Driving a vehicle for work (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) (Task Screening)	0= no; 1= yes;	Baseline, every 3 months
H3_79	H3 Job Tasks and Safety PART B	7b: Driving a vehicle for work (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Slip, trip or fall	0= no; 1= yes;	Baseline, every 3 months
H3_80	H3 Job Tasks and Safety PART B	7c: Driving a vehicle for work (PART B: Have you had any safety related incidents at work within the last 3 months? If yes,	0= no; 1= yes;	Baseline, every 3 months

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
		please mark below which type of incident occurred for each type of task.) Cuts or scratches		
H3_81	H3 Job Tasks and Safety PART B	7d: Driving a vehicle for work (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Strains or sprains	0= no; 1= yes;	Baseline, every 3 months
H3_82	H3 Job Tasks and Safety PART B	7e: Driving a vehicle for work (PART B: Have you had any safety related incidents at work within the last 3 months? If yes, please mark below which type of incident occurred for each type of task.) Other	0= no; 1= yes;	Baseline, every 3 months
H4_83	H4 General Health; SECTION A. GENERAL INFORMATION	1: Age in years	age in years	Baseline, 1st and 2nd annual
H4_84	H4 General Health; SECTION A. GENERAL INFORMATION	2. Gender: (Male/ Female)	M= male; F = female;	Baseline, 1st and 2nd annual
H4_85	H4 General Health; SECTION A. GENERAL INFORMATION	3a. Your Height: FEET ____	FEET ____	Baseline, 1st and 2nd annual
H4_86	H4 General Health; SECTION A. GENERAL INFORMATION	3a. Your Height: INCHES_____	INCHES_____	Baseline, 1st and 2nd annual
H4_87	H4 General Health; SECTION A. GENERAL INFORMATION	4. Your Weight: POUNDS_____	POUNDS_____	Baseline, 1st and 2nd annual
H4_88	H4 General Health; SECTION A. GENERAL INFORMATION	5. In the past year, on average, how much total time did you spend in a vehicle each day?	0= Less than 1 hour per day; 1= 1 hour to less than 2 hours per day; 2= 2 hours to less than 3 hours per day; 3= 3 hours to less than 5 hours per day; 4= More than 5 hours per day;	Baseline, 1st and 2nd annual
H4_89	H4 General Health; SECTION B. WORK INFORMATION	6. How long have you worked at this company?	0= Less than 3 months; 1= 3 months to less than 1 year; 2= 1 year to less than 3 years; 3= 3 years to less than 5 years; 4= 5 years to less than 10 years; 5= 10 years or more;	Baseline, 1st and 2nd annual
H4_90	H4 General Health; SECTION B. WORK INFORMATION	7. How long have you worked in your current job?	0= Less than 3 months; 1= 3 months to less than 1 year; 2= 1 year to less than 3 years; 3= 3 years to less than 5 years; 4= 5 years to less than 10 years; 5= 10 years or more;	Baseline, 1st and 2nd annual
H4_91	H4 General Health; SECTION B. WORK INFORMATION	8. On your job at this company, do you usually work:	0= Regular daytime shift (first shift); 1= Regular evening shift (second	Baseline, 1st and 2nd annual

