Development and Evaluation of a Questionnaire to Document Worker Exposures to Mechanical Loading at a Workplace Level

Amin Yazdani1,*, Philip Bigelow2, Niki Carlan2, Syed Naqvi3, Lynda S. Robson4, Ivan Steenstra4, Keith McMillan5, and Richard Wells1

1Department of Kinesiology, Faculty of Applied Health Science, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada
2School of Public Health and Health Systems, Faculty of Applied Health Science, University of Waterloo, Waterloo, ON, Canada
3Ergonomics Worldwide Consulting LLC, Trabuco Canyon, CA, USA
4Institute for Work and Health, Toronto, ON, Canada
5Occupational Cancer Research Centre, Toronto, ON, Canada

OCCUPATIONAL APPLICATIONS Despite many biomechanical risk factors being clearly linked to the development of musculoskeletal disorders, little measurement of the prevalence of physical loads in workplaces is being conducted. Through a collaborative partnership with unions, a health and safety organization, and researchers, this project developed and tested a questionnaire to document exposures to physical workloads in workplaces. Surveys were first completed independently by two members of each organization’s joint health and safety committee. The same survey was later completed collectively to arrive at a consensus between the two members. Results of the surveys were then compared to findings from a walk-through conducted by an ergonomist. Substantial to excellent agreement was found between the identification and assessment of exposure levels to 26 types of physical loading by the ergonomist and workplace. Such a survey could be an efficient technique to characterize the loads to which workers are exposed. Such data could have value for targeting prevention activities at a workplace or jurisdictional level.

TECHNICAL ABSTRACT Background: The presence and level of exposure to mechanical risk factors can be considered leading indicators in the development of musculoskeletal disorders. Although there are multiple methods for musculoskeletal disorder risk assessment, most of these methods record data related to an individual person performing a specific task. Rather in this questionnaire, we are collecting the exposure data at the workplace level (i.e., for all people experiencing this type of load). Purpose: The aim of this study was to develop and test a survey to document the presence and levels of multiple types of physical loading in a workplace. Methods: A survey requesting information on exposure to 26 types of loading was developed. It was distributed to management and worker representatives for their individual and then their consensus ratings. The same survey was completed by an ergonomist during a site visit. Results: Complete data sets were obtained from 30 workplaces across a
variety of sectors. The most prevalent loads reported were sitting, neck bent or twisted, computer use, and carrying loads. For the presence or absence of specific loads, the consensus and ergonomist’s ratings agreed well with over 90% for nine of 26 load types and over 70% agreement for 10 other load types. For a calculated exposure index, only four load types differed significantly across the two types of raters. **Conclusions:** The study demonstrates that a survey completed by individuals familiar with the workplace could be used to document exposure to physical loading at a workplace level in an efficient manner. Such a survey may be useful in understanding the nature and prevalence of such exposures and targeting prevention activities at a workplace or jurisdictional level.

**KEYWORDS** Musculoskeletal disorders, physical loads, ergonomics, hazard identification, risk assessment

### INTRODUCTION

The prevention of musculoskeletal disorders (MSD) is of importance to the health of workers and economic health of workplaces. There is extensive literature linking workplace physical risk factors to MSD. The risk factors are commonly summarized as force, posture, and repetition, with cold and vibration being contributing factors (Hagberg et al., 1995; Bernard, 1997; National Research Council [NRC], 2001; Hoogendorn et al., 2002). Results from the National Institute for Occupational Safety and Health (NIOSH) consortium studies, e.g., Harris, Eisen, Goldberg, Krause, and Rempel (2011), have confirmed these risk factors. This body of evidence supports the use of physical or mechanical loading as a leading indicator for development of a wide range of MSD.

There are a large number of tools available for MSD risk assessment (Hagberg et al, 1995; van der Beek & Frings-Dresen, 1998; Dellemere, Haslegrave, & Chaffin, 2004; David, 2005; Marras & Karwowski, 2006; Takala et al., 2010; Yazdani, 2015). Reviews of particular methods are also available, such as questionnaires (Stock, Fernandes, Delisle, & Vézina, 2005) or observational methods (Denis, Lortie, & Rossignol, 2000). However, the overwhelming majority of these tools are designed to record data related to an individual person performing a specific task. Rather in this questionnaire, we are collecting the exposure data at the workplace level (i.e., for all the people exposed to the load type).

