



The development of a conceptual model and self-reported measure of occupational health and safety vulnerability



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ABSTRACT

Injuries at work have a substantial economic and societal burden. Often groups of labour market participants, such as young workers, recent immigrants or temporary workers are labelled as being “vulnerable” to work injury. However, defining groups in this way does little to enable a better understanding of the broader factors that place workers at increased risk of injury. In this paper we describe the development of a new measure of occupational health and safety (OH&S) vulnerability. The purpose of this measure was to allow the identification of workers at increased risk of injury, and to enable the monitoring and surveillance of OH&S vulnerability in the labour market. The development included a systematic literature search, and conducting focus groups with a variety of stakeholder groups, to generate a pool of potential items, followed by a series of steps to reduce these items to a more manageable pool. The final measure is 29-item instrument that captures information on four related, but distinct dimensions, thought to be associated with increased risk of injury. These dimensions are: hazard exposure; occupational health and safety policies and procedures; OH&S awareness; and empowerment to participate in injury prevention. In a large sample of employees in Ontario and British Columbia the final measure displayed minimal missing responses, reasonably good distributions across response categories, and strong factorial validity. This new measure of OH&S vulnerability can identify workers who are at risk of injury and provide information on the dimensions of work that may increase this risk. This measurement could be undertaken at one point in time to compare vulnerability across groups, or be undertaken at multiple time points to examine changes in dimensions of OH&S vulnerability, for example, in response to a primary prevention intervention.

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1. Introduction

The burden of work injury and illness¹ is not equally distributed across labour market participants. Studies from Canada and elsewhere have observed a higher burden of work injury among workers with lower levels of education (Breslin et al., 2008; Cubbin and Smith, 2002; Oh and Shin, 2003), younger workers (Breslin and

Smith, 2005; Runyan and Zakocs, 2000), workers starting their employment (Breslin and Smith, 2006; Butani, 1988), recent immigrants (Smith and Mustard, 2009) and those in temporary employment relationships (Quinlan, 1999). As a result of above average injury rates, younger workers, new workers, temporary workers and recent immigrants are often labelled as “vulnerable workers” (Law Commission of Ontario, 2012; The National Institute of Occupational Safety & Health, 2011). However, using this approach to categorise workers as “vulnerable” does little to identify the specific factors that place identified sub-groups at higher risk of experiencing a work-related injury. This approach to categorising workers can also lead to risk of injury being seen as something inherent to an individual or a particular population

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¹ From here on we use the term “injury” and “injuries” to refer to both injury/injuries and illness/illnesses.

group (Weil, 2009). Studies that have compared measures of the working conditions and/or work relationships among “vulnerable” groups and non-vulnerable groups often find that these characteristics explain much of the increased risk of injury among the former (Breslin and Smith, 2010; Premji and Smith, 2013; Saunders, 2006). Further, while the hazards that a worker is exposed to are linked to their risk of work injury, there is a general acceptance that the factors that lead to increased risk of injury are broader than simply unsafe conditions in the workplace and unsafe actions taken by workers (Andersson and Menckel, 1995; Keyserling and Smith, 2007; Laflamme, 1990).

The objective of this paper is to describe the development of a new measure of occupational health and safety (OH&S) vulnerability. We had three goals in developing this measure:

1. To facilitate a better understanding of the contextual factors that create increased risk of work injury. This includes broadening the focus from identifying the types of workers who are more likely to sustain injuries, to understanding and measuring the work these workers do, and the characteristics of the workplace or industries in which they are employed. The lens of the analysis, however, is on the worker rather than the workplace, in recognition that vulnerability may vary markedly among workers in the same workplace, for reasons we explore below.
2. To allow surveillance to move from lagging indicators such as the rate of injury that occur to more leading indicators such as the level of work conditions and the work context that places workers at increased risk of injury. This data collection would in turn allow for more proactive primary prevention activities.
3. To facilitate the surveillance of OH&S vulnerability by providing insights into the relationship between sociodemographic and contextual factors and vulnerability. This surveillance could be at one point in time, or over time (e.g. in response to population level interventions), noting that a measure of OH&S vulnerability is likely more sensitive to changes in working conditions compared to a lagging indicator such as work injury rates or workers' compensation claim rates.

1.1. A conceptual framework of OH&S vulnerability

Our assumption in developing a conceptual framework of OH&S vulnerability was that the dimensions that lead to workplace injury (increased OH&S vulnerability) are broader than simply unsafe conditions in the workplace and unsafe actions taken by workers (Andersson and Menckel, 1995; Keyserling and Smith, 2007; Laflamme, 1990). As such, we conceptualised four related, but distinct dimensions, as the key features of our concept of OH&S vulnerability.

1. **Level of hazard potential faced by the worker:** A hazard is generally defined as a source of potential damage to a worker. The key objective of this dimension is to measure how often a worker is exposed to hazards such as the use of dangerous equipment or materials, work in dangerous locations, or undertaking work activities where there is a potential for injury.
2. **Workplace/organisation-level protections and policies:** This dimension deals with workplace-level procedures in place to protect workers. It acknowledges that understanding OH&S risk needs to take into account both the potential for, and protection from, exposures occurring within the workplace (Habeck et al., 1998; Hunt et al., 1993; LaMontagne et al., 2003, 2009). Examples include the systematic delivery of training on OH&S and worker rights; the labelling of hazardous materials within the workplace; the provision of safety equipment (e.g. safety guards for machines or personal protective equipment); and

procedures to identify and replace defective equipment and collect and act on information about near miss incidents. This dimension would also include specific policies or supports that address power differentials within the workplace such as the presence and effectiveness of OH&S or representative within the workplace; or the active collection of OH&S concerns from employees.