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
			shift); 2= Regular night shift (third shift);	
H4_92	H4 General Health; SECTION B. WORK INFORMATION	9a. Do you work overtime at this company?	0= No; 1= Yes;	Baseline, 1st and 2nd annual
H4_93	H4 General Health; SECTION B. WORK INFORMATION	If yes, 9b. How many overtime HOURS PER WEEK do you USUALLY work?	0= Less than 5 hours per week; 1= 5 to 10 hours per week; 2= 11 to 20 hours per week; 3= More than 20 hours per week ;	Baseline, 1st and 2nd annual
H4_94	H4 General Health; SECTION B. WORK INFORMATION	10a. Do you work at a second job (for a different employer)?	0= No; 1= Yes;	Baseline, 1st and 2nd annual
H4_95	H4 General Health; SECTION B. WORK INFORMATION	If yes, 10b. Does the second job involve LIFTING, PUSHING, PULLING, or CARRYING of MODERATE weight objects?	0= No; 1= Sometimes; 2= Often;	Baseline, 1st and 2nd annual
H4_96	H4 General Health; SECTION B. WORK INFORMATION	If yes, 10c. Does the second job involve LIFTING, PUSHING, PULLING, or CARRYING of HEAVY weight objects?	0= No; 1= Sometimes; 2= Often;	Baseline, 1st and 2nd annual
H4_97	H4 General Health; SECTION B. WORK INFORMATION	10d. Does this second job involve bending your back at least as far forward as shown in the picture?	0= Never or rarely; 1= Less than half of the time; 3= Half the time or more;	Baseline, 1st and 2nd annual
H4_98	H4 General Health; SECTION C. PHYSICAL ACTIVITIES OUTSIDE OF WORK	11. How many hours do you use your hands with moderate to heavy effort? (such as scrubbing, using a hammer, gripping a bowling ball, weight lifting, etc.):	0= Less than 5 hours a week; 1= 5 to less than 10 hours a week; 2= 10 to less than 20 hours a week; 3= 20 or more hours a week;	Baseline, 1st and 2nd annual
H4_99	H4 General Health; SECTION C. PHYSICAL ACTIVITIES OUTSIDE OF WORK	12a. How many hours on average do you spend on activities in which you twist your back or bend forward at least as much as shown in this picture? (such as raking, working under the hood of a car, bathing a child, etc.)	0= Less than 5 hours a week; 1= 5 to less than 10 hours a week; 2= 10 to less than 20 hours a week; 3= 20 or more hours a week;	Baseline, 1st and 2nd annual
H4_100	H4 General Health; SECTION C. PHYSICAL ACTIVITIES OUTSIDE OF WORK	12b. How many hours on average do you spend on activities in which you lift, push, pull or carry moderate to heavy weights? (such as children or groceries, moving furniture, shoveling, backpacking, etc.)	0= Less than 5 hours a week; 1= 5 to less than 10 hours a week; 2= 10 to less than 20 hours a week; 3= 20 or more hours a week;	Baseline, 1st and 2nd annual
H4_101	H4 General Health; SECTION D. HEALTH INFORMATION	13. How would you rate your health compared to other persons your age?	0= Poor; 1= Fair; 2= Good; 3= Very Good; 4= Excellent;	Baseline, 1st and 2nd annual
H4_102	H4 General Health; SECTION E. NECK SYMPTOMS	14. In the past 12 months, have you had NECK symptoms (pain, aching, stiffness, spasm, unable to move your head, burning, numbness or tingling) more than 3 times OR lasting a week (7 days) or longer?	0= no; 1= yes;	Baseline, 1st and 2nd annual
H4_103	H4 General Health; SECTION E. NECK SYMPTOMS	15. In the past 12 months, how would you rate your level of NECK pain AT ITS WORST?	0= No pain; 1= Mild pain; 2= Moderate pain;	Baseline, 1st and 2nd annual