Systematic health and safety management frameworks suggest that it is an organization’s responsibility to provide safe working conditions: to anticipate, identify, assess, and control a wide range of risks in the workplace (Yazdani et al., 2015); a formal risk assessment is therefore needed. A tiered approach is advocated by Malchaire’s (2004) screening, observation, analysis, and expert (SOBANE) approach. He noted that preliminary to formal risk assessment activities and screening of the workplace can be reasonably straightforward. He argued that:

> [T]his identification must be carried out internally, by people in the company who know perfectly the work situation, even if they have little qualification in safety, physiology or ergonomics. These people are the workers themselves, their immediate technical management, the employer itself in the small companies, with an internal OH practitioner, if available, in a medium-sized or large company. (Malchaire, 2004, p. 445)

At a broader level, the Fourth European Working Conditions Survey (European Foundation for the Improvement of Living and Working Conditions, 2007, p. 116) asked a population of workers and individuals “Please tell me, using the same scale, does your main paid job involve . . .?” Examples of the physical risk factors included tiring or painful positions, lifting or moving people, or carrying or moving heavy loads. Although the questions are highly relevant to our purpose of identifying leading indicators for MSD development, this survey was designed with the individual as the unit of observation, and in order to characterize a workplace, a substantial proportion of workers per workplace would need to be sampled.

**Development of a survey to document physical loads**
The goal of this research project was to create and evaluate a survey for the surveillance and tracking of physical loading. This survey could be used in companies and at the federal and provincial levels of the health and safety system for benchmarking and tracking MSD prevention activities. A company could use the results of the survey to help in planning MSD prevention activities. A second goal was to develop a survey to help organizations to document the physical loads related to the development of MSD at their workplace in an efficient manner without necessitating professional consultation or having to administer questionnaires to all individuals within each workplace.

**METHODS**

The research team was composed of academic researchers, including individuals with expertise in MSD, statistics, methodology, and knowledge transfer; the director of a not-for-profit health and safety association; and a national health and safety representative from a large private sector union. Representatives from several large unions in Ontario, Canada, were recruited to work on the development of the survey and assist in recruiting employers to participate in the testing of the approach.

**Developing the Survey**

The Washington State Survey (Foley, Silverstein, Polissar, & Neradilek, 2009) was the starting point to develop our questionnaire. The choice of the Washington State Survey was based on multiple similarities in goals, approaches, and purpose and because it was one of very few surveys created for the workplace level. As reported by Silverstein et al. (2004), the Washington State Department of Labor and Industry was in the process of implementing the Washington State Ergonomics Rule; the goal for the survey was to help evaluate the effect of the rule on workplaces in the state before and after the implementation of the rule. Although no such regulation currently exists in Ontario, a goal of the health and safety system is to reduce risk factors that lead to MSD. Another similarity is the primary prevention approach, which focuses on finding and fixing hazards before they cause MSD. A third parallel is their compatibility of purpose. The Washington State Survey was at the workplace level, which allowed users to document MSD prevalence, exposure to physical hazards, awkward movements and positions, and the preventive or reduction actions that had been taken. For example, to assess the level of hazards present in the workplace, employers were asked whether, how many, and for how long employees at their locations perform specified tasks (involving force, repetition, posture, and vibration) that were risks for MSD (e.g., Appendix S1.2–4 in Silverstein et al., 2004). Many of the items from Silverstein’s survey were also used in a Hazard Zone Jobs Checklist that was incorporated into the Ergonomics Rule. Additionally, many of these risk factors were used as a basis for the Ontario MSD Hazard Risk Assessment Checklist (Occupational Health and Safety Council of Ontario [OHSCO], 2008).

A key difference was that this survey was not intended to be a part of a health and safety regulation. We did not intend to usurp the responsibility of an organization to identify hazards and assess risk; the survey focused on identifying whether certain mechanical loadings were encountered by workers in a workplace, the number of workers exposed, and an estimate of the duration or frequency of their exposure. These mechanical loadings may or may not turn out to be considered actionable, based upon a more formal assessment.

The survey’s accessibility and ease of use by workplace parties was then considered by receiving informal and formal feedback from the participants and union representatives. An important issue was the ability of workplace parties to fill out the survey within a short time period. We aimed for a survey that did not take longer than half an hour to complete. The input from meetings with union representatives and other stakeholders was synthesized by the research team and used to inform the development of the final questionnaire. Tables 1(a) and 1(b) show the 26 types of mechanical loading chosen for the questionnaire along with their exposure metrics.