3. **Worker awareness of occupational hazards:** Based on theoretical models in health behaviour research, awareness is a key component of motivation to engage in health enhancing behaviours (or avoid unhealthy behaviours) (Ajzen, 1991, 2002; Prochaska and DiClemente, 1982). As such, when workers are made aware of the hazards in their workplace, this will – in part – likely serve as a motivator to use personal safety protections (e.g. if workers are not provided with information on why or when safety protections should be used, it is unlikely they will use them, even if they are regularly made available). Further, increased knowledge of legislated rights and responsibilities related to OH&S among workers and supervisors has been suggested as an important factor driving management and workers collaborations to improve OH&S and reduce injuries (Expert Advisory Panel on Occupational Health and Safety, 2010). Examples of this dimension include if workers feel they are aware of the hazards involved in their job as well as those within their workplace.
4. **Worker empowerment to participate in injury prevention:** This dimension deals with an individual's capacity to protect themselves from hazards at work. Examples include if workers feel able to correctly use provided protective equipment (equipment fit, instructions for use etc.); if they feel empowered to refuse unsafe work; or if they feel they can ask questions of their employer about perceived hazards in the workplace.

Although we expect these four dimensions would be related to each other, we feel they are conceptually distinct and important to measure separately. For example, two workers may be exposed to the same level of hazard potential, but if one is employed in a workplace with active policies and procedures to control these hazards they would be less vulnerable to workplace injury. Moreover, even within the same workplace, where a common set of workplace policies applies, individual workers might have different levels of vulnerability because of different levels of awareness or rights or hazards, or different degrees of labour market power. For example, a low-skill worker in a non-permanent job may feel much less able to speak up than a high-skill worker in a permanent job. Accordingly, we define OH&S vulnerability as exposure to workplace hazards, in combination with inadequate workplace policies and procedures and/or low OH&S awareness and/or a workplace culture that discourages workers' participation in injury prevention. While we acknowledge that measures are currently available that capture elements on each of these dimensions (e.g. available measures of safety climate often capture information on workplace policies and procedures), the uniqueness of our measure is that it seeks to measure these dimensions separately, and then combine these dimensions to better understand OH&S vulnerability.

2. Methods

The first step in developing a new measure is to identify a set of potential items (Guyatt et al., 1986; Kirshner and Guyatt, 1985; Streiner and Norman, 2008). We developed a pool of potential items that are related to our conceptual framework of OH&S vulnerability through two steps: (1) a systematic search for existing measures in the peer-reviewed, non-peer-reviewed, and

grey literature; and (2) focus groups discussions with relevant stakeholder groups.

A literature search was conducted using the following databases: MEDLINE, EMBASE (medical literature), PsycINFO (psychological literature), Sociological Abstracts (sociological literature), ABI Inform, Business Source Premier (business/management literature), EconLit (economic literature), Social Service Abstracts (social work and social service literature). Our search strategy focused on articles or reports that measure one or more of the dimensions within our conceptual framework. This search strategy was based on a framework and measurement filter strategy developed by the Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) group (Terwee et al., 2009). Controlled vocabularies were used whenever possible. The searches were run from the inception of each database until between June 25th and July 9th, 2012 depending on the database.

The databases listed above yielded both peer-reviewed and non-peer reviewed literature. In addition we searched the websites and subject directories of OH&S organisational websites for grey literature. At the completion of the search strategy we downloaded all references and removed duplicates. Remaining articles were randomly distributed for title and abstract screening by one of four trained reviewers. Articles were excluded if they did not include a measure related to one of our four dimensions. Prior to screening the four reviewers and the principal investigator reviewed a sample of 100 articles to determine whether they should be included for further review. Discrepancies between reviewers were discussed and resolved before review of the main group of articles commenced. After excluding articles based on the title and abstract, remaining articles were reviewed in detail and information was extracted on the instrument that was used to assess the dimension of interest. A complete list of items was then collated within each dimension and reviewed by the investigator team to identify any missing elements.

Eight focus groups were also conducted as part of this study (four in Ontario, Canada and four in Victoria, Australia). The objective of each focus group was to obtain feedback on our conceptual model of OH&S vulnerability and seek input into the types of questions we should ask within each of the four dimensions. We specifically sought feedback on the following areas during each focus group:

- What were the factors that lead someone to be at risk of work injury?
- Was our conceptual framework congruent with their beliefs about factors that lead to work injury?
- Is there utility in developing such a measure?
- What types of questions should be asked within each dimension?
- Is a worker-level measure of OH&S vulnerability feasible (*i.e.* could workers answer questions in each of the areas we had proposed)?

Three focus groups (two in Ontario and one in Victoria) included employees, and one focus group in each country included representatives from the state/provincial agency tasked with primary prevention of work injuries. In Ontario an additional focus group was conducted with employers and in Australia two additional focus groups were conducted, one with employer representatives, and one with employee representatives. Each focus group contained between four and seven participants. A key advantage of a focus group, compared to conducting one-on-one interviews, is that focus groups provide the opportunity to observe the participants interact on a particular topic (Morse and Field, 1995). Focus groups can be used to examine similarities and differences in the respondents' opinions and experiences through

group discussion, rather than inferring these differences from comparison of individual interviewees. By having relatively homogenous participants in a given focus group, our focus groups can be considered as a form of in-depth group interview concerning our OH&S vulnerability framework (Hughes and Dumont, 1993). We believed that policy makers, employers, employer representatives, employee representatives and employees would each bring a unique perspective and differing levels of experience in relation to OH&S vulnerability.

Each focus group was transcribed and then de-identified. We then thematically analysed the transcripts to identify discussion which supported our conceptual framework and where our conceptual framework could be improved. In addition, we documented questions or topics that would be important to include within each dimension.

