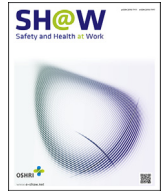




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Original article

## The Impact of Adverse Employment and Working Conditions on the Risk of Workplace Injury in Canada

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### ABSTRACT

**Background:** Employment standards (ES) include having a regular payday, regular breaks, the right to paid sick or vacation time, and paid wages. Inadequate ES contribute to the labour market vulnerability of workers; however, they are not typically considered to be risk factors for workplace injury. In a sample of Canadian workers, we examine the risk of injury associated with inadequate ES, independent of, and combined with inadequate workplace protections from workplace hazards.

**Methods:** Data from 2,803 adults working 15 hours or more/week in workplaces with at least five employees were analysed. We explored associations between exposure to workplace hazards with inadequate protections [termed occupational health and safety (OHS) vulnerability] and inadequate ES on workplace injury (physical or mental injury; injury requiring time off). Additive interaction models were used to examine the independent and combined effects of these exposures.

**Results:** Occupational health and safety vulnerability and inadequate ES were independently associated with increased injury outcomes. Adjusted models showed an additive relationship for all injury outcomes between OHS vulnerability and inadequate ES. Statistically significant superadditive relationships were observed for physical injury risk with policy and procedure vulnerability plus inadequate ES [synergy index (S) 1.50, 95% CI: 1.13–2.00] and for overall OHS vulnerability plus inadequate ES (S 1.53, 95% CI: 1.16–2.02), suggesting a combined effect greater than independent effects.

**Conclusion:** Occupational health and safety vulnerability and inadequate ES are independently associated with workplace injury. For certain injury outcomes, the combined effect of OHS vulnerability and inadequate ES is greater than the independent effects of each individual exposure.

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### 1. Introduction

Broadly defined, “labor market vulnerability” encompasses both inadequate employment standards (ES) in the workplace and occupational health and safety (OHS) vulnerability. The concept of OHS is more closely allied with the prevention of workplace injury and hazard exposure, while ES are related more closely to the scheduling and payment for work, and the availability of sick time and vacation. In Canada, both ES and OHS are legislated at the federal and provincial level. Canadian employers under federal regulation are required, among other things, to post information about the federal labour code, the workplace health and safety

policy, contact information for the health and safety representative, and other information useful in an emergency [1].

Employment standards include the minimum statutory rights and responsibilities that govern the terms of employment in a jurisdiction. Employment standards are typically defined by legislation (Acts) and regulations. Employment Standards Acts (ESAs) are one way of providing universal protection to workers. Many developed countries have standards around the maximum number of hours that can be worked in a week and minimum wages [2]. In Canada, there are federal and provincial regulatory standards for a range of workplace situations, such as how and when workers are paid and around the provision of breaks, sick leave, and vacation [3]. Ontario’s ESA, for example, encompasses a

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range of entitlements, including the provision of: a minimum wage; termination notice and pay for those who are eligible; two weeks paid vacation following 12 months of employment; vacation pay of at least four per cent of gross wages earned in an entitlement year; an eating break after no more than five working hours; a regular pay day; a regular pay period; and the requirement that all wages that are due be paid [4]. In some countries, ESAs have been in existence for many years; however, to date, their unique contribution to workplace health and injury risk has not been studied in detail.

Although it has been customary to label workers as ‘vulnerable’ to workplace injury according to their demographic characteristics, e.g., work status (temporary), age, or immigrant status, this approach assumes individual risk is defined by group risk, vulnerability is the intersection of various factors. From an OHS perspective, workers are at an increased risk for injury when they are exposed to hazards in the workplace from which they do not have adequate protection, a condition termed “OHS vulnerability” [5]. Hazards a worker might be exposed to include hazardous materials, workplace bullying and harassment, standing for long periods of time, and having to perform unfamiliar tasks. Protections available at the workplace may include 1) policies and procedures to reduce risk, such as health and safety training when workers start a new job; 2) ensuring that workers are aware of how to protect themselves from hazards, such as ensuring that employees understand how to perform their work in a safe manner; and 3) empowering workers to participate in hazard identification and control, such as ensuring that employees feel free to voice their concerns about workplace health and safety [5,6].

