Development of A Tool for Assessing Risk Factors Associated with Lower Extremity Work-related Musculoskeletal Disorders

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Study duration

The study was started in the beginning of Spring semester 2017 (January 2017) and finished in the end of Spring semester 2020 (May 2020).

Study Objective

To provide occupational safety and health (OSH) and ergonomics practitioners with alternative tools for assessing risk factors in the occupational setting, we conducted a study to develop a novel risk assessment tool that identifies and evaluates a comprehensive, evidence-based range of risk factors associated with lower extremity musculoskeletal disorders (LE-MSDs). The practitioners should be able to use the tools to identify the potential hazards specific to the lower extremity at the stage of job design/redesign or as part of a job evaluation process. Hence, prevention actions to minimize those hazards can be conducted. The long-term objective of this study is to decrease the occurrence of LE-MSDs experienced by the workers.

Methodology

The instrument development effort involved three-phase process that included development, validity assessment, and reliability assessment. Each phase would be described in the different sections below.

3.1 Tool development.

The tool development involved literature searches and reviews in identifying the risk factors for LE-MSDs. A Delphi survey, a technique utilizing questionnaire for consolidating multi-persons opinions (Dalkey & Rourke, 1971), was utilized to confirm the list of risk factors identified in the previous process. The Delphi survey involved subject-matter experts (SMEs) who have diverse backgrounds including biomechanics, epidemiology, ergonomics, occupational medicine, physical therapy, and podiatry. The comprehensive list of risk factors as the Delphi survey's output was further operationalized into a spreadsheet-based application. After initial construction of the tool, an initial tool review was performed by soliciting input from several occupational safety and health practitioners. User input was also used to make additional changes to the tool following the usability testing which is described below.

3.2 Preliminary validity assessment

Given the lack of lower extremity assessment tools to compare the tool's performance with, criterion validity (using concurrent measures) was examined. This is similar to the approach by Rucker & Moore (2002), which compared hazard classifications from the Strain Index with morbidity classifications; such a comparison assumes that jobs classified as high risk are more likely to be associated with high morbidity outcomes and jobs classified as low risk are more likely to be associated with low morbidity outcomes. The preliminary validity assessment of the tool was examined by evaluating the relationships between hazard classifications, determined based on the tools' outputs, and adverse health outcomes classifications. The tool was tested by using it to assess jobs performed by 62 employees from three manufacturing facilities and a distribution center in the northern and central parts of the State of Ohio. Observations and interviews were performed to gather exposure information required for completing a job assessment using the tool; this includes occupational and worker-specific factors exposures. The job assessments were performed by the tool developer (author A). The exposures data were further processed to determine the hazard classification determined by the tool.

For purposes of the study, a case (morbidity) was defined as any documented lower extremity musculoskeletal disorders in the hip, knee, foot, or ankle reported in the plant medical records, workers' compensation data, injury logs, or through worker complaint. An abbreviated MSD survey was administered to participants as part of the validity assessment, at the end of the exposure assessment. Any lower extremity discomfort or pain in the last 12 months self-reported on the survey was defined as another category of the case. In streamlining the terminology of the cases, cases defined by either company-provided data or through self-report were referred to as 'LE adverse outcomes.' The company-provided data were provided after the researcher had performed the exposure assessment to ensure that the researcher was blinded to the job history to minimize bias while assessing the job.

3.3 Reliability, usefulness, and usability assessment

The reliability assessment phase was designed to assess inter-rater consistency in using the tool. Participants of this phase were divided into two groups: tool user-participants and worker-participants. The tool user-participants were the raters who performed the job assessments using the tool, while the worker-participants were employees who were performing the jobs that were the objects of the assessment. Seven raters who held safety-related occupations from four job sites voluntarily participated in this study. Twelve employees (7 males, 5 females) were involved in the study as the worker-participants. The inter-rater reliability was determined by comparing the assessment results between the tool user-participants and one of the authors (A). Each tool user-participant and the researcher assessed two jobs using the tool independently. This assessment was limited to evaluate the items associated with occupational factors assessed by the tool.

The usefulness and usability of the tool were assessed by administering a questionnaire and conducting an interview debriefing session with the tool user-participants at the end of the job assessment. The usefulness inquiry asked whether the tool would be applicable to assess all jobs at the tool user-participants' workplace. Meanwhile, the usability assessment addressed terminology, the instructional manual, scoring system, and the particular factors that were included in the tool (David et al., 2008; Eliasson et al., 2015). The debriefing session was conducted by comparing and discussing where and why the tool user-participants and the researcher differed in their evaluation of the jobs. Worker-participants were also interviewed by the researcher, specifically to inquire about the degree to which they would or would not be comfortable being asked, by their employer, about the set of personal factors (all relevant to LE-MSDs) that are included in the tool.