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
			3= Severe pain; 4= Very severe pain;	
H4_104	H4 General Health; SECTION E. SHOULDER SYMPTOMS	16. In the past 12 months, have you had SHOULDER symptoms (pain, aching, stiffness, spasm, unable to raise your arms, burning, numbness or tingling) more than 3 times OR lasting a week (7 days) or longer?	0= no; 1= yes;	Baseline, 1st and 2nd annual
H4_105	H4 General Health; SECTION E. SHOULDER SYMPTOMS	17a. In the past 12 months, how would you rate your level of SHOULDER pain AT ITS WORST? LEFT shoulder:	0= No pain; 1= Mild pain; 2= Moderate pain; 3= Severe pain; 4= Very severe pain;	Baseline, 1st and 2nd annual
H4_106	H4 General Health; SECTION E. SHOULDER SYMPTOMS	17b. In the past 12 months, how would you rate your level of SHOULDER pain AT ITS WORST? RIGHT shoulder:	0= No pain; 1= Mild pain; 2= Moderate pain; 3= Severe pain; 4= Very severe pain;	Baseline, 1st and 2nd annual
H4_107	H4 General Health; SECTION E. ELBOW/ FOREARM SYMPTOMS	18. In the past 12 months, have you had ELBOW/FOREARM symptoms (pain, aching, stiffness, burning, numbness or tingling) more than 3 times OR lasting a week (7 days) or longer?	0= no; 1= yes;	Baseline, 1st and 2nd annual
H4_108	H4 General Health; SECTION E. ELBOW/ FOREARM SYMPTOMS	19a. In the past 12 months, how would you rate your level of ELBOW/FOREARM pain AT ITS WORST? LEFT elbow/forearm:	0= No pain; 1= Mild pain; 2= Moderate pain; 3= Severe pain; 4= Very severe pain;	Baseline, 1st and 2nd annual
H4_109	H4 General Health; SECTION E. ELBOW/ FOREARM SYMPTOMS	19b. In the past 12 months, how would you rate your level of ELBOW/FOREARM pain AT ITS WORST? RIGHT elbow/forearm:	0= No pain; 1= Mild pain; 2= Moderate pain; 3= Severe pain; 4= Very severe pain;	Baseline, 1st and 2nd annual
H4_110	H4 General Health; SECTION E. HAND/WRIST SYMPTOMS	20. In the past 12 months, have you had HAND/WRIST symptoms (pain, aching, stiffness, burning, numbness or tingling) more than 3 times OR lasting a week (7 days) or longer?	0= no; 1= yes;	Baseline, 1st and 2nd annual
H4_111	H4 General Health; SECTION E. HAND/WRIST SYMPTOMS	21a. In the past 12 months, how would you rate your level of HAND/WRIST pain AT ITS WORST? LEFT hand/wrist:	0= No pain; 1= Mild pain; 2= Moderate pain; 3= Severe pain; 4= Very severe pain;	Baseline, 1st and 2nd annual
H4_112	H4 General Health; SECTION E. HAND/WRIST SYMPTOMS	21b. In the past 12 months, how would you rate your level of HAND/WRIST pain AT ITS WORST? RIGHT hand/wrist:	0= No pain; 1= Mild pain; 2= Moderate pain; 3= Severe pain; 4= Very severe pain;	Baseline, 1st and 2nd annual
H4_113	H4 General Health; SECTION E. BACK SYMPTOMS	22. In the past 12 months, have you had BACK pain every day for a week (7 days) or more?	0= no; 1= yes;	Baseline, 1st and 2nd annual
H4_114	H4 General Health; SECTION E. BACK SYMPTOMS	23. a) In the past 12 months, ON AVERAGE, how intense was your back pain rated on a 0–10 scale where 0 is ‘no pain’ and 10 is ‘pain as bad as could be’? (That is, your usual pain at times you were experiencing pain.)	0=0, 1=1; 2=2; 3=3; 4=4; 5=5; 6=6; 7=7; 8=8; 9=9; 10=10;	Baseline, 1st and 2nd annual
H4_115	H4 General Health; SECTION E. BACK SYMPTOMS	23 b) In the past 12 months, how intense was your WORST back pain rated on a 0–10 scale where 0	0=0, 1=1; 2=2; 3=3; 4=4; 5=5; 6=6; 7=7; 8=8; 9=9; 10=10;	Baseline, 1st and 2nd annual

Item	Survey Module	Description	Data Scale Descriptors	Data Collection Frequency
		is ‘no pain’ and 10 is ‘pain as bad as could be’?		
H4_116	H4 General Health; SECTION E. BACK SYMPTOMS	23c) How would you rate your back pain AT THE PRESENT TIME on a 0–10 scale, where 0 is “no pain” and 10 is “pain as bad as could be”?	0=0, 1=1; 2=2; 3=3; 4=4; 5=5; 6=6; 7=7; 8=8; 9=9; 10=10;	Baseline, 1st and 2nd annual