There are models and scales that explore labour market vulnerability. Quinlan and Bohle’s Pressures, Disorganization and Regulatory failure model describes factors that explain the poor OHS outcomes among precarious workers: 1) economic and reward pressures, which relate to income insecurity; 2) workplace disorganization, which is the degree to which the practices and management related to OHS are weakened by precarious employment arrangements; and 3) regulatory failure, whereby labour standards and their enforcement are weakened [7]. The model indicates that insecurity around employment and income and competition for work contribute to practices at work that put workers at risk for injury, especially so for those in precarious work. Research into this model generally explores the interconnections between these three categories of risk [7]. The Employment Precariousness Scale includes dimensions of workplace protections, employment standards (rights), ability to exercise rights, scheduling of work hours, wage level, and temporariness of employment as components of overall labour market vulnerability [8]. Users of this scale are to sum its components to produce an overall score, which assumes its components have an additive impact, although an additive impact may not be the case. When examining highly overlapping exposures associated with similar effect, the effect of one may be lesser when the other is present. Conversely, it is also possible that when exposures are combined, the effects of joint exposures may be greater than predicted, based on their independent effects. This type of effect is referred to as a synergistic, or a super-additive interactive effect.

Given that inadequate ES and OHS vulnerability may both be associated with increased injury risk and may overlap among certain labour market groups, it is important to examine the effects of these two exposures on injury risk both individually and in combination. The objective of this paper is to disentangle and examine the impact of inadequate ES and OHS vulnerability on

multiple work-injury outcomes and explore how ES and OHS vulnerability may interact.

## 2. Material and methods

### 2.1. Data collection

The data collection for this study was contracted to a research company that maintains an existing roster of individuals who have provided contact details and consent to being approached to participate in surveys from time to time. Participants were living in the Canadian provinces of Ontario, British Columbia (B.C.) and Alberta, 18 years of age or over, and working 15 hours or more per week at organizations with five or more employees. For participating, respondents were entered into a draw for a prize of \$200. A second, small sample was obtained, using the same selection criteria, from a phone bank and dialled randomly (random digit dial, RDD). The RDD sample was gathered so that the authors could make comparisons and ensure that the roster collection method was representative of what could be captured with RDD. Data were collected in Ontario and B.C. in November 2017 and in Alberta in May and June of 2018. The total sample consisted of 2,943 participants, of which 714 were from B.C. (10% collected by RDD), 1,026 were from Alberta (25% by RDD), and 1,203 were from Ontario (9% by RDD). The response rates for panel members were 18% for B.C., 15% for Alberta, and 11% for Ontario, and the RDD response rates were 20%, 7%, and 22%, respectively. Ethics approval for this project was obtained from the Research Ethics Board at the University of Toronto IRB 29512.

The questions relevant to this analysis were part of a larger questionnaire that measures factors associated with injury risk. Participants were asked about their socio-demographics, their work, nine questions about their exposure to common workplace hazards, seven questions about the OHS policies and procedures in their workplace, six questions about their awareness of OHS rights and responsibilities, and five questions about their empowerment to participate in injury prevention. These are described in greater detail in section 2.3.1. With respect to employment standards in the workplace, respondents were asked five questions (listed in section 2.3.2) about practices in their workplace.

### 2.2. Data cleaning and imputation

Imputation was used for missing responses in the sections relating to policies and procedures; awareness; or empowerment. The mean of the individual’s other answers within the section were used to impute responses. Individuals who answered less than three questions in a section were removed. Next, respondents missing an answer for any of the covariates (specified below) were removed from the analysis. Following cleaning and imputation, 2,803 respondents were analysed, 95% of the original sample.

### 2.3. Independent variables

We explored two different types of labour market vulnerability: OHS vulnerability and ES inadequacy. These are described below.

#### 2.3.1. Occupational health and safety vulnerability

A previously validated, published 27-item tool was used to measure OHS vulnerability [6]. The tool was developed by a search of existing instruments, focus group consultations, and item selection by investigators and stakeholders [6]. It classifies an individual as ‘vulnerable’ to workplace injury when they are exposed weekly or daily to two or more of nine common workplace hazards or to one key hazard, such as interacting with chemicals,

flammable liquids and gasses; or experiencing bullying or harassment in the workplace against which the workplace does not adequately protect the worker [6]. Adequacy of worker protection was measured in three areas of interest: 1) OHS policies and procedures (PP), using seven items, e.g., "There is regular communication between employees and management about safety issues", "Systems are in-place to identify, prevent and deal with hazards at work", "Communication about workplace health and safety procedures is done in a way I can understand"; 2) OHS awareness (AW), using six items, e.g., "If I became aware of a health or safety hazard at my workplace, I know who [at my workplace] I would report it to", "I know how to perform my job in a safe manner", "I know what the necessary precautions are that I should take while doing my job"; and 3) empowerment (EM) to participate in injury prevention, using five items, e.g., "I know that I can stop work if I think something is unsafe and management will not give me a hard time", "I have enough time to complete my work tasks safely", "I feel free to voice concerns or make suggestions about workplace health and safety at my job". Respondents were categorized as "inadequate" within one of the three areas if they disagreed or strongly disagreed with one or more of the statements within each [6,9].