Using the findings from the literature search and focus groups feedback a comprehensive pool of potential items was developed. This initial list of items was then reduced to a smaller subset of items based on item similarity and using feedback from the investigator team and selected members of the focus groups. Following this first stage of item reduction remaining items were administered to a small sample of workers in Ontario and British Columbia (Pilot test sample; $N=328$). Information was also collected on demographic (*e.g.* age, gender, if the respondent was born in Canada), occupational (*e.g.* self-reported type of occupation worked coded to the Canadian National Occupational Classification, work hours, and employment arrangement), and workplace level (*e.g.* industry of employment and workplace size) information. A second stage of item reduction was completed based on the results of this survey. Items with a high level of non-response, items with poor reliability, and items which were not conceptually related to one particular dimension of vulnerability were removed. Final item reduction was undertaken by members of the research team to obtain a final set of 29 items which was administered to a sample of 1835 employees in Ontario and British Columbia (final sample), after which additional item checks and exploratory factor analyses were undertaken. Similar to the pilot testing questionnaire, information was also collected on demographic, occupational and workplace variables.

2.1. Pilot test sample

The sample for our initial pilot test included 328 respondents from the Canadian provinces of Ontario and British Columbia who were part of an existing panel of approximately 90,000 households maintained by EKOS Research Associates where respondents have agreed to participate in EKOS surveys from "time-to-time". This sample (referred to as the Probit sample) has been drawn using both landline and cellular telephones. A phone-based sample, while not as inclusive of low-income respondents as a household based survey, is a feasible approach to population-based sampling when a household-based sample frame is not known. A similar approach is used to recruit the sample for Statistics Canada's General Social Surveys (Statistics Canada, 2000). An additional advantage of the EKOS frame is the addition of the cellular telephone frame, which based on US data will potentially include more young, non-white, and low income respondents (Blumberg and Luke, 2011; Call et al., 2011). The sample was additionally restricted to workers who were employed more than 15 h per week in workplaces with five or more employees, and who could complete the survey in either English or French. The exclusion of self-employed workers and those in workplaces with less than five employees is to ensure the relevance of questions concerning workplace policies and procedures. Based on the Survey of Employment Payroll and Hours, workers in workplaces with less than five employees represent

approximately 6% of the employed labour market ([Canadian Socio-Economic Information Management System \(CANSIM\), 2011](#)).

2.2. Test-retest sample

To examine test-retest reliability all respondents were asked at the end of the pilot survey if they would agree to be recontacted in approximately two weeks to complete the survey again. Sixty two respondents were recontacted to complete the survey again. The size of the test-retest sample was based on previous guidelines in the literature ([Streiner and Norman, 2003](#); [Walter et al., 1998](#)). At the start of each survey section respondents were asked “Between now and when you responded to our last questionnaire (about 2 weeks ago), have there been any changes in the kinds of [given dimension of vulnerability] you might be exposed to in your workplace?”. Responses from respondents reporting no changes in a given dimension of vulnerability (ranging between 94% and 97% across dimensions) were used to identify questions with large variations in responses attributed to error.

2.3. Final sample

The final sample consisted of 1835 workers (62.9% in Ontario, 37.1% in British Columbia) who were administered the shortened 29-item version of the survey between May and June 2014. Of this sample, 1567 responses were completed using the Probit panel described above (15% by telephone and 85% online). The remaining 268 surveys were completed using a random digit dial (RDD) approach. Collecting data from this second sample enabled comparisons to be made between the Probit sample and a more traditional RDD approach. The RDD was also conducted by EKOS Research Associates. The same exclusions for working hours and workplace size which were used in the pilot testing sample were adopted for the final sample. A total of 20,904 respondents from the Probit panel were approached to complete the survey. Of this sample 1062 could not be contacted (invalid numbers) leaving 19,842 possible respondents. Of this sample 3363 respondents agreed to participate in the survey (17% response rate), with 1567 respondents meeting the eligibility criteria for our study. For the RDD sample a total of 12,402 phone numbers were called, with 10,572 numbers being valid. From these numbers 1370 respondents agreed to participate in the survey (13% response rate), of which 268 met the eligibility criteria for the study. Unfortunately limited information was available on the non-respondents to enable a detailed examination of trends in non-response in relation to demographic or work characteristics. However, we did undertake a comparison of the individual, occupational and industrial characteristics of our sample with the sample of the Canadian Labour Force Survey in Ontario and British Columbia over the same time period.

2.4. Analyses

Item selection and reduction in the pilot test sample was done using frequency distributions of responses to each question. We also examined item to item, and item to total correlations, within and across dimensions. Given the quasi-continuous nature of the response options (ranging from 4 to 5 categories) we examined test-retest reliability using both categorical (kappa ([Sim and Wright, 2005](#))) and continuous (ICC(2,1)) ([Shrout and Fleiss, 1979](#)) approaches.

In our final sample exploratory factor analysis was undertaken for three dimensions of our measure: Awareness; Policy and Procedures; and Empowerment. The hazard scale was not included in the factor analysis as the items in this scale are not expected to be correlated with each other ([Fabrigar et al., 1999](#); [Streiner, 2003](#)).

Factor extraction was performed using the maximum likelihood estimation method with three factors specified *a priori*. Factor rotation was performed using Promax (oblique) rotation. All analyses was performed using SAS Version 9.3 ([The SAS Institute, 2011](#)).