Table A2:

Survey Outcome Scoring

Outcome	Description	Measure Frequency	Scale	Code
Annual Back Symptom Frequency > 0	Measures whether there was any workerreported back pain [every day for a week (7 days) or more) in the past 12 months] on the modified Nordic assessment survey modules.	Baseline, 1st and 2nd annual	0 to 1	SUM all “1s” that appear in H4_113
Nass-Pain Frequency > 0	Measures whether there was any workerreported back pain in the past week on the Nass-Pain survey modules.	Baseline, every 3 months	0 to 1	If abs(Nass-Pain Severity-16.666) > .1 then Nass-Pain Severity = 1; else NassPain Severity = 0
Nass-Pain Severity	Measures the level of worker-reported back pain in the past week on the NassPain survey modules.	Baseline, every 3 months	16.7 to 100	Sum H1_1, H1_2, H1_9, H1_10, H1_11, H1_12, H1_13, H1_14, H1_15, H1_16, H1_17, divide total by 66, multiply by 100
Nass-Neuro Frequency > 0	Measures whether there was any workerreported back pain in the past week on the Nass-Neuro survey modules.	Baseline, every 3 months	0 to 1	If abs(Nass-Neuro Severity - 16.666) > .1 then Nass-Neuro Severity = 1; else Nass-Neuro Severity0 = 0
Nass-Neuro Severity	Measures the level of worker-reported back pain in the past week on the NassNeuro survey modules.	Baseline, every 3 months	16.7 to 100	Sum H1_3, H1_4, H1_5, H1_6, H1_7, H1_8, divide total by 36, multiply by 100
Annual Upper Extremity Symptom Frequency > 0	Measures whether there was any workerreported upper extremity pain [more than 3 times or lasting a week (7 days) or longer in the past 12 months] on the modified Nordic assessment survey modules.	Baseline, 1st and 2nd annual	0 to 5	SUM all “1s” that appear in H4_102, H4_104, H4_107, H4_110
DASH-Disability Frequency > 0	Measures whether there was any workerreported upper extremity pain in the last week on the DASH-Disability survey modules.	Baseline, every 3 months	0 to 1	If abs(DASH-Disability Severity - 0) > .1 then DASH-Disability Severity = 1; else DASH-Disability Severity = 0
DASH-Disability Severity	Measures the level of worker-reported upper extremity pain in the last week on the DASH-Disability survey modules.	Baseline, every 3 months	0 to 100	Sum 018_H2 to 028_H2 then average, producing a score out of five. This value is then transformed to a score out of 100 by subtracting one and multiplying by 25
DASH-Work Frequency > 0	Measures whether there was any worker-reported upper extremity pain in the last week on the DASH-Work survey modules.	Baseline, every 3 months	0 to 1	If abs(DASH-Work Severity - 0) > .1 then DASH-Work Severity = 1; else DASH-Work Severity = 0
DASH-Work Severity	Measures the level of worker-reported upper extremity pain in	Baseline, every 3 months	0 to 100	Sum 030_H2W to 033_H2W then average, producing a

Outcome	Description	Measure Frequency	Scale	Code
	the last week on the DASH-Work survey modules.			score out of five. This value is then transformed to a score out of 100 by subtracting one and multiplying by 25
Any Safety Events Frequency > 0	Measures whether there were any worker-reported safety related incidents at work within the last 3 months.	Baseline, every 3 months	0 to 1	SUM all “1s” that appear in 047_H3B
Material Handling Task-related Safety Events Frequency > 0	Measures whether there were any worker-reported safety related incidents at work associated with specific material handling tasks within the last 3 months.	Baseline, every 3 months	0 to 3	SUM all “1s” that appear in (048_H3B; 053_H3B; 058_H3B)