From the answers to the aforementioned questions, three types of OHS vulnerability were constructed: 1) PP vulnerability, which indicates the respondents were exposed to hazards and were not protected from them in the area of policies and procedures; 2) AW vulnerability, which indicates the respondents were exposed to hazards and were not protected from them in the area of awareness; and 3) EM vulnerability, which indicates the respondents were exposed to hazards and were not protected from them in the area of empowerment to participate in injury prevention. A fourth measure of overall vulnerability was also created, based on whether respondents experienced one or more of the three types of vulnerability.

### 2.3.2. *Employment standard inadequacy*

Standards differ across jurisdictions; here, ES refers to employment legislation or regulation separate from OHS regulation or legislation. Regarding ES, respondents were asked, with response options of yes, no, and don't know: "In the last 12 months, has your employer ever failed to pay you the wages you are due?", "Do you have a regular payday?", "Do you have the right to paid vacation?" and "Do you have the right to paid sick leave?" Respondents were also asked "In your job how often do you work more than 5 hours without a meal break?" with response options never, sometimes, often and always, re-coded into never/sometime and often/always. A respondent was classified as "inadequate ES" if they had one or more of these negative employment conditions.

### 2.4. *Dependent variables*

Three injury outcomes were considered. Respondents were asked, with response options of yes or no: "In the last 12 months have you sustained a physical injury or illness due to your work?" and "In the last 12 months have you sustained a mental or psychological injury or illness due to your work?" Those indicating a physical and/or mental injury were asked "Did this injury or illness require you to take time off work or receive health care from a medical professional such as a doctor, physiotherapist or psychologist?" (yes/no).

### 2.5. *Covariates*

A number of covariates commonly included in workplace studies [10] were included: education (less than bachelor's degree; bachelor's degree or higher), sex (male; female), age group (<35;

35–44; 45–54; 55 and over), industry (primary; manufacturing, trade, transport; other & service industries; education; health; arts, food retail; public administration), work relationship (permanent; temporary), workplace size (5–19; 20–99; 100–499; 500 and up), and employment status (full time; part time). Education, age, industry, and workplace size were grouped according to logical association and frequency distributions.

## 3. *Analysis*

Injury outcomes were explored across all study variables; then injury outcomes were analysed by ES and for each type of OHS vulnerability (PP; AW; EM; overall). To examine the individual and collective contributions of inadequate ES and OHS vulnerability to the risk of an injury outcome, we used an 'additive interaction approach' [11]. In this approach, having adequate ES and OHS protection is considered the referent category; then inadequate ES and OHS vulnerability were individually compared to referent, followed by the risk posed by both inadequate ES and OHS vulnerability together.

The four categories are 1) ES adequate and OHS protected (referent); 2) ES inadequate and OHS protected; 3) ES adequate and OHS vulnerable; and 4) ES inadequate and OHS vulnerable. This categorization was completed for the four types of OHS vulnerability (PP; AW; EM; and overall). The Synergy Index (S) [12] was used to determine if the relationship between inadequate ES and OHS vulnerability was additive, subadditive, or superadditive, using the following equation [13]:

$$S = [RR_{11} - 1] / [(RR_{10} - 1) + (RR_{01} - 1)]$$

Here,  $RR_{11}$  refers to the relative risk posed by *both* inadequate ES and OHS vulnerability,  $RR_{10}$  refers to the relative risk when there is inadequate ES alone (i.e., without OHS vulnerability), and  $RR_{01}$  refers to the relative risk posed by OHS vulnerability alone (i.e., without inadequate ES). When S is greater than one, it indicates a superadditive interaction between exposures, while values of one indicate no interaction and values of less than one indicate a subadditive interaction. As S increases above one, the superadditive interaction increases; as the value decreases below one, it indicates that the sub-additive interaction is increasing. Confidence intervals were calculated using the Hosmer and Lemeshow delta method, which is a Taylor expansion of variances and covariances [13]. When using regression models adjusting for other covariates S is the best index, preferred over other measures of additive interaction, such as the relative excess risk due to interaction and the attributable proportion due to interaction [14]. S requires relative risks, and odds ratios can overestimate the risk of common outcomes, therefore log-binomial models were used to estimate relative risks. All models were adjusted for education, sex, age group, workplace size, employment relationship, industry, and employment status. Convergence problems occurred with the log-binomial models when multiple covariates were included; therefore covariates were adjusted for using propensity scores, estimated from a multinomial logistic model with the independent variable as the outcome, with covariates sex, age group, workplace size, employment relationship, industry, and employment status included as predictors [15]. To ensure that this approach was an adequate adjustment for the confounders, we compared logistic models using the propensity scores with logistic models including all covariates. Only small differences were observed between models, which indicated that the adjustment approach was suitable. All analyses were completed using SAS 9.4 (SAS Institute, Cary, NC, USA). Data were weighted to reflect each province's age, sex, and workforce

distribution at the time the data were collected, using Canadian labour force survey data.

## 4. Results

### 4.1. Sample description

The final sample of 2,803 respondents, weighted, is 51% male, 49% female, with 63% under 45 years of age, 50% with, at minimum, a bachelor's degree, 86% employed full-time, just over half working in establishments with less than 100 employees (54%), and most in permanent employment (88%). In the last 12 months (weighted), 18% of respondents reported a physical injury or illness due to work, 17% reported a mental or psychological injury or illness due to work, and 15% of respondents had a work-related injury that required that they take time off work for medical care. Chi square comparisons by demographic characteristic were completed using the outcome (Table 1) and show some significant differences, e.g., those with lower education and temporary workers were more likely to experience inadequate ESA.

### 4.2. Injury outcomes by OHS vulnerability and inadequate ES

Table 2 presents the prevalence of injury outcomes by areas of OHS vulnerability and inadequate ES. OHS vulnerability types (PP; AW; EM; all) had statistically significant ( $p < .0001$ ) relationships with injury outcomes (physical injuries, mental injuries, and injuries requiring time off work). For example, among respondents who were “vulnerable” in “empowerment”, 38.7% had a physical injury, while 11.4% of those who were “protected” under “empowerment” had a physical injury.

At the bottom of Table 2, the overall measure of inadequate ES is shown. Across all injury outcomes in the row, statistically significant differences exist between those with inadequate ES and those with adequate ES ( $p < .0001$ ). Above the overall values in Table 2, the individual aspects of ES and injury outcomes are displayed. Statistically significant differences for injury outcomes exist between participants with an employer who has failed to pay wages versus those who are paid regularly and again for those who are regularly required to work five hours without a meal break versus those who have regular meal breaks. The difference between those with versus those without a regular payday and those with versus those without the right to paid vacation was statistically significant

when the risk of physical injury was examined. There was a statistically significant difference in the risk of physical injury between those with adequate sick leave versus those with inadequate sick leave.

Table 3 presents injury outcomes according to combinations of ES adequacy/inadequacy and OHS protection/vulnerability. Across all measures, there were statistically significant differences ( $p < .0001$ ). This table shows that participants with adequate ES plus OHS protection had the lowest proportion of injury outcomes. This table also shows that those with inadequate ES plus OHS vulnerability had the greatest proportion of injury outcomes. For example, in the first row of Table 3, participants with adequate ES plus PP protection had a low percentage of physical injury (10.4%). In the second row, the proportion of physical injuries was 19.1% for those with inadequate ES, yet did have workplace protection in PP. The proportion of physical injuries was 26.2% among participants with adequate ES plus PP vulnerability; among those with inadequate ES plus PP vulnerability, the percentage with a physical injury jumped to 48.4%. As another example, among those with inadequate ES who also had vulnerability in AW, 50.2% experienced a physical injury, whereas among those with adequate ES and were protected in AW 11.9% of participants had a physical injury. The greatest proportion of injury outcomes among all groupings in Table 3 occurs among those with ES inadequacy plus one of the OHS vulnerabilities.