3. Results

3.1. Literature search

The initial literature search identified 9771 articles that met our search criteria, of which 688 were selected for further data extraction after the title and abstract review. Among these 688 articles a total of 343 examined measures of level of hazards; 264 articles examined policies and procedures; 188 worker awareness; and 126 worker empowerment. Note that a given article could cover more than one of the dimensions. Further review of these articles by the investigator team led to a full-text review and extraction of measures from 83 articles (59 articles covering level of hazards; 30 policies and procedures; 25 worker awareness; and 29 empowerment). Detailed scales were able to be extracted from 58 articles (26 covering level of hazards; 28 covering organizational policies and procedures; 19 covering worker awareness; and 29 covering empowerment). Additional measures were also included from the following documents not identified in the original literature search: WorkSafe Victoria’s Hazard Exposure Surveillance Survey ([WorkSafe Victoria, 2012](#)); WorkSafe Victoria’s Worker’s Perception of Safety and Future Improvements Survey ([WorkSafe Victoria, 2013](#)); The European Agency for Safety and Health and Work’s measure of worker participation in OH&S ([European Agency for Safety and Health at Work, 2012](#)); The OH&S Self-Diagnosis Questionnaire ([Cadieux et al., 2006](#)); The Survey of Perceived Organisational Support ([Eisenberger et al., 1986](#)); the Team Learning Questionnaire ([Martinez-Corcoles et al., 2012](#)); Safety Voice ([Tucker and Turner, 2011, 2014](#)); and the Organizational Performance Metric ([Institute for Work & Health, 2011](#)).

The focus group discussions were generally supportive of the conceptual framework presented with uniform agreement that vulnerability to work injury was a multifaceted concept that extends beyond hazard exposure. Each of the four dimension presented were seen by focus group participants to be important to the overall concept and no new or additional dimensions were proposed. Feedback was received, in particular from the employee representatives’ focus group, about the potential that empowerment could be perceived as an individual attribute, but that it was important to acknowledge that an individual worker’s level of empowerment could be influenced by workplace policy and procedures, their employment arrangements, as well as their previous experiences in the workplace. Specific feedback was also received on the content that should be included within each dimension. For example, a number of focus groups highlighted that the policy and procedure dimension needed to include questions on communication between employers and employees, the provision of training and perceptions of the importance of safety practices relative to the productivity.

The resulting list of questions, along with summaries of the six focus groups were then given to each of the team investigators, who selected items or developed items they thought were most consistent with the conceptual framework for the measure and the feedback received through the focus groups. After review by the research team we had a list of 97 items (20 hazards, 43 policy and procedure, 20 awareness and 14 empowerment). This list was sent to each study investigator and selected focus group participants who independently ranked the items from most important, to least important, to include in a revised measure. After reviewing and summarizing the rankings from the investigator team and focus

Table 1
Original 64 items used for pilot testing OH&S vulnerability measure with original sources and modifications made.

Item ID	Item used	Source	Modifications made
Hazards			
H1	How often do you have to manually lift, carry or push items heavier than 20 kg at least 10 times during the day?	(Kausto et al., 2011)	Wording
H2	How often do you have to do repetitive movements with your hands or wrists (packing, sorting, assembling, cleaning, pulling, pushing, typing) for a least 3 h during the day?	(Kausto et al., 2011)	Wording
H3	How often do you have to perform work tasks, or use work methods, that you are not familiar with?	(Lombardi et al., 2002)	Combination of two items
H4	How often do you interact with hazardous substances such as chemicals, flammable liquids and gases?	(WorkSafe Victoria, 2012)	
H5	How often are you subjected to persistent criticism of your work and effort?	(Tsuno et al. 2010)	Wording
H6	How often do you have to work in a bent or twisted work posture?	(Leijon et al., 2014)	Wording
H7	How often do you have to work using a vibrating tool for at least 2 h during the day?	(Kausto et al., 2011)	
H8	How often do you have pain or discomfort as a result of your job?	Focus groups	
H9	How often do you have mental pain or discomfort as a result of your job?	Focus groups	
H10	How often do you work at a height that is 2 m or more above the ground or floor?	(WorkSafe Victoria, 2012)	
H11	How often do you work in noise levels that are so high that you have to raise your voice when talking to people less than one meter away?	(WorkSafe Victoria, 2012)	
H12	How often do you have to work very fast?	(Lilley et al., 2010)	
H13	How often do you have to concentrate very hard to perform your work without any mistakes?	Focus groups	
H14	How often do you have to stand for more than two hours in a row?	(Hildebrandt et al., 2001)	Wording
H15	How often do you come to work feeling fatigued?	Focus groups	
H16	Have you been bullied or harassed at work?	(WorkSafe Victoria, 2012)	Wording
Policies and procedures			
P1	Everyone has the tools and/or equipment they need to complete their work safely	(Ossmann et al., 2005; Lu and Tsai, 2008)	Wording
P2	Everyone receives the necessary occupational health and safety training when starting a job, changing jobs or using new techniques	(Fernandez-Muniz et al., 2007)	Wording
P3	Formal safety audits at regular intervals are a normal part of our business	(Institute for Work & Health, 2011)	
P4	Managers and supervisors follow up on employee suggestions and initiatives to improve safety	(Cadieux et al., 2006)	Wording
P5	There is regular communication between employees and management about workplace health and safety issues	(Fernandez-Muniz et al., 2007)	Wording
P6	Workplace safety is given high priority by managers and supervisors	(Vinodkumar and Bhasi, 2010)	
P7	Systems are in-place to identify, prevent and deal with hazards at work	Focus groups	
P8	Systems are in-place to identify, prevent and deal with psychosocial (bullying, harassment, unreasonable work pace pressures) hazards at work	Focus groups	
P9	Those in charge of health and safety have the authority to make the changes they have identified as necessary	(Institute for Work & Health, 2011)	
P10	Everyone (employees, supervisors and managers) values ongoing safety improvement	(Institute for Work & Health, 2011)	Wording
P11	Workplace health and safety is considered to be at least as important as production and quality	(Amick et al., 2000)	Wording
P12	At my workplace, there is an active and effective health and safety committee and/or worker health and safety rep	(Parker et al., 2007)	Wording
P13	Incidents and accidents are investigated quickly in order to improve workplace health and safety	(Amick et al., 2000; Cadieux et al., 2006)	Combination of two items
P14	My workplace spends time and money on improving safety	(Amick et al., 2000)	Wording
P15	Lip service is paid to safety (reversed scored)	(Phipps et al., 2012)	Wording
P16	Managers and supervisors do not show interest in the safety of workers (reversed scored)	(Vinodkumar and Bhasi, 2010)	
P17	Workers and supervisors are given the information they need to work safely	(Institute for Work & Health, 2011)	
P18	Communication about workplace health and safety procedures is done in a way that I can understand	Focus groups	
P19	Management consider that employees' participation and involvement in decisions that are made at work is fundamental to health and safety	(Fernandez-Muniz et al., 2007)	Wording
Awareness			
A1	I know all of the potential hazards that are associated with my job	(Vinodkumar and Bhasi, 2010)	Wording
A2	I am clear about my rights and responsibilities in relation to workplace health and safety	(Lin et al., 2008)	Wording
A3	I am clear about my employers' rights and responsibilities in relation to workplace health and safety	Focus groups	
A4	I have been trained in the standard safety procedures involved in all my work tasks	Focus groups	
A5	I use the standard safety procedures for my work tasks every time I do my work	Focus groups	
A6	I am comfortable with my ability to identify work conditions that I feel are unsafe in my workplace	(Parker et al., 2007)	Wording
A7	I know how to perform my job in a safe manner	(Griffin and Neal, 2000)	
A8	I am aware of who I should talk to if I feel my working conditions might damage my physical health	Focus groups	
A9	I know that some hazards can injure me on the job, but other hazards might make me sick months or years later	Focus groups	
A10	I feel that there are hazards involved in my job that I don't know about (reversed)	(Vinodkumar and Bhasi, 2010)	Wording
A11	I know who I should talk to if I feel my working conditions might damage my mental health	Focus groups	
A12	If I became aware of a health and safety hazard at my workplace, I know who (at my workplace) I would report it to	(Vinodkumar and Bhasi, 2010)	Wording
A13	I have the knowledge to assist in solving any health and safety concerns at my workplace	(Parker et al., 2007)	Wording
A14	I know what the necessary precautions are that I should take while doing my job	(Vinodkumar and Bhasi, 2010)	
A15	I always follow safety rules and standard operating procedure at my workplace	(Lu and Yang, 2011)	Wording