**Choice of Breakpoint Weights for Lifting**

Our purpose was to describe the loads experienced in a workplace as a first step to allow planning of hazard identification activities; it is therefore not intended as a risk indicator by itself. A number of lifting situations were identified, and breakpoints useful in understanding loading at a workplace level were chosen.
### TABLE 1(a) The 26 types of physical loading and their corresponding exposure metrics.

| Short Form | Type of Physical Loading | Full question: For all shifts, how many people working here . . . | Exposure Metric |
|------------|--------------------------|-------------------------------------------------------------|-----------------|
| Q1: Carry loads | . . . Carry loads more than a few steps—loads greater than 10 kg | No exposure, 0–2 hours, 2–4 hours, 4–8 hours, over 8 hours |
| Q2: Trunk flexed | . . . Work while bending forward—with few pauses | |
| Q3: Push/pull loads | . . . Push or pull loads more than a few steps—wheeling more than 100 kg or dragging more than 35 kg | |
| Q4: Lift >23 kg<sup>b</sup> | . . . Lift or lower 23 kg, or more—unassisted | No exposure, 1 time/shift, 1–9 times/shift, 10–100 times/shift, >100 times/shift |
| Q5: Lift >40 kg<sup>b</sup> | . . . Lift or lower 40 kg or more—unassisted | |
| Q6: Lift people | . . . Lift or reposition people—unassisted | |
| Q7: Hand above shoulder<sup>b</sup> | . . . Work with one or both hands above shoulder level—with minimal loads in the hands with few pauses | No exposure, 0–2 hours, 2–4 hours, 4–8 hours, over 8 hours |
| Q8: Lift above shoulder<sup>b</sup> | . . . Lift or lower objects above the shoulders | |
| Q9: Neck bent/twisted<sup>b</sup> | . . . Work with neck in an awkward position—with few pauses | |
| Q10: Static upper body<sup>b</sup> | . . . Hold a fixed position of the upper body—with few pauses | |
| Q11: Repetitive arm<sup>b</sup> | . . . Perform repetitive movement of whole arm—more than twice per minute | |
| Q12: Repetitive hand<sup>b</sup> | . . . Move the hand, wrist, or forearm more than 10 times per minute—not typing | |
| Q13: Pinch grip<sup>a</sup> | . . . Pinch grip small objects between thumb and finger—continuously or with few pauses | |
| Q14: Power grasp<sup>a</sup> | . . . Use the whole hand to grasp objects—continually or squeeze objects repeatedly | No exposure, 0–2 hours, 2–4 hours, 4–8 hours, over 8 hours |
| Q15: Computer use<sup>a</sup> | . . . Use a keyboard or mouse—intensively | |
| Q16: Hand as hammer<sup>a</sup> | . . . Use their hand as a hammer to pound objects | |
| Q17: Gloves | . . . Grasp objects while wearing heavy gloves or gloves that get in the way | |
| Q18: Standing | . . . Stand—with infrequent walking | |
| Q19: Sitting | . . . Sit—not in vehicles | |
| Q20: Driving on-road | . . . Sit in or drive—on-road vehicles only | |
| Q21: Driving off-road | . . . Sit or stand on vibrating surfaces—machines or off—road vehicles | |
| Q22: Kneel/squat<sup>b</sup> | . . . Kneel or squat | |
| Q23: Knee hammering | . . . Use their knee as a hammer—more than once/minute | |
| Q24: Cold temperature | . . . Work in the cold | |
| Q25: Moderate vibration<sup>a</sup> | . . . Use or grasp moderate vibration tools or objects | No exposure, <15 minutes, 15–30 minutes, 30–60 minutes, >60 minutes |
| Q26: High vibration<sup>a</sup> | . . . Use or grasp high vibration tools or objects | |

<sup>a</sup>Items taken from Washington State Caution Zone Checklist.  
<sup>b</sup>Items based upon Washington State Caution Zone Checklist.