Table 4 presents the results of the log-binomial models examining the relationship between inadequate ES and OHS vulnerability and each injury outcome. Below each RR value are estimates for S, which assesses the presence of additive interaction between exposures. The estimates in all models show a pattern: those with inadequate ES are at an increased risk of workplace injury outcomes; those with one of the OHS vulnerability types alone are at a higher risk than are those reporting inadequate ES alone; and when both types of vulnerability are combined (i.e., inadequate ES plus OHS vulnerability together), there is a greater risk of injury outcomes than either type of vulnerability alone. For example, those reporting PP vulnerability in combination with inadequate ES (adjusted) are at 4.4 times greater risk for a physical injury than are those without either type of vulnerability ( $RR = 4.43$ , 95% CI: 3.67–5.35). For all but one adjusted model and all but one of the crude models (data not shown), the S values were greater than 1.00, which suggests an additive interaction between the two exposures on each outcome. Statistically significant S

**Table 1**  
Sample characteristics by outcome.\*

	Total %	Physical injury % of row; p value	Mental injury % of row; p value	Time off % of row; p value	ESA inadequate % of row; p value	OHS vulnerable % of row; p value	Both inadequate ESA, OHS vulnerable % of row; p value
Sex							
Male	50.9	9.5	7.1	7.1	14.3	18.7	8.1
Female	49.2	8.7	9.6	8.0	11.8	17.5	6.2
			$p < .0001$		$p = 0.01$		$p = 0.02$
Education							
<Bachelor's	49.9	10.9	7.7	8.0	13.7	21.7	8.8
/=Bachelor's	49.8	7.2	8.8	7.0	12.2	14.2	5.3
		$p < .0001$	$p = 0.001$		$p = 0.0005$	$p < .0001$	$p < .0001$
Work type							
Permanent	87.6	16.0	14.4	13.0	22.0	31.1	11.8
Temporary	12.4	2.3	2.3	2.1	4.2	5.1	2.5
					$p = 0.0006$		$p = 0.0007$
Hours of work							
Full time	86.3	15.1	14.6	12.5	22.6	30.3	12.4
Part time	13.7	3.2	2.1	2.5	3.5	5.9	1.9
		$p = 0.007$		$p = 0.04$		$p = 0.002$	

ESA, Employment Standards Act; OHS, occupational health and safety.

\* Weighted to age and sex of labour force of each province; unweighted the N = 2803.



**Table 2**

Injury outcomes across levels of occupational health and safety vulnerability and employment standards inadequacy, N = 2,813\*

	Overall		Physical injury			Mental injury			Injury requiring time off work		
	N	%	N	%†	p	N	%†	P	N	%†	p
Policies and Procedures (PP)											
Protected	2081	74.0	254	12.2	<.0001	240	11.5	<.0001	218	10.5	<.0001
Vulnerable	732	26.0	259	35.4		230	31.4		206	28.2	
Awareness (AW)											
Protected	2418	85.9	361	14.9	<.0001	317	13.1	<.0001	288	11.9	<.0001
Vulnerable	396	14.1	152	38.4		153	38.6		136	34.5	
Empowerment (EM)											
Protected	2110	75.0	241	11.4	<.0001	228	10.8	<.0001	205	9.7	<.0001
Vulnerable	703	25.0	272	38.7		241	34.3		219	31.1	
All											
Protected	1795	63.8	175	9.8	<.0001	179	10.0	<.0001	154	8.6	<.0001
Vulnerable	1018	36.2	338	33.2		291	28.5		271	26.6	
Standards- Employer failed to pay wages											
Adequate	2618	93.1	430	16.4	<.0001	402	15.4	<.0001	363	13.9	<.0001
Inadequate	195	6.9	83	42.5		68	34.7		61	31.3	
Standards-Regular payday											
Adequate	2749	97.7	495	18.0	0.03	460	16.7	0.78	412	15.0	0.35
Inadequate	64	2.3	18	28.5		10	15.4		12	19.2	
Standards-Work 5 hours without meal break											
Adequate	2240	79.6	339	15.1	<.0001	301	13.5	<.0001	284	12.7	<.0001
Inadequate	573	20.4	174	30.4		168	29.4		141	24.5	
Standards-Right to paid vacation											
Adequate	2446	87.0	430	17.6	0.02	402	16.4	0.36	362	14.8	0.32
Inadequate	367	13.0	83	22.5		67	18.4		62	16.8	
Standards-Right to paid sick leave											
Adequate	2147	76.3	365	17.0	0.002	364	16.9	0.53	330	15.4	0.41
Inadequate	666	23.7	148	22.2		106	15.9		94	14.1	
Standards-Overall protection											
Adequate	2078	73.9	284	13.1	<.0001	262	12.7	<.0001	249	12.0	<.0001
Inadequate	735	26.1	229	31.1		208	28.2		175	23.8	

\* % column 1 with outcome.