Results

4.1 Risk Factors for LE-MSDs

The literature review and the Delphi survey resulted in the inclusion of 16, 27, and 19 items on the comprehensive list of risk factors for LE-MSDs in the hip, knee, foot/ankle, respectively. The comprehensive list of risk factors revealed the contribution of two types of risk factors: occupational and worker-specific (personal) factors in the development of LE-MSDs. Occupational risk factors that contribute to LE-MSDs include certain lower extremity postures/activities, manual material handling activities, and whole-body vibration (Baker et al., 2002; Lau et al., 2000; Manninen et al., 2002; Sandmark et al., 2000). The lower extremity postures/activities could be categorized as less knee straining postures such as prolonged standing or knee-straining postures such as kneeling and squatting. Heavy lifting and carrying are other types of risk factors that contribute to LE-MSDs. The presence of these occupational risk factors can be compounded by adverse environmental factors such as uneven terrain (Voloshina et al., 2013). On the other hand, several studies have reported some positive effects of matting in potentially decreasing LE adverse outcomes (Gauvin, 2016; King, 2002). Furthermore, personal risk factors, particularly high body mass index (BMI), the medical history associated with LE-MSDs, and sports participation, are additional contributors to the development of LE-MSDs. A diagram illustrated the risk factors for LE-MSDs can be seen in Figure 1.