### TABLE 1(b) The 26 types of physical loading and their corresponding exposure metrics.

| Short Form | Type of Physical Loading | Full question: For all shifts, how many people working here . . . | Exposure Metric |
|------------|--------------------------|-------------------------------------------------------------|-----------------|
| Q14: Power grasp<sup>a</sup> | . . . Use the whole hand to grasp objects—continually or squeeze objects repeatedly | No exposure, 0–2 hours, 2–4 hours, 4–8 hours, over 8 hours |
| Q15: Computer use<sup>a</sup> | . . . Use a keyboard or mouse—intensively | |
| Q16: Hand as hammer<sup>a</sup> | . . . Use their hand as a hammer to pound objects | |
| Q17: Gloves | . . . Grasp objects while wearing heavy gloves or gloves that get in the way | |
| Q18: Standing | . . . Stand—with infrequent walking | |
| Q19: Sitting | . . . Sit—not in vehicles | |
| Q20: Driving on-road | . . . Sit in or drive—on-road vehicles only | |
| Q21: Driving off-road | . . . Sit or stand on vibrating surfaces—machines or off—road vehicles | |
| Q22: Kneel/squat<sup>b</sup> | . . . Kneel or squat | |
| Q23: Knee hammering | . . . Use their knee as a hammer—more than once/minute | |
| Q24: Cold temperature | . . . Work in the cold | |
| Q25: Moderate vibration<sup>a</sup> | . . . Use or grasp moderate vibration tools or objects | No exposure, <15 minutes, 15–30 minutes, 30–60 minutes, >60 minutes |
| Q26: High vibration<sup>a</sup> | . . . Use or grasp high vibration tools or objects | |

<sup>a</sup>Items taken from Washington State Caution Zone Checklist.  
<sup>b</sup>Items based upon Washington State Caution Zone Checklist.
Taking into account the range of loads used for lighter lifts in questionnaires, we had a choice of 5 or 10 kg (≈10 or ≈25 lb). We set the breakpoint value at 10 kg by considering Hoozemans, Kingma, de Vries, and van Dieën (2008), who showed that for lower loads, trunk posture was the main determinant of spine compression. It was just within the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for frequent long-duration lifting (except for extreme reaches) and fell within the range of the 75% values for females from Snook and Ciriello (1991). In addition, Kelsey et al. (1984) found increased risks for lifting more than 25 pounds 25 times per day, lifting more than 25 pounds while twisting more than five times per day, and lifting more than 25 pounds per day while twisting and having the knees straight. Moreover, Macfarlane et al. (1997) reported increased risks to the low back for lifting or moving 25 or more pounds.

The breakpoint of 23 kg was based upon the load constant in the revised NIOSH equation (Waters, Putz-Anderson, Garg, & Fine, 1993). The breakpoint of 40 kg was intended to capture very heavy lifting, which our advisory group pointed out was all too common. The breakpoint value was based on a value above the highest weights (32 kg) in the ACGIH lifting TLV. Macfarlane et al. (1997) found that heavy, infrequent lifting (more than 75 pounds once per day) increased risk. Finally, lifting people was regarded as high risk, and we believed that it was important to identify such loading.

**Recruitment**

A core concept in the administration of the survey was that it was to be completed by both the management and the worker co-chairs of the joint health and safety committee (JHSC) within each organization. The original Washington State Survey was accompanied by a cover letter that was mailed to each company with a request to have the survey completed by someone with detailed knowledge of that workplace who could answer the questions about employee exposures, injuries, and company programs to address MSD hazards. The presence of a JHSC in Ontario's workplaces naturally produces a group of people well versed in health and safety at the workplace. The existence of the labor and management co-chairs suggests two knowledgeable and certified people per site who would be expected to have a good overview of the physical loads present in their workplace. The two respondents were asked to fill out the surveys independently. These two surveys provided two independent, yet comparable, data sources per workplace. After the questionnaires had been filled out independently, the two respondents were requested to meet. Their objective was to come to a consensus decision on the level of physical loads in their workplace. Their consensus decision was recorded as a third data source in the same format. In small organizations, the survey was completed by the safety representative and one worker. Each question on the survey also asked each respondent to rate their confidence in their rating of the load type.

For this study, the goal was to obtain a range of workplace sizes and sectors and not to obtain a representative sample of workplaces in Ontario. The study was conducted in partnership with multiple unions that helped the research team gain access to organizations. Small- and medium-sized enterprises (SMEs) comprise the majority of companies in Ontario, and we therefore attempted to recruit such organizations. Team members attended a bi-annual health and safety union conference to recruit participants. The project manager also sent out recruitment letters to potential participants known to the research team and made follow-up phone calls to encourage participation and completion of the packages that had been distributed.

Survey packages were distributed to 302 workplaces with the assistance of the seven unions. In larger organizations, a separate survey was to be completed for each distinct worksite. It was judged to be distinct for the purposes of this study if the site had a separate JHSC. All of the unions had support from their leadership, which endorsed the project with their membership. All participants provided informed consent, as approved by the Research Ethics Board at the University of Waterloo, prior to completing the survey.