† weighted to age and sex of labour force of each province; unweighted N = 2803.

values indicating a superadditive risk were found for the risk of physical injury for those with a PP vulnerability combined with inadequate ES (RR 1.50, 95% CI: 1.13–2.00) and for any type of OHS vulnerability combined with inadequate ES (RR 1.53, 95% CI: 1.16–2.02).

## 5. Discussion

The purpose of this study was to examine if inadequate ES is associated with an increased risk of injury; if inadequate ES and OHS vulnerability are independently associated with injury

**Table 3**

Injury outcomes according to combinations of employment standards adequacy/inadequacy and occupational health and safety protection/vulnerability N = 2,813\*

Level of ESA and OHS protections	Overall		Physical injury			Mental injury			Injury requiring time off work		
	N	%	N	%†	p	N	%†	P	N	%†	p
Policy and Procedures (PP)											
ES adequate, PP protected	1649	58.6	172	10.4	<.0001	155	9.4	<.0001	145	8.8	<.0001
ES inadequate, PP protected	432	15.4	82	19.1		85	19.6		73	16.8	
ES adequate, PP vulnerable	429	15.3	112	26.2		107	24.9		104	24.3	
ES inadequate, PP vulnerable	303	10.8	146	48.4		123	40.6		102	33.7	
Awareness (AW)											
ES adequate, AW protected	1858	66.1	221	11.9	<.0001	196	10.5	<.0001	187	10.0	<.0001
ES inadequate, AW protected	559	19.9	141	25.2		121	21.7		101	18.1	
ES adequate, AW vulnerable	220	7.8	64	28.9		66	30.2		63	28.6	
ES inadequate, AW vulnerable	176	5.9	88	50.2		86	49.1		74	41.8	
Empowerment (EM)											
ES adequate, EM protected	1691	60.1	160	9.4	<.0001	150	8.9	<.0001	141	8.4	<.0001
ES inadequate, EM protected	419	14.9	81	19.4		78	18.7		64	5.3	
ES adequate, EM vulnerable	387	13.7	124	32.2		112	28.9		108	28.0	
ES inadequate, EM vulnerable	316	11.2	148	46.7		129	40.9		111	35.0	
All											
ES adequate, ALL protected	1462	52.0	126	8.6	<.0001	119	8.1	<.0001	108	7.4	<.0001
ES inadequate, ALL protected	333	11.8	50	14.9		60	18.0		45	13.6	
ES adequate, ALL vulnerable	616	21.9	158	25.7		143	23.2		141	22.9	
ES inadequate, ALL vulnerable	402	14.3	179	45.6		148	36.7		129	32.2	

CI, confidence interval; ES, employer failed to pay wages and/or no regular payday and/or work 5 or more hours without a break and/or no paid vacation, and/or no paid sick leave; ESA, Employment Standards Act; OHS, occupational health and safety; RR, relative risk.

\* % column 1 with outcome.

† weighted to age and sex of labour force of each province; unweighted N = 2803.

**Table 4**  
Adjusted\* log-binomial models examining the relationship between combinations of employment standards adequacy/inadequacy and OHS protection/vulnerability and injury outcomes

Policy and procedure (PP) vulnerability	Physical injury/illness		Mental injury/illness		Injury required time off	
	RR	95% CI	RR	95% CI	RR	95% CI
ES adequate, PP protected	ref.		ref.		ref.	
ES inadequate, PP protected	1.90	1.49–2.42	2.14	1.68–2.73	1.98	1.52–2.57
ES adequate, PP vulnerable	2.39	1.93–2.96	2.76	2.20–3.45	2.73	2.17–3.44
ES inadequate, PP vulnerable	4.43	3.67–5.35	4.65	3.79–5.70	3.90	3.11–4.89
<i>Synergy index</i>	1.50	1.13–2.00	1.26	0.95–1.67	1.07	0.78–1.47
<b>Awareness (AW) vulnerability</b>						
ES adequate, AW protected	ref.		ref.		ref.	
ES inadequate, AW protected	2.18	1.81–2.64	2.11	1.71–2.59	1.84	1.47–2.30
ES adequate, AW vulnerable	2.30	1.80–2.93	2.66	2.08–3.40	2.66	2.06–3.44
ES inadequate, AW vulnerable	3.97	3.27–4.82	4.60	3.76–5.63	4.03	3.22–5.05
<i>Synergy index</i>	1.20	0.88–1.63	1.30	0.96–1.76	1.21	0.85–1.73
<b>Empowerment (EM) vulnerability</b>						
ES adequate, EM protected	ref.		ref.		ref.	
ES inadequate, EM protected	2.18	1.71–2.78	2.19	1.70–2.81	1.93	1.46–2.54
ES adequate, EM vulnerable	3.27	2.66–4.03	3.42	2.75–4.27	3.34	2.66–4.19
ES inadequate, EM vulnerable	4.86	4.01–5.88	4.84	3.95–5.93	4.26	3.41–5.32
<i>Synergy index</i>	1.12	0.88–1.43	1.06	0.82–1.38	1.00	0.75–1.34
<b>ALL vulnerability types</b>						
ES adequate, ALL protected	ref.		ref.		ref.	
ES inadequate, ALL protected	1.82	1.34–2.48	2.29	1.72–3.05	1.91	1.38–2.64
ES adequate, ALL vulnerable	2.86	2.30–3.55	2.98	2.38–3.74	3.15	2.49–3.98
ES inadequate, ALL vulnerable	5.11	4.17–6.27	4.83	3.89–6.00	4.59	3.63–5.81
<i>Synergy index</i>	1.53	1.16–2.02	1.17	0.90–1.53	1.18	0.87–1.58

