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RESEARCH ARTICLE

Occupational Injury and Suicide in Washington State, Adjusting for Pre-Injury Depression

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ABSTRACT

Introduction: Occupational injuries have been associated with increased suicide mortality, but prior studies have not accounted for pre-injury depression.

Methods: We linked injuries that occurred from 1994 to 2000 in the Washington State workers' compensation system with Social Security Administration data on earnings and mortality through 2018. We estimated the subdistribution hazard ratio (sHR) and 95% confidence interval using competing risks regression of suicide deaths with lost time compared with medical-only injuries separately for men and women, adjusting for age, pre-injury annual earnings, and industry. We further adjusted for pre-injury diagnosis of major depressive disorder by using a quantitative bias analysis (QBA), with the prevalence of this disorder in workers derived from an external health insurance claims data set.

Results: Elevated suicide mortality was observed following lost-time injuries compared with medical-only injuries for men (sHR = 1.49, 95% CI [1.14, 1.93]) and women (sHR = 1.30, 95% CI [1.00, 1.69]), adjusting for age, pre-injury earnings, and industry. Adjusted for pre-injury depression using a QBA, elevated suicide risk in men remained statistically significant (median sHR = 1.33, simulation interval [1.18, 1.47]) but not for women.

Discussion: Workplace injury requiring time off work appeared to remain influential in increasing suicide risk among men, even after controlling for pre-injury depression. The relationship between mental health before and after occupational injury is complex and studies should better integrate mental health pre-injury.

Conclusions: Though many questions remain on the complex relationship between work, depression, injuries, and suicide, employers should work to prevent injuries and consider implementing mental health programs, which could be helpful in reducing suicide risk.

1 | Introduction

The Surgeon General of the US issued a call to action on suicide prevention in 2021 [1], though the unfortunate increase in the United States has continued as the number of suicides in 2022 was the highest ever recorded [2]. There is a need to understand the full range of factors that contribute to suicide risk, and how the workplace may influence suicide mortality has not been fully explored.

Workplace injuries can have significant consequences for individuals, including loss of income [3–5] and job insecurity [6]. Moreover, nonfatal workplace injuries may lead to permanent disability [7, 8], poorer quality of life [9], and elevated long-term mortality [10–14]. Injured workers may be at increased risk for subsequent depression, though it is uncertain if this may differ by gender [15–18].

In particular, nonfatal workplace injuries have been associated with increased risk of suicide, and studies in the United States have begun to examine this relationship by gender. For example, in a study based in New Mexico, we reported that, for both men and women, those with lost-time injuries, which is compensation for an injury, generally defined as workers' compensation payment for time off of work in addition to reimbursement for medical expenses, were at increased risk of suicide relative to those whose compensation was for medical expenses alone [19]. A study in West Virginia detected an elevated standardized mortality ratio for suicide for men who experienced lost-time lower back injuries compared with the general population, while no association was detected for women [14].

Analyses conducted outside of the US also support a relationship between experiencing a work injury and subsequent suicide. In Korea, both men and women who received compensation for a work injury had a higher suicide risk compared with the general population. In Taiwan, compensation for a permanent occupational disability of the upper or lower extremities was associated with suicide, though this study did not present results separately by gender [20]. However, countries outside of the US may experience different background injury rates at work than the US, so more studies in the United States, specifically, are needed.

Another challenge in prior studies of workplace injury and suicide was that the data sources typically were missing information on potential confounding variables, such as pre-injury depression. In earlier analyses of overall mortality following workplace injury (comparing those with lost-time to those with medical-only injuries), we used a quantitative bias analysis (QBA) to adjust for missing pre-injury confounders for general health [21, 22]. In the present analysis, we similarly applied a QBA, this time to control for pre-injury major depression in our investigation of workplace injury and suicide mortality. Our objective was to estimate the risk of suicide mortality among workers who experienced lost-time injuries relative to workers who experienced medical-only injuries in Washington State, after using external data for pre-injury depression. We present results separately for men and women.

2 | Methods

2.1 | Washington State Workers' Compensation Data

We used the same methods for identifying injured workers and assessing follow-up mortality as described in earlier studies [13, 19, 22]. The Washington State Department of Labor and Industries provided workers' compensation data, including worker, employer, injury, and benefit characteristics. Our study population consisted of workers aged 15−80 years old who received workers' compensation benefits for injuries occurring from 1994 through 2000. This study population was chosen to allow for a long follow-up period and for comparability with previous research.

Injured workers in Washington who experienced > 3 days off work or experienced a permanent disability received cash benefits for lost earnings in addition to full coverage for medical expenses. For the present study, we defined these workers as our exposed group, which we refer to as the "lost-time" injured. The comparison group was "medical-only" injured workers who experienced 3 or fewer days lost from work. Workers with medical-only injuries received reimbursement for medical expenses but they did not receive lost earnings. For workers with one or more injuries in the study period, our analysis used the first injury. We excluded from the sample workers whose injuries were classified as fatal [22].