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Table 1:

Survey Sections Used to Determine Exposure Control Groups

This part of the survey asks about your daily work tasks and if you experienced certain safety incidents in the last three MONTHS. For Questions 34–37, please rate how often on average you performed the following tasks in your daily work over the LAST 3 MONTHS.	
34: Handling objects or stacked loads over 100 lbs. (such as appliances, large electronics equipment)?	-Never (0% of the time) – *if Never, go to Question 38* -Occasional (1–33% of the time) -Frequent (34–66% of the time) -Regular (67–100% of the time)
• 35: How often was the new Safety Grant equipment used to handle objects or stacked loads over 100 lbs.?	-Never (0% of the time) -Occasional (1–33% of the time) -Frequent (34–66% of the time) -Regular (67–100% of the time) -Not applicable (Safety Grant equipment not in place yet)
• 36: How often was another tool (such as a regular hand truck) used to handle objects or stacked loads over 100 lbs.?	-Never (0% of the time) -Occasional (1–33% of the time) -Frequent (34–66% of the time) -Regular (67–100% of the time)
• 37: How often did you use your body strength alone to handle large objects or stacked loads?	-Never (0% of the time) -Occasional (1–33% of the time) -Frequent (34–66% of the time) -Regular (67–100% of the time)
38: Handling objects or stacked loads 50–100 lbs. (such as large boxes, shipping containers)?	-Never (0% of the time) – *if Never, go to Question 42* -Occasional (1–33% of the time) -Frequent (34–66% of the time) -Regular (67–100% of the time)
• 39: How often was the new Safety Grant equipment used to handle objects or stacked loads 50–100 lbs.?	-Never (0% of the time) -Occasional (1–33% of the time) -Frequent (34–66% of the time) -Regular (67–100% of the time) -Not applicable (Safety Grant equipment not in place yet)
• 40: How often was another tool (such as a regular hand truck) used to handle objects or stacked loads 50–100 lbs.?	-Never (0% of the time) -Occasional (1–33% of the time) -Frequent (34–66% of the time) -Regular (67–100% of the time)
• 41: How often did you use your body strength alone to handle objects or stacked loads 50–100 lbs.?	-Never (0% of the time) -Occasional (1–33% of the time) -Frequent (34–66% of the time) -Regular (67–100% of the time)

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Table 2:

Employer Demographics and Intervention Summaries

NORA Industry	NAICS	Total Number of Employees	Baseline Affected Employee Count	Number of Completed Surveys	Specific Intervention Type
Construction	236115, New Single-Family General Contractors	4	4	13	(1) Telescoping forklift
	237310, Highway Street & Bridge Construction	7	7	26	(1) Heated tack tank and (1) direct fire melter
	238110, Poured Concrete Foundation and Structure Contractors	14	10	41	(2) Stair climbing hand trucks
	238140, Masonry Contractors	56	42	12	(1) Lift gate
	238210, Electrical Contractors	84	8	10	(1) Lift gate
	238220, Plumbing & HVAC Contractors	27	14	10	(1) Stair climbing hand trucks
		22	10	45	(1) Lift gate
		11	9	1	(2) Stair climbing hand trucks
		14	8	27	(2) Stair climbing hand trucks
		6	4	18	(1) Stair climbing hand truck
		4	4	0	(1) Stair climbing hand truck
		6	2	29	(1) Stair climbing hand truck
		1	1	9	(1) Stair climbing hand truck
Healthcare & Social Assistance	621991, Blood and Organ Banks	554	19	58	(4) Rail gates
	624310, Vocational Rehabilitation Services	55	9	17	(1) Lift gate
	812910, Pet Care (except Veterinary) Services	18	18	9	(1) Stainless steel bath
Manufacturing	311942, Spice & Extract Manufacturing	572	16 s	52	(6) Anti-fatigue mats
	333120, Construction Machinery Manufacturing	38	10	33	(1) Crane work station system
		18	10	18	(1) 5-ton jib crane; (1) 3-ton hoist
	333319, Other Commercial & Svc Machinery Manufacturing	15	12	1	(1) Scissor lift table
	333412, Industrial & Commercial Fan & Blower Manufacturing	36	10	0	(1) Scissor lift table
Public Safety	92214, Correctional Institutions	30	30	26	(1) Scissor lift table
Services (except Public Safety)	532299, All Other Consumer Goods Rental	50	50	36	(1) Lift gate