\* Adjusted for education, and using propensity scores which account for gender, age group, workplace size, employment relationship, industry, and full time/part time status, weighted to age and sex distribution of each province; CI = confidence interval; OHS = occupational health and safety; RR = relative risk; ES = employer failed to pay wages and/or no regular payday and/or work 5 or more hours without a break and/or no paid vacation, and/or no paid sick leave.

outcomes; and if the combination of OHS vulnerability plus inadequate ES have synergistic (or super-additive) effects on three injury outcomes. Our study shows that inadequate ES increases the risk of physical and mental injuries in the workplace and increases risk of time off work due to those injuries. As well, different types of OHS vulnerability (PP, AW, EM, and all types combined) increased the risk of the workplace injury outcomes. When workers experience inadequate ES *plus* OHS vulnerability, the risk of injury outcomes increases further; in all cases the risk is greater than the risk posed by inadequate ES or OHS vulnerability by themselves. This suggests in some situations these risks are not simply additive, as sometimes assumed with global measures of labour market precarity or vulnerability.

Our results supplement the literature which established a relationship between workplace hazards and inadequate workplace protections [5] by adding employment legislation or regulation that is separate from OHS regulation or legislation, namely the employer responsibility to ensure workers are regularly paid, paid what they are due, have the breaks they are entitled to, along with paid vacation and sick time, and demonstrating an approach to assess the independent and combined effects associated with both exposures. Employers may elect to implement policies and practices that impact the risk for workplace injury posed by OHS vulnerability [16]. This paper and others demonstrate that there are other factors that can worsen the relationship between OHS vulnerability and risk of injury. Although in our sample, only 14% of the participants vulnerable for OHS on the overall measure also had inadequate ES, of this 14%, almost half (46%) had a physical injury in the previous 12 months. That is, for individuals with both risk factors, the chance of injury is greater than what happens when an individual only has one risk; and in some cases the relationship is synergistic. Although based on a small number of injuries, the trend shows that policies and programs to increase the adequacy of ES,

such as regular paydays, full payment, breaks, and paid sick and vacation time may also protect workers from the risk of injuries and illnesses posed by OHS vulnerability.

As noted in the introduction, there are scales of precarious employment in the research literature which typically combine both OHS vulnerability and ES vulnerability [8,17] This paper adds to the body of research by exploring the relationship between the two types of vulnerability and their synergistic effects on health outcomes and shows that they are different concepts and there is information to be gained by examining them separately.

The changes in the traditional work relationship have eroded the provision of breaks, sick time, and other entitlements and have real health consequences for workers [18]. A recent systematic review found that for workers, dimensions of precarious employment, which include holding multiple jobs, being a temporary worker, or being a subcontractor, are associated with occupational injuries [17], and it has been reported that shift work and a short turn around between shifts are associated with a greater risk of injury [19]. Our findings suggest that inadequate ES combined with OHS vulnerability is likely to put workers at greater risk for work-related injury and illness, likely related to the increase in precarious or temporary work [8]. The individual risk factors examined here combine with other risk factors in negative ways, and the results suggest that simple changes, such as the provision of frequent breaks can have an impact.