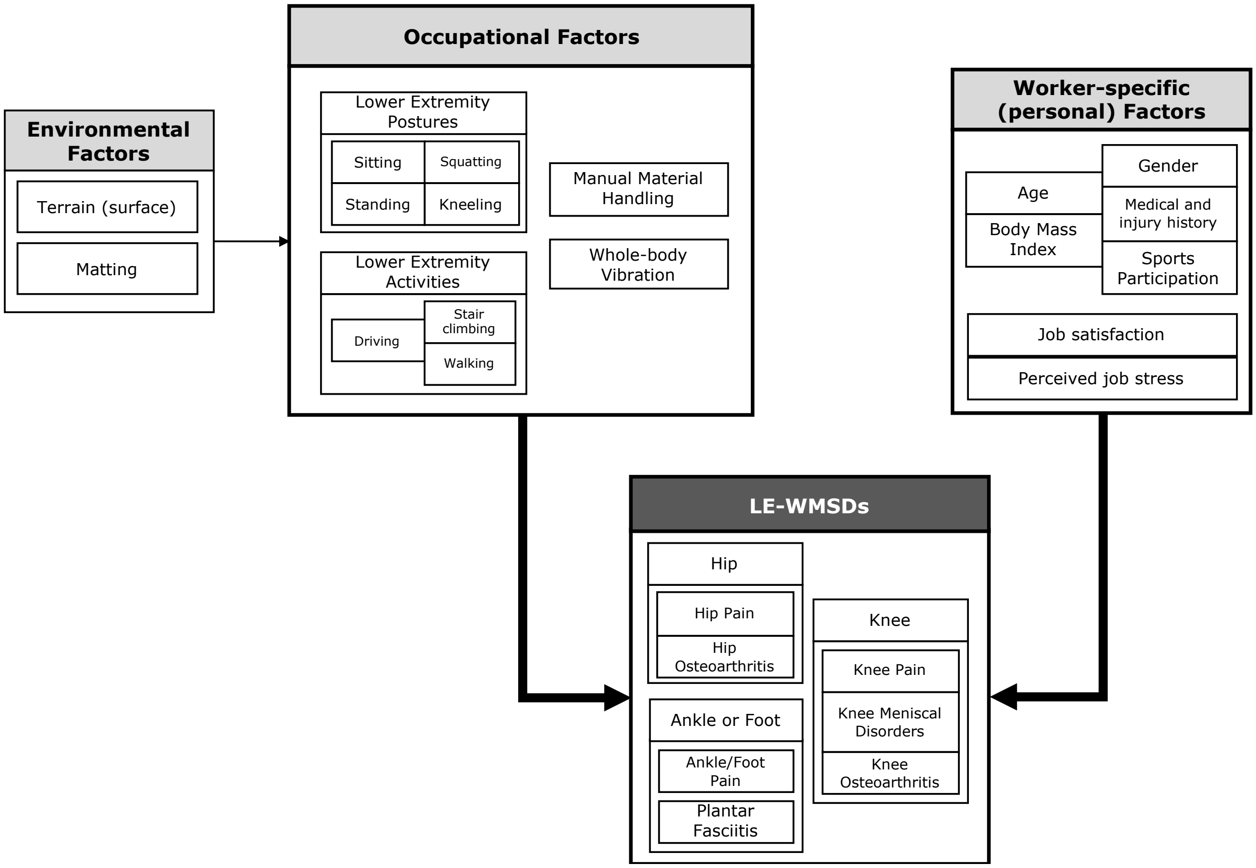

Figure 1. Risk factors for LE-MSDs

4.2 The tool

The tool development was performed by operationalizing the comprehensive list of risk factors into a spreadsheet-based application. The tool was designed to have two main windows, including the input (Figure 2) and the output window (Figure 3). The input window provided the tool users with inquiries for assessing the presence and exposure quantity of the risk factors. Meanwhile, the output window provided the tool users with information about the assessment results such as hazard score, hazard classification, and the risk factors that contribute to the classification.

The proposed assessment tool was named Lower-extremity Ergonomics Assessment Tool. In making the tool name easy to remember, this tool is hereinafter referred to as LEAT. The LEAT was designed as an 8-hour or a whole shift job-based assessment tool.