**Workplace Site Visits (Document and Observational Analysis)**

Workplaces that completed and returned the three surveys (two separate surveys completed by management and
labor co-chairs of the JHSC and one consensus survey; see the supplemental online appendices) were scheduled to receive a site visit from an ergonomist. Each ergonomist received mentoring and training from the lead ergonomist on the project to develop a standard protocol for mechanical load assessment. To improve the reliability of the measures, the project ergonomist initially visited workplaces with the ergonomist. Each of the ergonomists involved in collecting the data for this project had multiple years of field work experience. One had a Master of Science in Occupational Health and Safety and was a Ph.D. candidate with 4 years of workplace experience in a health, safety, and ergonomics leadership role in the manufacturing and construction sectors. The other had a Master of Science in Kinesiology with 2 years of ergonomics work experience and is now working for an ergonomics consulting company.

The site visit included a walk-through, inspection, and review of the workplace’s documents to obtain an independent assessment of loading. This typically took from 2 to 4 hours, depending on the size and number of departments within the organization. The ergonomist used all available information: discussions with workers and supervisors, a walk-through of all departments, and company administrative data, which could include minutes of the JHSC, notes from health and safety representatives, occupational health nurse communications, job descriptions and specifications, work instruction sheets, job safety analyses (JSAs), ergonomic reports, and physical demands analyses (PDA). All this information was used by the ergonomist to complete the survey. The ergonomist’s evaluation comprised the fourth data source. The ergonomist was blinded to the survey data completed by JHSC members.

**Ergonomist’s Report to the Workplace**

The ergonomist’s observations were formatted to be directly comparable to the surveys completed at the workplace. A portable color printer was used to produce a graphical representation of the physical loading present in the workplace as a report to the company visited. As well, the ergonomist selected, based upon the loading and specific details observed during a walk-through, two load types likely to be hazards within the workplace and gave corresponding generic ideas for solutions to reduce loading. The report was given to the workplace representatives before the ergonomist left the premises.

**Debriefing of JHSC Co-Chairs and Safety Representatives**

To evaluate challenges in filling out the questionnaire, a debriefing of the individuals who filled out the questionnaires was performed. A qualitative researcher visited a site during the consensus process and interviewed a selection of those who filled out the questionnaire (either management and union co-chairs or safety representatives) in a number of other organizations to assess the usability and ease with which the respondents completed the survey.

**Analysis**

The surveys were checked for completeness and entered into a spreadsheet. The workplace was the unit of observation and analysis. The number of employees exposed to a given load for a particular loading category was converted to a proportion by dividing by the total number of employees. Two measures were calculated from the surveys:

1) Exposed—yes or no? Did the workplace have any exposure to a particular load type (PRES)?

2) Exposure index (EI):

\[
EI = 0 \cdot CAT_1 + 1 \cdot CAT_2 + 3 \cdot CAT_3 + 6 \cdot CAT_4 + 10 \cdot CAT_5, \tag{1}
\]

where

- EI is the weighted average of the exposure durations, across the workers evaluated;
- CAT denotes the proportion of workers in each category of exposure; CAT1–CAT5 are defined in Table 2; and
- multipliers are the exposure times at the mid-points of the ranges; for the highest category, a 12-hour shift was taken as the upper shift length.

The EI ranged between 0 (nobody exposed) and 10 (all people exposed for the maximum time or repetitions).

The percentage of agreement for the dichotomous variable PRES was calculated. This reflected the most basic of decisions, i.e., whether anybody at the site was
exposed to the particular load. With respect to agreement between raters, to the best of the authors’ knowledge, there is no well-accepted criterion (i.e., good, moderate) and a wide range of values and labels can be found. In this study, the values from Landis and Koch (1977) were used, interpreting a value of 0–0.20 as slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1 as almost perfect agreement.

The distribution across organizations and questions was non-normal; therefore, the data were log transformed. As there were four ratings for each load in each workplace, a repeated-measures analysis was used to test for any differences for both the log EI and the proportion exposed between management, labor, consensus, and ergonomist. Differences were taken as statistically significant at \( p < 0.05 \). Multiple paired \( t \)-tests with a Bonferroni correction were performed to determine the statistically significant differences in ratings between raters for each load. The confidence ratings for each load type were plotted as stacked bar charts. In this study, higher exposure was defined as loading for more than 4 hours or a repetition of >10 per shift for lifting. Finally, the relationship between raters’ agreement (ergonomists and consensus) and consensus confidence reported as “sure” was assessed using a scatter plot.