2.2 | Mortality Data

We linked the workers' compensation data and social security earnings and mortality data through December 31, 2018, based on name, date of birth, sex, and social security number, successfully linking more than 95% of the total sample [22]. In addition, we used the Social Security Administration's (SSA's) Vital Status System (the internal staff version of SSA Service to Epidemiological Researchers) to categorize vital status as dead, alive, and unknown and to determine the date of death [23]. Our primary data set consisted of an exposed group of 236,905 persons with lost-time injuries and a nonexposed group of 496,694 persons with medical-only injuries.

As we previously reported [21], it was cost-prohibitive to match our complete study sample to the National Death Index (NDI) for the full observation period. Therefore, we took stratified random samples of injured workers within SSA vital status categories (e.g., SSA classified as alive, unknown, or dead) and linked them with the NDI, which addressed two issues. First, having results on whether alive/dead for both SSA and NDI data allowed us to confirm the SSA vital status as of December 2018 for the alive, unknown, and death cases. We were able to link 97.5% of a random sample of 17,000 deaths, stratified by gender and by lost-time versus medical-only and classified as dead by the SSA. We also sent 1600 workers identified by SSA as alive or having unknown vital status to test the reliability of the SSA status. Only 0.7% of 600 workers classified as having unknown vital status and none of 1000 workers classified as alive by the SSA were identified as deceased in the NDI data. This led us to treat as alive all observations classified as

unknown or alive by the SSA. Our analysis sample consists of these observations combined with sampled unknown and alive observations validated as alive by NDI and the 16,571 (of 17,000) observations considered dead by both the SSA and NDI. The final data set has 669,689 individuals which, when weighted by the inverse of their sampling probabilities, represents 733,599 injured workers. The second issue the NDI link allowed us to address was the cause of death. The SSA data do not include the cause of death, which could only be obtained from NDI. This study focuses on suicide mortality, which we categorized using the International Classification of Diseases (ICD) codes for self-harm: ICD10: U03, X60–X84, Y87.0, and Y10–Y33; ICD9: E950–E959, and E9800–E9899.

2.3 | External Data Set for Pre-Injury Depression of Injured Workers

We do not know pre-injury depression status for workers in our Washington State data set. Had pre-injury major depression been available in the data, we would have adjusted for it directly in our regression models. In the absence of that data, we turned to use QBA, which is a set of methods that relates the observed data to what the results would have been had a potential source of bias, in this case, unmeasured pre-injury major depression, not been absent [24].

To assess the association between occupational injury (lost-time vs. medical-only injury) and suicide mortality adjusted for potential confounding by pre-injury major depression, we needed two pieces of information for the QBA: an estimate of the association between pre-existing major depression and death from suicide and a measure of the impact of major depression on injury. There was not an appropriate external data set that provided both of these estimates, an issue we encountered in a prior QBA and addressed by using appropriate estimates from two separate external sources [22]. In the present analysis, we applied a similar approach of using two external sources. For estimates of the association between major depression and death from suicide by gender, we obtained estimates from a meta-analysis covering studies from 1994 through 2018 that estimated the relative risk of suicide mortality among those with pre-existing major depression (described in section 2.4).

Prior publications did not provide the information we would need for a QBA. Necessary estimates of prevalence of clinically diagnosed major depression among those with workers' compensation lost-time and medical-only injuries were unavailable because depression was not clinically diagnosed, the injuries were not in the workplace [25, 26], or the injuries may not have been severe enough to be representative of a lost-time injury [17]. Given the difficulty of applying results from published studies, we found a microdata resource that would allow us to estimate this relationship for both men and women. We used the Merative MarketScan Research Commercial Claims and Encounters (CCAE) and Health and Productivity Management (HPM) databases to determine the prevalence of pre-injury major depression among men and among women with lost-time and medical-only injuries. The Merative MarketScan databases have been constructed and maintained by IBM from over 250 medium and large employers and health plans throughout the US. The data were fully compliant with the Health Insurance Portability and Accountability Act (HIPAA), and no Institutional Review Board approval was necessary because individual patients were not identifiable within the data [27]. The CCAE database had several data files that included medical diagnosis codes (International Classification of Diseases, 9th Revision, or ICD-9 codes). The HPM database contained workers' compensation information including the date of injury and medical and indemnity payments. In this MarketScan study, we used the 2004–2010 CCAE and HPM data, which were close to the dates of injury in our Washington State data, to identify those who experienced workplace lost-time injuries or medical-only injuries. To determine the prevalence of depression, we examined whether injured workers had a major depressive disorder in the 12 months before injury. We considered the following ICD-9 codes to measure major depression: 296.20–296.29 and 296.30–296.39. Below, we provide more detail about how these were used for the QBA.