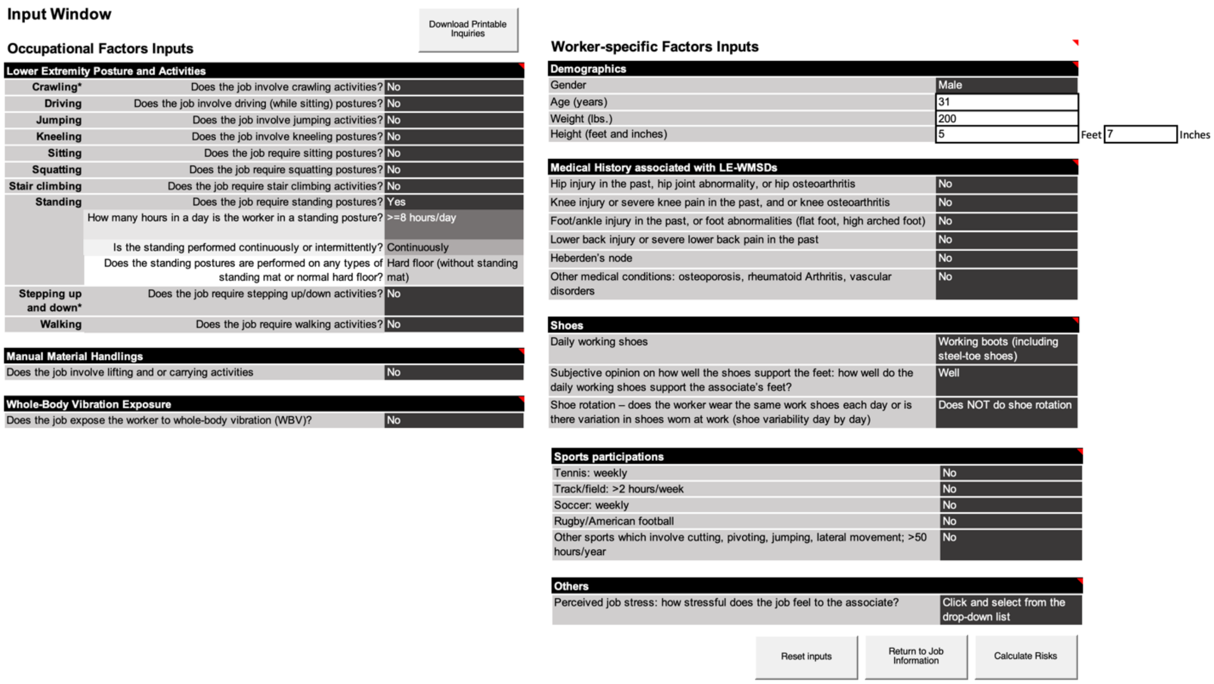

Figure 2. The input window of the tool

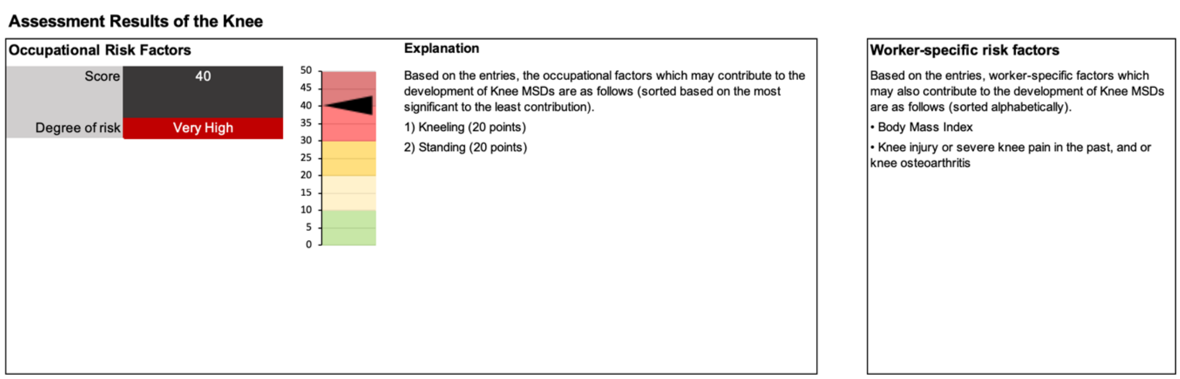

Figure 3. Example output from LEAT; in the application, output is provided for each region of the LE, hip, knee, and foot/ankle, separately. The risk determination is based on the occupational risk factors (left side of Fig. 3). Individual risk factors are provided as additional information (right side of Fig. 3).

4.3 Preliminary validity of the tool

The highest performance was observed in the tool's ability to classify jobs that posed risks associated with LE-MSDs in the knee (AUC=.45). This classification is based only on the occupational factors. Similar performance was observed in the tool's ability in classifying jobs that posed risks associated with LE-MSDs in the hip (AUC=.43). The lowest performance was seen in the lack of an association between the hazard classification from the tool and the morbidity classification of adverse outcomes in the foot/ankle (AUC=.10). Furthermore, the assessment revealed a high prevalence of worker-specific factors such as high body mass index

(BMI) and a history of lower extremity injuries. As such, there could be benefits to considering worker-specific/personal factors as assessed by the tool when attempting to reduce the risk of workers developing LE-MSDs or reducing the exacerbation of existing symptoms.

4.4 Reliability, usefulness, and usability of the tool
The reliability assessment revealed two input questions that the percent agreements were less than 75%, while the percent agreement for other questions were either 100% or close to 100%. The debriefing session indicated that the reliability was subject to interpretations of the instrument's questions. The questions that could lead to fewer interpretations, such as inquiry asked the type of flooring where the workers stand, were associated with higher reliability (close to 100% agreement). On the other hand, a question asked whether the walking postures are performed on even or uneven surfaces could make different interpretations that affected the reliability. Furthermore, the usefulness and usability assessment revealed several issues, most notably the difficulties in determining the exposure quantities of jobs with inconsistent duties. Furthermore, although most worker-participants indicated comfortable feelings answering questions that addressed worker-specific factors, the tool user-participants reported uncomfortable feelings asking about those factors, particularly body weight and medical history associated with LE-MSDs.

Discussion
The literature searches and evidence assessment which were performed for developing the comprehensive list of risk factors revealed that LE-MSDs were associated with two primary categories of risk factors: occupational and worker-specific risk factors. Considering the worker-specific factors such as the personal and psychosocial factors in an ergonomic risk assessment tool can be a debatable issue, because of the potential concerns for worker privacy. However, recent trends demonstrated that the workforce in the next few years a significant percentage of workers will be older and/or of high body mass index (BMI) (Finucane et al., 2011). Therefore, considering worker-specific factors in an ergonomics tool could have value in increasing awareness, for both workers and management, of these issues. One concern is that one inadvisable management approach to addressing LE-MSDs might be to exclude workers with personal risk factors for LE-MSDs. A much better approach would be for management to adopt a 'Total Worker Health' approach (Centers for Disease Control and Prevention, 2019) and address both occupational and personal risk factors.

The present study was conducted in manufacturing and warehousing settings, and as such the lower extremity postures and activities were dominated by standing and walking. Most manufacturing jobs require the workers to adopt the prolonged standing (Zander et al., 2004). As a consequence, the preliminary validity assessment does not adequately test the predictive ability of the tool in determining the risks associated with more knee-straining postures. Therefore, further studies should be conducted on occupations that require more knee straining postures such as jobs in construction and maintenance (Rytter et al., 2008).

The current study revealed that the tool's reliability is subject to interpretations of the users on terminology utilized in the input question. Therefore, in ensuring that diverged interpretations do not occur in the future, clear descriptions of the terminology should be added in the tool as well as in the user manual. Visual references can also be added to minimize different interpretations (Lowe et al., 2014).