NORA Industry	NAICS	Total Number of Employees	Baseline Affected Employee Count	Number of Completed Surveys	Specific Intervention Type
	561730, Landscaping Services	24	24	18	(1) Log Loader; (1) compost spreader; (1) grapple attachment; (1) nursing jaws
	713120, Amusement Arcades	15	15	29	(1) Stair climbing hand trucks
	811310, Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance	6	6	11	(1) Electric lift for back of pick-up truck
	92, Public Administration	119	10	26	(1) Lift gate
Transportation, Warehousing & Utilities	484110, General Freight Trucking, Local	16	16	3	(3) Stair climbing hand trucks
Wholesale Retail Trade	423210, Furniture Merchant Wholesalers	50	50	165	(2) Scissor lift tables
		94	20	98	(12) Manual hand trucks; (7) scissor lift tables; (7) ramps
		25	20	9	(10) Manual hand trucks; (10) stair climbing hand trucks; (8) lift gates; (16) chassis modifications
	423610, Electric Equip & Wiring Merchant Wholesalers	207	32	81	(30) Boom lifts; (1) swing lift; (2) electric hoists; (33) super winches
	442110, Furniture Stores	152	35	63	(9) Appliance manual hand trucks
	Mean	64.2	15.1	27.4	
	Total	2,350	535	994	

Table 3:

Pain Symptoms Comparison at Baseline*

Measure	Schedule A	Schedule B	P Value	Schedule A + B	9 Surveys	Dropout	P Value
	N = 92	N = 79		N = 171	N = 71	N = 100	
NASS-Pain Severity Scaled	19.7 (16.7, 25.8)	22.7 (16.7, 31.8)	0.022	21.2 (16.7, 30.3)	19.7 (16.7, 30.3)	21.2 (16.7, 28.8)	0.446
NASS-Neuro Severity Scaled	16.7 (16.7, 27.8)	19.4 (16.7, 27.8)	0.251	16.7 (16.7, 27.8)	19.4 (16.7, 30.6)	16.7 (16.7, 27.8)	0.707
DASH-Disability Severity	1.1 (0, 9.1)	4.5 (0, 11.4)	0.209	2.3 (0, 11.4)	4.5 (0, 11.4)	2.3 (0, 9.1)	0.086
DASH-Work Severity	0 (0, 0)	0 (0, 12.5)	0.127	0 (0, 6.3)	0 (0, 6.3)	0 (0, 6.3)	0.995
NASS-Pain Frequency > 0	0.60	0.75	0.039	0.67	0.58	0.73	0.037
NASS-Neuro Frequency > 0	0.45	0.57	0.106	0.50	0.52	0.49	0.688
DASH-Disability Frequency > 0	0.50	0.61	0.159	0.55	0.61	0.51	0.216
DASH-Work Frequency > 0	0.22	0.32	0.142	0.26	0.27	0.26	0.911
Highly Exposed	0.46	0.56	0.190	0.50	0.46	0.53	0.401
Body User	0.39	0.59	0.008	0.49	0.42	0.53	0.166
Age	39 (30, 50)	44.5 (31, 54)	0.032	41.5 (30, 51)	48 (39, 55)	37 (29, 47)	0.000
Gender (%Male)	0.945652	0.924051	0.566	0.9357	0.929577	0.94	0.784
Company Tenure	5 (3, 6)	5 (4, 6)	0.550	5 (4, 6)	5 (5, 6)	5 (3, 5)	0.004
Job Tenure	5 (3, 6)	5 (3, 6)	0.584	5 (3, 6)	5 (4, 6)	4 (3, 5)	0.147
Annual Upper Extremity Symptom Frequency > 0	0.57	0.71	0.052	0.63	0.69	0.59	0.181
Annual Low Back Symptom Frequency > 0	0.39	0.56	0.030	0.47	0.41	0.51	0.190

*One company performing seasonal work was not included.