Table 1 (Continued)

Item ID	Item used	Source	Modifications made
Empowerment			
E1	I feel free to voice concerns or make suggestions about workplace (occupational) health and safety at my job (workplace)	(Amick et al., 2000)	Wording
E2	I am thanked for reporting safety incidents or near misses	(Lu and Yang, 2010)	Wording
E3	I feel free to ask for safety information	(Lin et al., 2008)	Wording
E4	If I notice a workplace hazard, I would point it out to management	Focus groups	
E5	I receive the necessary support to conduct my job safely (e.g. training, feedback, instructions, procedures)	(Cadieux et al., 2006)	Wording
E6	It is normal for me and my co-workers to discuss and/or report safety problems with our supervisors or managers	(Lin et al., 2008; Parker et al., 2007)	Combination of two items
E7	I speak to co-workers at risk and encourage them to fix safety problems	(Tucker and Turner, 2011)	
E8	I am able to get information on safety during working hours, if I ever needed	(Lin et al., 2008)	Wording
E9	I am not aware of anyone who takes shortcuts in relation to safety	(Walker, 2010)	Wording
E10	I know that I can stop work if I think something is unsafe and management will not give me a hard time	Focus groups	
E11	I use all necessary safety equipment to do my job	(Vinodkumar and Bhasi, 2010)	
E12	I voluntarily carryout tasks or activities that help to improve workplace safety	(Vinodkumar and Bhasi, 2010)	
E13	I have enough time to complete my work tasks safely	(Singer et al., 2009)	Wording
E14	If my work environment were unsafe I would not say anything and hope the situation eventually improves	(Tucker and Turner, 2014)	Wording

group participants 64 items (16 hazards, 19 policy and procedure, 15 awareness and 14 empowerment) were retained for use in the pilot test survey. These items, their sources, and modifications made (if any) are presented in Table 1.

3.2. Pilot test survey

The 64 items were administered to a sample of 328 employed workers in Ontario and BC (51.5% in Ontario), and to a test-retest reliability assessment sample of 62 respondents. In addition to the OH&S vulnerability questionnaire information was also collected on demographic and labour market variables. Table 2 compares the pilot testing sample to the Canadian Labour Force Survey across key demographic and labour market characteristics. The sample recruited through the EKOS panel was older than the employed labour force, and had a greater proportion of workers in health, education, social or community services occupations, and from larger employers, and included fewer employees from sales and services occupations. Table 3 lists the items outlined in Table 1 that were removed, and the reasons for removal. Further details of specific reliability scores or percentage of missing/not applicable responses are available from the authors on request. Where the reason for removal is indicated as ‘investigator team and stakeholder opinion’ this indicates that the item in question has reasonable psychometric properties, but was considered to be less important than other questions within the same dimension for inclusion in the final measure. As such, these items were removed in order to reduce the number of items in the scale to be under 30, as this number was believed to be the upper limit to ensure the measure was feasible to administer.

3.3. Final survey

A final survey of 29 items was administered to a sample of 1835 employed respondents in British Columbia and Ontario. Table 4 presents the distribution of the sample of respondents compared to estimates from the Canadian Labour Force survey for the same period as when the survey was administered (May/June 2014). Differences between the sample recruited and the Canadian labour force were most pronounced for age and workplace size, with younger age groups and workers in small businesses (less than 20 employees) being under represented in our sample. In addition, although the sample recruited was from a variety of occupational groups it was more heavily weighted towards

education, social and community services occupations, while sales and service occupations were under-represented. Differences were also observed between the Probit panel and the RDD sample, with respondents recruited through the RDD approach being younger and more likely to have English as their first language.