**RESULTS**

**Responses**

Of the 302 packages that were distributed to potential participating organizations, 60 were returned (19.9% response rate). To be included in the data analysis, questionnaires from two respondents within the organization, along with a questionnaire reflecting their consensus decisions, as well as a completed workplace site visit from the ergonomist were required. A total of 30 complete data sets were available for analysis. Table 3 shows the characteristics of the 30 organizations used in the analysis. The units ranged in size from 14 to 2,675 employees. Sectors represented included healthcare, manufacturing, municipal, and transportation.

To match the categories in the European Survey (European Foundation for the Improvement of Living and Working Conditions), a workplace was designated as sedentary if more than 50% of the workers sat for at least 4 hours; three were classed as such.

**Exposed Versus Not Exposed**

The proportion of exposed versus non-exposed workers to the different types of loading (based upon the ergonomist’s observations) can be expressed as the proportion of workers exposed OR the proportion of workplaces with that exposure. The loading types that had the greatest proportion of workplaces with exposure were sitting, neck bent/twisted, and computer use (Fig. 1). The smallest proportion of workplaces had workers exposed to lifting people, using the hand as a hammer, and knee hammering. The loading types that had the greatest proportion of workers with exposure were carrying loads, power grasp, standing, and sitting (Fig. 2).

Workplaces with many people with higher exposure (defined here as loading for more than 4 hours or a repetition of >10 per shift for lifting) are of particular interest (Foley et al., 2009). These workers should benefit most from workplace intervention, and their exposures strongly signal to the workplace that further risk assessment and, if necessary, interventions are needed. Figure 3 represents the percentage of the workplaces with high exposure to each of the 26 types of loading as rated by the ergonomist. A high percentage of workplaces are exposed to prolonged sitting and standing, computer use, lifting, and carrying loads.

**EI**

Figure 4 shows the distribution of the EI across the 26 loading types. In general, the trend of exposures mimics what is seen in Fig. 2: the percentage of workers

| Exposability | No exposure | 0–2 hours | 2–4 hours | 4–8 hours | Over 8 hours |
|--------------|-------------|-----------|-----------|-----------|-------------|
| A            | No exposure | 0–2 hours | 2–4 hours | 4–8 hours | Over 8 hours |
| B            | No exposure | 1 time/shift | 1–9 times/shift | 10–100 times/shift | >100/shift |
| C            | No exposure | <15 minutes | 15–30 minutes | 30–60 minutes | >60 minutes |

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with any exposure to the load type. The single highest EI was observed in one organization for lifting 23 kg with an EI of 8.6. Most of the workers in this smaller workplace were involved in baggage handling. Other load types where single organizations had high EIs were for computer use (maximum = 6.9), sitting (maximum = 6.1), standing (maximum = 7.7), and vibration exposure (maximum = 6.1); however, these distributions are highly skewed and the median EI was much lower.

![Percentage of workplaces with exposure to each of the 26 types of loading as rated by an ergonomist.](image)

**FIGURE 1** Percentage of workplaces with exposure to each of the 26 types of loading as rated by an ergonomist.
FIGURE 2  Percentage of workers having any exposure to each of the 26 types of loading as rated by the ergonomist.

FIGURE 3  Percentage of workplaces with exposure over 4 hours or greater than 10 occurrences per shift to each of the 26 types of loading as rated by the ergonomist.

FIGURE 4  Distribution of the EI across all workplaces as rated by the ergonomist. EIs lie between 0 (nobody exposed) and 10 (all people exposed to the maximum time or repetitions). Box and whisker plots show the mean = ■; box = 25th, 50th (median), and 75th percentile and the “whiskers” show minimum and maximum values.

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Agreement Between Raters

Estimates from four raters as to whether there was any exposure to a specific load in a workplace is shown in Fig. 5. Qualitatively, good agreement is seen with no single type of rater being consistently higher or lower than other types of raters. As can be seen in Fig. 5, the ergonomist had better agreement with consensus data in identifying any exposure to physical loads.