Table 4:

Pain Symptom Frequency and Severity Time Trends *

Schedule **	Data Collection	N Affected Employees	Upper Extremity Symptom Frequency > 0	Back Symptom Frequency > 0	NASS Pain Frequency > 0	NASS Neuro Frequency > 0	DASH Disability Frequency > 0	DASH Work Frequency > 0	NASS Pain Severity Scaled	NASS Neuro Severity Scaled	DASH Disability Severity	DASH Work Severity
A	Baseline	29	66%	31%	48%	45%	55%	17%	23.48	23.02	7.37	4.74
	First Annual	29	62%	34%	59%	34%	55%	38%	27.25	22.97	9.01	9.15
	Second Annual	29	48%	24%	52%	34%	52%	34%	26.38	22.51	10.15	8.41
B	Baseline	42	71%	48%	64%	57%	64%	33%	24.94	25.07	7.47	6.45
	First Annual	42	64%	40%	74%	48%	60%	24%	25.43	26.12	7.80	7.01
	Second Annual	42	62%	38%	64%	40%	55%	29%	25.94	24.14	8.77	7.44
A+B	Baseline	71	69%	41%	58%	52%	61%	27%	24.34	24.25	7.43	5.75
	First Annual	71	63%	38%	68%	42%	58%	30%	26.17	24.86	8.28	7.88
	Second Annual	71	56%	32%	59%	38%	54%	31%	26.12	23.47	9.33	7.83

* Restricted to those with nine complete surveys; one company performing seasonal work was not included.

** Schedule A employers received the intervention immediately; Schedule B received it after a six-month waiting period.

Table 5:

Pain Symptom Comparison by Exposure and Intervention Usage Groups*

Measure	Exposure / Intervention Usage Groups	All Interventions			Ergonomic Material Handling Only (Anti-fatigue Mats Excluded)		
		N Surveys	Mean	Effect of Intervention**	N Surveys	Mean	Effect of Intervention**
NASS-Pain Frequency > 0	1	592	58.3%	−46.8% (−100.4%, 6.9%)	554	56.1%	**−52.5% (−101.3%, −3.7%)**
	2	172	73.3%		162	71.6%	
	3	56	66.1%		53	66.0%	
	4	148	79.1%		146	78.8%	
NASS-Neuro Frequency > 0	1	592	40.9%	−9.1% (−90.3%, 72%)	554	39.2%	−14.3% (−94.1%, 65.4%)
	2	172	57.0%		162	54.9%	
	3	56	48.2%		53	49.1%	
	4	148	57.4%		146	56.9%	
DASH-Disability Frequency > 0	1	592	52.4%	−31.7% (−92.4%, 29%)	554	51.1%	−17.2% (−93.9%, 59.5%)
	2	172	54.1%		162	54.3%	
	3	56	55.4%		53	52.8%	
	4	148	62.2%		146	61.6%	
DASH-Work Frequency > 0	1	592	26.2%	−2.1% (−86.8%, 82.6%)	554	25.1%	−7.1% (−90.1%, 75.9%)
	2	172	31.4%		162	30.3%	
	3	56	28.6%		53	28.3%	
	4	148	40.5%		146	40.4%	
Annual Upper Extremity Symptom Frequency > 0	1	197	58.9%	**−86.6% (−96.6%, −47.9%)**	183	57.9%	**−88% (−105.1%, −70.9%)**
	2	57	52.6%		53	50.9%	
	3	21	42.9%		20	40.0%	
	4	68	79.4%		67	79.1%	
Annual Low Back Symptom Frequency > 0	1	197	34.5%	−59.2% (−89.4%, 57.5%)	183	33.9%	**−63.9% (−115.4%, −12.4%)**
	2	57	45.6%		53	45.3%	
	3	21	57.1%		20	55.0%	
	4	68	58.8%		67	59.7%	
NASS-Pain Severity Scaled	1	592	16.1	−7% (−19.3%, 7.2%)	554	15.8	−9.8% (−23.2%, 3.6%)