Table 2

Descriptive information of pilot testing sample in Ontario (ON) and British Columbia (BC), compared to the Canadian Labour Force Survey (LFS) ($N=328$).

	Pilot survey		2013 LFS (BC, ON)
	N^a	(%)	(%)
Gender			
Male	164	50.0	49.7
Female	164	50.0	50.3
Age group			
Less than 25 yrs	7	2.2	15.3
25–34 yrs	55	17.4	22.8
35–44 yrs	88	27.8	21.9
45–54 yrs	84	26.6	23.3
55–64 yrs	68	21.5	14.0
65+ yrs	14	4.4	2.5
Employment status			
Full time	279	85.1	81.1
Part time	49	14.9	18.9
Employment relationship			
Permanent	291	89.3	87.3
Not permanent	35	10.7	12.7
Occupation			
Management	34	10.6	7.0
Business/finance/admin	68	21.2	19.5
Natural/applied science	9	2.8	7.8
Health	35	10.9	6.6
Education/social/community	71	22.1	11.5
Art and culture/rec and sport	12	3.7	2.7
Sales and service	34	10.6	24.6
Trades/transport/equipment	32	10.0	13.4
Natural resources/agriculture	5	1.6	1.5
Manufacturing/utilities	14	4.4	5.5
Other	7	2.2	
Workplace size			
Less than 20 employees	75	22.9	32.5
20–99 employees	112	34.2	33.5
100–500 employees	84	25.6	21.0
500 or more employees	57	17.4	12.9

^a N within groups may not add up to 328 due to missing data.

Table 3
Items removed after pilot testing and reason removed.

Item ID	Reason removed
Hazards	
H5	Low test-retest reliability
H7	Hazard exposure rare (ceiling effect)
H9	Low test-retest reliability
H12	Low test-retest reliability
H13	Low test-retest reliability
Policies and procedures	
P1	Investigator team and stakeholder opinion
P3	High percent of missing values
P4	Low test-retest reliability
P6	Investigator team and stakeholder opinion
P8	Investigator team and stakeholder opinion
P9	High percent of missing values
P10	Investigator team and stakeholder opinion
P14	Redundant with other measures and low test-retest reliability
P15	High percent of missing values
P16	Low test-retest reliability
P17	Investigator team and stakeholder opinion
P19	Investigator team and stakeholder opinion
Awareness	
A1	Low test-retest reliability
A4	High percent of not-applicable responses
A5	High percent of not-applicable responses
A6	Low test-retest reliability
A8	Low test-retest reliability and conceptually overlapping with empowerment
A9	High percent of not-applicable responses, low test-retest reliability
A10	Not clearly related to any dimension of OH&S vulnerability
A11	Conceptually overlapping with empowerment
A15	Investigator team and stakeholder opinion
Empowerment	
E2	High percent of not-applicable responses
E3	Conceptually overlapping with policies and procedures
E5	Conceptually overlapping with policies and procedures
E6	Low test-retest reliability and high percent of not-applicable responses
E7	Low test-retest reliability and high percent of not-applicable responses
E8	Investigator team and stakeholder opinion
E9	Investigator team and stakeholder opinion
E11	High percent of not-applicable responses and conceptually overlapping with awareness
E12	Low test-retest reliability and high percent of not-applicable responses

Table 5 presents the distribution of survey responses for each of the 29 questions included in the OH&S vulnerability measure. In general only a very small percentage of missing (do not know or not applicable) responses were present; the one exception being a policy and procedure question on investigation of incidents and accidents (Q17). For most questions, responses were distributed across possible response options, although in a few cases (Q21, Q24, Q26) responses were heavily weighted towards positive (agreement) responses.

Table 6 presents the factor loadings resulting from the exploratory factor analysis on the Policy and Procedure, Awareness and Empowerment dimensions of our measure. The results indicate a clean three-factor solution with all items loading on dimensions specified *a priori*. All dominant loadings were above 0.4, with one exception being a reverse score empowerment item (Q28). However, in this situation the loading on the empowerment dimension (0.32) was stronger than the loadings for the policy and procedure (−0.006) and awareness (−0.05) dimension, supporting a three-factor solution. Factor correlations between dimensions

Table 4

Descriptive information on study sample for final survey of 1835 respondents in Ontario (ON) and British Columbia (BC), compared to the Canadian Labour Force Survey (LFS).

	Final sample survey		2014 LFS (BC, ON)
	N ^a	%	(%)
Province			
Ontario	1154	62.9	75.3
British Columbia	681	37.1	24.7
Gender			
Male	946	51.7	50.0
Female	882	48.3	50.0
Age group			
Less than 25 yrs	27	1.5	16.3
25–34 yrs	135	7.7	22.7
35–44 yrs	343	19.6	21.3
45–54 yrs	599	34.2	22.7
55–64 yrs	557	31.8	14.4
65+ yrs	90	5.1	2.6
Employment status			
Full time	1530	83.4	81.8
Part time	305	16.6	18.2
Employment relationship			
Permanent	1638	89.5	86.7
Not permanent	191	10.4	13.3
Occupation			
Management	247	13.8	6.4
Business/finance/admin	255	14.3	18.6
Natural/applied science	129	7.2	8.2
Health	162	9.1	6.7
Education/social/community	412	23.1	10.4
Art and culture/rec and sport	40	2.2	2.4
Sales and service	289	16.2	26.4
Trades/transport/equipment	181	10.1	13.4
Natural resources/agriculture	21	1.2	1.9
Manufacturing/utilities	50	2.8	5.6
Workplace size			
Less than 20 employees	345	18.8	32.3
20–99 employees	550	30.0	34.3
100–500 employees	500	27.2	20.5
500 or more employees	440	24.0	12.8

^a N within groups may not add up to 1835 due to missing data.

were $r=0.61$ between policies and procedures and awareness; $r=0.62$ between policies and procedures and empowerment; and $r=0.63$ between awareness and empowerment.