Previous studies have examined elements of ES. For example, it has been shown that the relative risk of injury in the last hour of a shift than in the first half hour is significantly greater [20], that rest breaks are important in lowering the risk of injury among workers, that sick time decreases the likelihood of nonfatal workplace injuries [21], and that the introduction of sick leave can lead to a reduction in occupational injuries and illnesses [22]. After a rest break, it has been found that the risk of injury is returned to the

baseline level [23,24], and a recent study from the United States found that employees with paid sick leave through work had lower hazards of all-cause mortality and that it is protective against injuries [25]. A recent systematic review and meta-analysis found that work schedule, closely allied with the ES examined here, has an important impact on the risk of injury. It found that, compared to morning shifts, the risk of injury increased slightly on afternoon/evening shifts, and significantly on night shifts (compared to morning shifts), that the risk of injury increased with shift length, that risk decreased with the provision of breaks, and that risk increased with time working, in comparison with the first 30 minutes [23]. The review developed a risk index for workplace injury according to workplace schedule, with the greatest risk when rest breaks are too short, are not frequent enough, when shifts are too long, and when work takes place at night and proposes that, using this knowledge, hazards can be evaluated and safety maximized [23]. In our study, where the importance of ES is disentangled from OHS vulnerability, all injury outcomes showed a significant difference between those who have regular meal breaks and those who do not, and that the right to paid vacation and paid sick leave also had a significant difference for physical injury between those who had and did not have this right. This study adds further weight to the risk index, described above, and suggests the importance of simple scheduling adjustments in the prevention of workplace injury [23].

As the Covid-19 pandemic has revealed, ES and OHS are fluid concepts. The location of work, sources of injury risk, maintenance of work-life balance, and ES in a home office all have implications for worker health [26]. The flexible arrangements that employers benefit from are not the same as those that benefit workers [26]. Although this cross-sectional study was not undertaken during a period of economic slowdown, the subsequent Covid-19 pandemic likely magnified the importance of ES and warrants further investigation. During the pandemic, the impact of precarious and part-time employment on the health of workers in long-term care, and among workers who did not have access to sick leave became a major concern [27]. While in previous periods of economic slowdown, a decrease in occupational injuries occurred, thought to be because the most experienced workers remained employed [28], it is possible the impact of the current pandemic may differ. How ES and other protections apply to the workforce and work-related injury and illness post-pandemic is a topic of further research.

Interpretation of results of this study should account for important strengths and limitations. It is a limitation that the data were collected from a cross-sectional study based on personal perceptions of risk and injury, i.e., the results have not been objectively validated. Objective validation would require linkage with workplace safety insurance board (WSIB) administrative data, which is both costly and problematic because a large percentage of workplace injuries are not reported to workplace insurance in Canada [29]; therefore, the authors did not undertake linkage. The questions about ES have not been validated, which is another limitation. The ES questions are simply worded, have face validity and ask about standard practice in Canada. The sample of workers collected is large; however, it is comparatively older than the Canadian labour market. To address this, we recalibrated our sample to the age and sex distribution of the labour force in each province. The sampling method excluded those working less than 15 hours a week, the self-employed, and those in workplaces with fewer than five employees, which was balanced by including a range of occupational categories, workplace sizes, and employment relationships. While the low response rate and use of an existing survey panel might limit the generalizability of the research findings, in earlier analyses the responses collected by RDD were compared with those given by panel respondents, and no meaningful

differences were observed between groups [30]. Possibly those who had a workplace injury remembered their hazards and protections differently than those without injury, a limitation of cross-sectional studies. As such, we recommend that longitudinal studies be conducted to replicate these findings. Furthermore, this limitation is potentially less likely to impact the relationship between ES and work injury outcomes. A strength of this study is the novel examination of the interplay between OHS risk factors and ES.

## 6. Conclusions

This study contributes to the literature by identifying opportunities to for integrated approaches to reduce workplace injury risk. Here we have disentangled the risk of injury from a lack of basic employment standards (which are having a regular payday, being paid wages that are due, having regular breaks, sick and vacation time) from other OHS risk factors. When inadequate ES and OHS vulnerability are both present, the increased risk of injury is the sum (or greater) of the risk of each alone, and in some cases the risk is even greater (super-additive). Having an employer who pays wages that are due, when they are due, and ensures they are having regular breaks, vacation, and sick time can reduce the odds of staff being injured, even in cases when staff experience OHS vulnerability. In workplaces when it is difficult to decrease the vulnerability of workers, regular pay, breaks, and paid time off when sick or for vacation are important ways to prevent workplace injury and illness.

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## Conflicts of interest

All authors have no conflicts of interest to declare.

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