From Fig. 6, it can be seen that agreement between the ergonomist and the workplace consensus on the simple presence or absence of a loading type within a workplace rating was highest (≥90%) for lifting more than 40 kg, lifting people, hand above shoulder, lift above shoulder, using the hand as a hammer, wearing gloves, standing, driving on road, knee hammering, and high vibration. The lowest agreement (<70%) was for the categories neck bent/twisted, repetitive hand use, use of pinch grip, use of power grip, and computer use.

Load types in Q11 to Q15 (repetitive arm use, repetitive hand use, use of pinch grip, use of power grip, and intensive computer use) were among the lowest agreement between the consensus and ergonomist’s scores. These are all distal upper limb specific loadings, and respondents appeared to have the most challenges identifying these. In contrast, there was very high agreement on “lifting people,” which was observed in healthcare-related workplaces.

The values of the EI across all organizations for each load type as rated by management, labor, consensus, and the ergonomist for the exposures are shown in Figs. 7(a) and 7(b). The EI derived from the four raters differed significantly (p < 0.05) for Q1 (carry loads), Q4 (lift >23 kg), Q5 (lift >40 kg), Q9 (neck bent/twisted), Q11 (repetitive arm), Q16 (hand as a hammer), Q18 (standing), and Q19 (sitting). However, we are most interested in the consensus-ergonomist differences, where the...
ratings for only four load types differed significantly ($p < 0.05$) with the ergonomist rating the EI for Q5 (lift $>40$ kg; higher), Q11 (repetitive arm; lower), Q16 (hand as a hammer; higher), and Q18 (standing; higher).

**Confidence in Ratings**

The workplace raters’ confidence in their ratings varied across loading types (Fig. 8). There were very few reports
of people being “not sure” of their rating; most respondents were at least somewhat sure. Based upon the consensus response, they had the highest confidence (lowest responses of “not sure”) for Q4 (lift >23 kg), Q5 (lift >40 kg), Q6 (lift people), Q7 (hand above shoulder), Q18 (standing), Q21 (driving off road), Q23 (knee as hammer), Q24 (cold temperatures), and Q25 (moderate vibration). They had the lowest confidence (“sure” rating less than 50%) for loading types Q3 (push/pull loads), Q9 (neck bent/twisted), Q12 (repetitive hand activity), Q14 (power grip), and Q19 (sitting). Items with the lowest confidence ratings and low agreements between raters were Q9 (neck bent/twisted), Q12 (repetitive hand activity), and Q14 (power grip). For all questions, there was a moderate ($R^2 = 0.30$) relationship between raters’ agreement (ergonomist and consensus) and consensus confidence reported as “sure.”

**Feedback From Workplaces**

Based upon debriefing interviews with respondents who completed the surveys, feedback was provided that could be incorporated into future development of the survey and the approach to its administration. Suggestions included expanding the number and range of the examples and using imperial units, such as pounds, as well as metric units, such as kilograms. The respondents also requested that the instructions be improved in a number of areas, including how to account for multiple shifts, part-time employees, and how to count employees (full-time equivalent [FTE] or number on payroll). Respondents said that they found it quite challenging to estimate the number of people in each exposure category.

Many SMEs had not had the prior benefit of ergonomic assessments and found that this process was the beginning of a more formal and informed approach to health and safety for them. Union representatives found the reports to be especially useful. They saw the consensus document as a starting place for proactive health and safety discussions. It was important to them that the survey be presented in the scientific literature.

**DISCUSSION**

This project aimed to create and evaluate a survey for benchmarking exposures to mechanical loading for tracking prevention of MSD activities and collecting this information in an efficient manner without necessitating professional consultation or having to administer questionnaires to all individuals within each workplace. The multi-stakeholder team was helpful in clarifying or modifying the questions from the Washington State Survey. The team also identified types of work and loading that were not well covered by that
survey. The Washington State Survey included only risk factors where a substantial body of literature supported not only the work-related nature of the loading (i.e., risk factors) but also defined levels of exposure for action. In addition, the Washington State Survey was answered by the management only, while in our survey, we were looking at reinforcing the Internal Responsibility System (IRS) by having both labor and management come to an agreement and use a consensus approach. Given the different purposes of the two instruments (for legislation versus as a broadly applied screening tool), a wider range of loading types was included than that seen in the Washington State survey.

FIGURE 8  Confidence in ratings by load type (L = labor, M = management, and C = consensus).
Overall, the survey showed moderate to substantial agreement between the consensus ratings by workplace representatives and the ergonomists’ ratings, with a large majority of respondents reporting that they were at least “somewhat sure” of their ratings. In addition, the completion time of each survey (based on self-reported data) was of the order of 30 minutes, which, compared to the alternatives of hiring outside persons or having all workers fill out a questionnaire, could be considered efficient.