4. Discussion

In this paper we have described the development of a multi-dimensional measure of OH&S vulnerability. Importantly, by extending OH&S vulnerability to incorporate dimensions of workplace policies and procedures, OH&S awareness and empowerment to participate and speak out about OH&S concerns, this measure moves beyond hazard exposure in isolation to identify groups of workers who are at increased risk of injury. This is in concordance with our conceptual model of OH&S vulnerability which posits that increased risk of injury arises because of greater potential for exposure to occupational hazards, *in combination with*: inadequate workplace policies and procedures to control such hazards; and/or lack of worker awareness about hazards and OH&S rights and responsibilities; and/or the absence of a workplace culture that encourages workers to voice concerns about OH&S. Of note, in developing this conceptual framework we received input from workers, employers, policy makers, and employee and employer representatives, located in two different jurisdictions.

Table 5
Percentage distributions of responses for vulnerability questions by vulnerability dimension among 1835 employees in Ontario and British Columbia.

	Never	Once a year	Every 6 months	Every 3 months	Every month	Every week	Every day	DK/NA
Hazards: How often do you/are you ...								
1. Have to manually lift, carry or push items heavier than 20 kg at least 10 times during the day?	64.1	4.0	4.9	2.6	4.1	4.8	12.2	0.4
2. Have to do repetitive movements with your hands or wrists (packing, sorting, assembling, cleaning, pulling, pushing, typing) for at least 3 h during the day	26.4	2.8	2.3	2.0	3.2	8.7	54.1	0.5
3. Have to perform work tasks, or use work methods, that you are not familiar with?	57.6	12.2	8.6	5.9	7.4	3.9	2.9	1.5
4. Interact with hazardous substances such as chemicals, flammable liquids and gases?	63.0	5.8	2.8	2.8	4.3	6.2	14.1	1.1
5. Have to work in a bent, twisted or awkward work posture?	54.8	5.1	4.3	3.8	5.2	8.9	17.2	0.8
6. Experience pain or discomfort as a result of your job?	35.4	7.5	6.5	6.7	11.8	14.1	16.5	1.4
7. Work at a height that is 2 m or more above the ground or floor?	74.1	4.8	2.7	1.8	4.6	4.1	7.4	0.5
8. Work in noise levels that are so high that you have to raise your voice when talking to people less than one metre away	57.6	6.6	4.4	2.9	5.5	8.7	13.7	0.8
9. Have you been bullied or harassed at work?	57.9	14.4	5.9	4.3	5.9	5.6	4.2	1.8
10. Have to stand for more than two hours in a row?	47.0	4.1	3.9	3.3	4.6	8.9	27.9	0.3
11. Come to work feeling fatigued?	19.0	3.1	6.1	8.5	18.2	29.3	14.4	1.5
				Strongly agree	Agree	Disagree	Strongly disagree	DK/NA
Policies and Procedures: At my workplace ...								
12. Everyone receives the necessary workplace health and safety training when starting a job, changing jobs or using new techniques			30.5	40.2	16.2	8.1	5.0	
13. There is regular communication between employees and management about safety issues			32.3	42.5	15.5	6.7	3.0	
14. Systems are in-place to identify, prevent and deal with hazards at work			37.8	45.0	9.1	4.1	4.1	
15. Workplace health and safety is considered to be at least as important as production and quality			33.2	38.3	17.4	7.2	3.8	
16. At my workplace, there is an active and effective health and safety committee, and/or worker health and safety rep			38.9	36.7	12.5	7.2	4.7	
17. Incidents and accidents are investigated quickly in order to improve workplace health and safety			36.5	37.9	11.4	3.9	10.4	
18. Communication about workplace health and safety procedures is done in a way that I can understand			38.4	46.2	8.8	4.1	2.5	
Awareness: At my workplace ...								
19. I am clear about my rights and responsibilities in relation to workplace health and safety			42.7	43.3	10.3	2.2	1.4	
20. I am clear about my employers' rights and responsibilities in relation to workplace health and safety			39.7	43.0	12.3	2.5	2.6	
21. I know how to perform my job in a safe manner			55.2	42.3	1.7	0.4	0.4	
22. If I became aware of a health or safety hazard at my workplace, I know who (at my workplace) I would report it to			50.9	39.5	6.7	1.9	1.0	
23. I have the knowledge to assist in responding to any health and safety concerns at my workplace			34.3	45.3	15.4	2.9	2.1	
24. I know what the necessary precautions are that I should take while doing my job			48.3	46.9	3.2	0.7	0.9	
Empowerment: At my workplace ...								
25. I feel free to voice concerns or make suggestions about workplace health and safety at my job			44.5	42.9	8.0	3.7	1.0	
26. If I notice a workplace hazard, I would point it out to management			51.9	41.7	4.0	1.5	0.9	
27. I know that I can stop work if I think something is unsafe and management will not give me a hard time			40.3	37.9	13.4	5.0	3.5	
28. If my work environment was unsafe I would not say anything, and hope that the situation eventually improves (reverse scored)			4.8	8.3	31.1	54.9	0.9	
29. I have enough time to complete my work tasks safely			37.1	48.7	10.4	3.2	0.6	

DK/NA: Do not know or not applicable.