Impact

The current study was performed as a contribution to the field of work-related musculoskeletal disorder prevention. The research draws attention to the understudied topic of work-related lower extremity musculoskeletal disorders. While BLS-reported incidence rates of LE-MSDs are generally lower than rates of Trunk and Upper Extremity MSDs, the median lost days for LE-MSDs (14-16 days) exceeds the median lost days for Trunk-MSDs (8-12 days) (U.S. Department of Labor, 2018). In 2018, 16% of work-related MSDs occurring in the private industry involved the lower extremity, while for jobs in local governments, the percentage was 25%. These statistics suggest that LE-MSDs are common and costly.

The research produced compiled lists of occupational and personal risk factors for LE-MSDs, based on a systematized review and evaluation of the literature and interaction with subject matter experts. These lists provide a curated resource that can be used to support LE-MSD prevention efforts. Furthermore, the main output of the study, the LEAT, is a new assessment tool that occupational safety and health practitioners and researchers can begin to use for identifying, assessing, and targeting risk factors associated with LE-MSDs. The LEAT was developed using a participatory ergonomics process, gathering input from potential users throughout the development and evaluation process.

References

Baker, P., Coggon, D., Reading, I., Barrett, D., McLaren, M., & Cooper, C. (2002). Sports injury, occupational physical activity, joint laxity, and meniscal damage. *The Journal of Rheumatology*, *29*(3), 557–563.

Centers for Disease Control and Prevention. (2019, December 11). *What is Total Worker Health?* https://www.cdc.gov/niosh/twh/default.html

Dalkey, N. C., & Rourke, D. L. (1971). *Experimental Assessment of Delphi Procedures with Group Value Judgments (R-612-ARPA)*. RAND Corp.

David, G., Woods, V., Li, G., & Buckle, P. (2008). The development of the Quick Exposure Check (QEC) for assessing exposure to risk factors for work-related musculoskeletal disorders. *Applied Ergonomics*, *39*(1), 57–69.

Eliasson, K., Nyman, T., & Forsman, M. (2015). Usability of six observational risk assessment methods. *Proceedings 19th Triennial Congress of the IEA, Melbourne*, 9–14.

Finucane, M. M., Stevens, G. A., Cowan, M. J., Danaei, G., Lin, J. K., Paciorek, C. J., Singh, G. M., Gutierrez, H. R., Lu, Y., & Bahalim, A. N. (2011). National, regional, and global trends in body-mass index since 1980: Systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9· 1 million participants. *The Lancet*, *377*(9765), 557–567.

Gauvin, A. (2016). *Do portable anti-fatigue mats affect the mechanics or discomfort of walking* [Laurentian University of Sudbury]. https://zone.biblio.laurentian.ca/handle/10219/2640

King, P. M. (2002). A comparison of the effects of floor mats and shoe in-soles on standing fatigue. *Applied Ergonomics*, *33*(5), 477–484.

Lau, E. C., Cooper, C., Lam, D., Chan, V. N. H., Tsang, K. K., & Sham, A. (2000). Factors associated with osteoarthritis of the hip and knee in Hong Kong Chinese: Obesity, joint injury, and occupational activities. *American Journal of Epidemiology*, *152*(9), 855–862.

Lowe, B. D., Weir, P., & Andrews, D. (2014). *Observation-based posture assessment: Review of current practice and recommendations for improvement*. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH.

Manninen, P., Heliövaara, M., Riihimäki, H., & Suomalainen, O. (2002). Physical workload and the risk of severe knee osteoarthritis. *Scandinavian Journal of Work, Environment & Health*, 25–32.

Rucker, N., & Moore, J. S. (2002). Predictive validity of the strain index in manufacturing facilities. *Applied Occupational and Environmental Hygiene*, *17*(1), 63–73.

Rytter, S., Jensen, L. K., & Bonde, J. P. (2008). Clinical knee findings in floor layers with focus on meniscal status. *BMC Musculoskeletal Disorders*, *9*(1), 144–154.

Sandmark, H., Hogstedt, C., & Vingaard, E. (2000). Primary osteoarthrosis of the knee in men and women as a result of lifelong physical load from work. *Scandinavian Journal of Work, Environment & Health*, 20–25.

U.S. Department of Labor, B. of L. S. (2018). *Occupational Injuries and Illnesses and Fatal Injuries Profiles*. https://data.bls.gov/gqt/ProfileData

Voloshina, A. S., Kuo, A. D., Daley, M. A., & Ferris, D. P. (2013). Biomechanics and energetics of walking on uneven terrain. *Journal of Experimental Biology*, *216*(21), 3963–3970. https://doi.org/10.1242/jeb.081711

Zander, J. E., King, P. M., & Ezenwa, B. N. (2004). Influence of flooring conditions on lower leg volume following prolonged standing. *International Journal of Industrial Ergonomics*, *34*(4), 279–288.