We were encouraged by the ability of the workplace parties to document the types of physical loading present in their workplaces. It must be acknowledged that respondents were much more successful with some loading types based on the comparison of their data to the ergonomist data. This may be the result of the difficulty in visualizing upper limb movements. Bao et al. (2009) reported that the reliability of estimates for large body parts was better than for small segments, such as the wrist. Those types of loading showing poor agreement between raters or low confidence in ratings should be further examined to determine whether this could be due to some deficiency in the questionnaire format and wording or if it is inherent in the identification of the particular loading type.

As a part of the evaluation of their survey, Silverstein et al. (2004) reported performing site visits. To ascertain the accuracy of workplace survey responses, the caution zone job checklist was re-administered as one way to crosscheck whether there were any caution zone jobs at the workplace. At least one manager at all workplaces in 2001 identified at least one caution zone risk factor in their workplace. Silverstein et al. remarked that this means that almost all workplaces had at least one caution zone job, whereas only 29%–50% of workplaces previously reported having such exposure, leading to the suspicion that the risk factors were underreported. However, when individual interviews were performed with both managers and workers and they were asked to report on the presence or absence of the risk factors, workers and managers reported very similar presence of risk factors (Silverstein et al., 2004; Table S2.16). This mimics our experience that both workers and managers recognized loading in their own workplaces. Foley et al. (2009) reported that exposures changed between the baseline questionnaire and the proposed introduction of the Ergonomics Rule. This suggests that the survey developed here may also be sufficiently responsive to show the effects of changes in mechanical loading that are achievable in workplaces.

Respondents within larger organizations with established JHSCs and ergonomic expertise found the survey simplistic, as they already performed comprehensive hazard identification and assessment activities and said that the survey should be much more detailed. Smaller organizations on the other hand, found the act of completing the survey useful in getting an overview of their work and to form the basis for the JHSC to plan hazard identification and risk assessment activities. It was emphasized to the workplace parties that this was not a formal hazard identification or a risk assessment; this remained the responsibility of the workplace. However, the SMEs that participated in this project said that this survey could help them initiate a more formal and informed approach to MSD prevention.

Strengths of the project included a collaborative process with multiple workplace parties and researchers, a broad sample of workplaces both in terms of size and sector, using the co-chairs of the JHSC as respondents who had good knowledge of the workplace, having them come to a consensus decision, evaluating the workplaces’ ratings with observations based upon a site visit by an ergonomist, and using the project ergonomist to mentor the ergonomists who would go on site visits.

This initial project attempted to validate ratings of physical loads at the workplace level, and there was limited guidance available in the literature. A challenge was recruiting workplaces, despite the involvement of multiple labor organizations. Although 60 responses were received, only 30 of these were fully usable in the final analysis; the remainder of the workplaces suffered from incomplete data due to combinations of misunderstanding of the instructions, one of the three surveys from the workplace not being completed, or a workplace deciding after completing the survey that it did not want an ergonomist to visit. Over the course of the project, a total of four ergonomists were hired part time, one after another, but each resigned as full-time employment became available. To reduce the effect of inter-ergonomist variability, we chose to only use evaluations from two ergonomists who worked during the latter part of the study. This final data set comprised 30 companies. A further limitation was the restricted range of sectors represented in the final sample, as the workplaces were concentrated in the industrial, healthcare, and municipal sectors.
CONCLUSION

The project demonstrated that it is possible for workplace parties to document exposure to physical loads at the workplace level in an efficient manner. Based upon the multiple measures of exposure, there was substantial to excellent agreement with ratings produced by an ergonomist on a walk-through site visit. We found that the process of managers and workers independently completing the survey with a subsequent consensus rating worked well, and it can be recommended as a preferred method of survey administration. This survey method is much quicker and much less resource intensive than the alternatives of having an ergonomist visit each worksite or distributing questionnaires to all workers in each worksite. It may thus form a basis for creating surveillance and benchmarking tools for exposures to mechanical loading in workplaces and leading indicators of MSD development.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPLEMENTAL MATERIAL

Supplemental online appendices showing the surveys to benchmark physical loads in Ontario workplaces (Appendix A: Consensus Book; Appendix B: Labour Book; Appendix C: Management Book) are available online at http://dx.doi.org/10.1080/21577323.2016.1179701.

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