Our final 29-item instrument is the result of a rigorous process of item generation that involved both a systematic search of existing instruments and focus group discussions. The reduction of items involved a transparent and independent selection process that included the investigator team and various OH&S stakeholders. The final item reduction process was informed by an analysis of response distribution, item-to-item and item-to-dimension correlations, and a test-retest reliability assessment of a larger 64-item questionnaire. In a large sample of employees in Ontario and British Columbia the resulting 29 items selected displayed minimal missing responses (with one exception), reasonably good distributions across response categories, and strong factorial validity. In addition, the correlations between the factors of Awareness, Policies and Procedures and Empowerment indicate that these are distinct, but related dimensions (McHorney et al., 1993). Taken together, the processes outlined above are likely to result in a measure that is reliable and structurally valid, representing the underlying concept of vulnerability as defined by the investigator team.

We suggest that the four dimensions of vulnerability captured by our measure be examined separately, rather than summed together to form an aggregate scale score. This is because we do not know if the groups of workers previously labelled as “vulnerable”

(e.g. young workers compared to temporary workers compared to immigrant workers) are vulnerable in the same ways. By examining dimensions separately we can identify more specifically where differences are present across labour market sub-groups, which can in turn direct the types of primary prevention activities required to reduce inequalities in work injury risk. This is important as it is unlikely that a given prevention intervention would impact all four dimensions of OH&S vulnerability in the same way. Identifying dimensions of OH&S vulnerability where there is variation can be used to target primary prevention strategies in general, and to reduce inequalities in injury burden (Keyserling and Smith, 2007). For example, if all workers are aware of their OH&S rights, then primary prevention programs designed to increase awareness are unlikely to be effective in reducing injury risk or inequalities in injury burden in the labour market. Conversely, if there is large variation in levels of empowerment then primary prevention activities could focus on activities that support workers to voice concerns about OH&S issues, and could in turn reduce OH&S vulnerability in the labour market. Consistent with our conceptual framework, vulnerability could be examined as a combination of high hazards with sub-optimal ratings on one of the other three dimensions of vulnerability.

Table 6
Factorial validity of a 29-item measure of OH&S vulnerability (N = 1469 employed respondents in Ontario and BC). Highest factor loadings for each question are bolded.

	Factor loadings		
	P&P	Aware	Emp
Policies and procedures (P&P): At my workplace ...			
12. Everyone receives the necessary workplace health and safety training when starting a job, changing jobs or using new techniques	0.76	0.09	−0.03
13. There is regular communication between employees and management about safety issues	0.84	−0.02	0.01
14. Systems are in-place to identify, prevent and deal with hazards at work	0.79	0.07	0.02
15. Workplace health and safety is considered to be at least as important as production and quality	0.75	−0.04	0.14
16. At my workplace, there is an active and effective health and safety committee, and/or worker health and safety rep	0.73	−0.003	0.03
17. Incidents and accidents are investigated quickly in order to improve workplace health and safety	0.76	−0.07	0.12
18. Communication about workplace health and safety procedures is done in a way that I can understand	0.76	0.11	0.02
Awareness (Aware): At my workplace ...			
19. I am clear about my rights and responsibilities in relation to workplace health and safety	0.08	0.87	−0.04
20. I am clear about my employers' rights and responsibilities in relation to workplace health and safety	0.09	0.82	0.002
21. I know how to perform my job in a safe manner	−0.07	0.66	0.22
22. If I became aware of a health or safety hazard at my workplace, I know who (at my workplace) I would report it to	0.13	0.54	0.23
23. I have the knowledge to assist in responding to any health and safety concerns at my workplace	0.14	0.67	−0.004
24. I know what the necessary precautions are that I should take while doing my job	−0.003	0.72	0.11
Empowerment (Emp): At my workplace ...			
25. I feel free to voice concerns or make suggestions about workplace health and safety at my job	0.15	0.008	0.74
26. If I notice a workplace hazard, I would point it out to management	−0.06	0.17	0.67
27. I know that I can stop work if I think something is unsafe and management will not give me a hard time	0.17	0.04	0.64
28. If my work environment was unsafe I would not say anything, and hope that the situation eventually improves (reverse scored)	−0.006	0.05	0.32
29. I have enough time to complete my work tasks safely	0.08	0.08	0.54

Factor extraction was performed using the maximum likelihood estimation method with three factors specified *a priori*. Factor rotation was performed using Promax (oblique) rotation.

This measure could then be administered at a single time point to identify groups with higher levels of OH&S vulnerability, or to compare different types of OH&S vulnerability across segments of the labour market, or for a given employer compared to other employers within the same industry. In addition, the measure could be administered at multiple time points to examine changes in specific dimensions of OH&S vulnerability; for example, in response to regulatory or other preventive interventions at the population, employment sector, or workplace level.

As noted in Section 2.4, the sample used for both our pilot survey and final survey was not representative of all labour market subgroups in Ontario and British Columbia. In particular, the sample recruited for each survey under represented younger workers, those in small workplaces and those in the goods and service industry. As a result, we cannot definitively generalise the results of the current analysis that demonstrates strong factorial validity of our survey methods to these under-represented groups. In particular there may be cultural or employment-related factors that may lead to systematic differences between self-reports from younger workers or recent immigrants and those included in this current sample. We suggest future studies should examine the distribution of our survey items and the factorial validity of our measure in a sample of these harder to reach groups, to ensure that items and the relationship across measures is consistent across these groups. That said, our sample did have variation in occupational groups, employment status and employment relationships, and contained even proportions of men and women, which suggests that our findings are likely generalisable to the Ontario and British Columbia labour market as a whole. Future studies should also examine the relationship between vulnerability as defined by our measure with labour market characteristics associated with higher risk of injury, and ideally with the occurrence of work-injury.

5. Conclusion

In conclusion, we suggest our 29-item measure (used along with demographic and labour market data) can be used to assess different dimensions of OH&S vulnerability across labour market participants.

This assessment could be performed at one time point – to assess the ways in which increased risk of injury arises in particular labour market groups – or at multiple time points to assess changes in OH&S vulnerability in response to primary prevention activities.

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