Measure	Exposure / Intervention Usage Groups	All Interventions			Ergonomic Material Handling Only (Anti-fatigue Mats Excluded)		
		N Surveys	Mean	Effect of Intervention**	N Surveys	Mean	Effect of Intervention**
	2	172	17.7		162	17.4	
	3	56	16.7		53	16.8	
	4	148	19.6		146	19.6	
NASS-Neuro Severity Scaled	1	592	8.3		554	8.2	
	2	172	9.3	0% (−19.4%, 24.1%)	162	9.1	−6.3% (−27.1%, 14.6%)
	3	56	9.2		53	9.3	
	4	148	9.3		146	9.3	
DASH-Disability Severity	1	592	7.9		554	7.5	
	2	172	8.9	**−28.8% (−46.2%, −5.7%)**	162	8.6	**−30.1% (−50.1%, −10.1%)**
	3	56	8.2		53	7.3	
	4	148	11.4		146	11.4	
DASH-Work Severity	1	592	6.5		554	6.2	
	2	172	7.5	**−39.9% (−58.8%, −12.1%)**	162	7.2	**−44.7% (−66.5%, −22.9%)**
	3	56	7.4		53	7.6	
	4	148	11.8		146	11.9	

*One company performing seasonal work was not included.

**Based on comparing Groups 2 and 4, with 95th percentile confidence intervals shown

• Group 1: Least Exposed

• Group 2: Highly Exposed Intervention User

• Group 3: Highly Exposed Other

• Group 4: Highly Exposed Body User

Table 6:

Safety Incident Frequency Time Trends *

Schedule **	Data Collection	N Workers	Any Safety Events Frequency > 0	Material Handling Task-related Safety Events Frequency > 0
A	Baseline	29	6.9%	0.0%
	First Annual	29	20.7%	13.8%
	Second Annual	29	6.9%	3.4%
B	Baseline	42	9.5%	9.5%
	First Annual	42	7.1%	4.8%
	Second Annual	42	2.4%	0.0%
A+B	Baseline	71	8.5%	5.6%
	First Annual	71	12.7%	8.5%
	Second Annual	71	4.2%	1.4%

* Restricted to those with nine complete surveys; one company performing seasonal work was not included.

** Schedule A employers received the intervention immediately; Schedule B received it after a six-month waiting period.

Table 7:

Safety Incidents Comparison by Exposure and Intervention Usage Groups

Measure	Exposure / Intervention Usage Group	All Interventions			Ergonomic Material Handling Only (Anti-fatigue Mats Excluded)		
		N Surveys	Mean	Effect of Intervention**	N	Mean	Effect of Intervention**
Any Safety Events Frequency > 0	1	592	4.7%	5.4% (−58%, 164.4%)	554	4.2%	5.7% (−94.6%, 106.1%)
	2	172	9.9%		162	9.9%	
	3	56	8.9%		53	9.4%	
	4	148	10.1%		146	10.3%	
Material Handling Task-related Safety Events Frequency > 0	1	592	3.0%	−15.2% (−66.2%, 112.8%)	554	2.5%	−9.4% (−91.3%, 72.4%)
	2	172	7.6%		162	8.0%	
	3	56	5.4%		53	5.7%	
	4	148	8.8%		146	8.9%	

*One company performing seasonal work was excluded.

**Based on comparing Groups 2 and 4, with 95th percentile confidence intervals shown.