2.4 | Statistical Analysis

We examined summary statistics for workers in the Washington State analysis data set. We generated percentages at baseline, weighted by inverse sampling probabilities, for the distribution of age at injury, pre-injury annual earnings, and industry for workers with lost-time injuries and medical-only injuries, separately for men and women.

We determined the duration of follow-up for each worker, with follow-up beginning at the date of injury and continuing until the date of death or December 31, 2018 (the end of follow-up), whichever occurred first. We calculated the median years of follow-up and interquartile range (IQR) by injury type (lost-time, medical-only) and gender. We also calculated the number of suicide deaths (and percentage) observed in each combined injury type and gender category.

For this analysis, we have competing risks of death. In other words, workers could die of another cause before a potential suicide. In this situation, the Kaplan–Meier estimator for standard survival analysis is inappropriate because it assumes the marginal probability of the outcome of interest is independent of any competing cause of death and leads to biased estimates for the marginal probabilities of cause-specific mortality. Therefore, we use an alternative approach, Fine and Gray competing risks regression [28]. This approach models a subdistribution hazard, which is derived from modeling the effects of covariates on a cumulative incidence function (CIF). The CIF estimates the probability of death as a function of its cause-specific probability and overall survival probability. For the present analysis, we estimated subdistribution hazard ratios (sHRs) and 95% confidence intervals (CIs) for the association between lost-time injuries and suicide. This approach estimates the hazard of an event due to a specific underlying cause after accounting for previously occurring deaths from all other causes.

Separate estimates were generated for men and women, controlling for earnings category and industry at baseline. We stratified by age category to account for non-proportional

hazards by age. We weighted all analyses by inverse sampling probabilities.

We first estimated the association between pre-injury major depression and medical-only and lost-time injuries categories in the external MarketScan data set. We conducted a probabilistic QBA [24] in which we adjusted the observed Washington data to account for an unmeasured confounder, pre-injury major depression. QBA is a set of methods which relates the observed data to what the results would have been had a key source of bias, in this case pre-injury major depression, not been absent. Had this potential confounder been available in the Washington State data, we would have adjusted for it directly in our regression models. Instead, to simulate the unmeasured confounder, we required three pieces of information for the bias parameters: (1) the strength of the effect of pre-injury major depression on suicide mortality; (2) the estimated prevalence of pre-injury major depression among those with lost-time injuries; (3) the estimated prevalence of pre-injury major depression among those with medical-only injuries. With these three pieces of information, we could then simulate a 2×2 table relating lost-time injury to suicide mortality stratified by pre-injury depression. We used this 2×2 table to calculate the probability of having the unmeasured confounder within levels of lost-time injury and mortality. We then used these probabilities to simulate the unmeasured confounder in our Washington data set by conducting a Bernoulli trial for each person in the data set with a probability of returning a 1 equal to the probability calculated in the previous step, contingent on the lost-time injury and mortality status. For the QBA, we modified the SAS QBA program in Fox et al. [29] to apply to competing risks regression.

The first piece of information needed for the QBA, the association between pre-injury major depression and suicide, we obtained from a published meta-analysis. Moitra et al. [30] reported relative risks of 7.78 (95% CI 4.34, 13.93) for men and 7.51 (95% CI 4.18, 13.51) for women for the association of major depression and suicide mortality. We used these estimates to simulate the suicide mortality relative risk for major depression in the QBA. The next two pieces of information for the QBA, prevalence of pre-injury major depression among those with lost-time injuries and with medical-only injuries, came from the MarketScan data. We identified 68,291 men and 31,243 women who experienced lost-time or medical-only injuries. Lost-time injured workers differed from medical-only injured workers by gender, age, and industry in the MarketScan data. We used one-to-one nearest-neighbor propensity score matching on age, industry, and year of injury, without replacement to match medical-only to lost-time cases within gender. This gives us a similar distribution of confounders for both injury groups for the prevalence of major depressive disorder. Our propensity-score-adjusted estimates of the probability of pre-injury major depression are described in the Results.

The values we used in the QBA were themselves measured with random error and may not perfectly apply to our population. Instead of conducting a single (simple) bias analysis, we put distributions around the bias parameters to represent our uncertainty in the estimation of the parameters. For our base QBA, we used beta distributions with mean pre-injury major depression percentages derived from the MarketScan estimates. We used trapezoidal distributions to approximate the mortality relative risks from the Moitra et al. meta-analysis.

Having specified the distributions for the bias parameters, we then conducted a probabilistic bias analysis using Monte−Carlo simulations to repeatedly sample from the estimated bias parameter distributions. We generated 10,000 simulations of pre-injury depression prevalence and then calculated sHRs for the association between lost-time injury and mortality adjusted for simulated pre-injury depression and measured covariates (age, earnings, and industry). Running many iterations of QBA regressions allows us to obtain a distribution of adjusted hazard estimates. With available computing resources, it would have taken several weeks to run 10,000 QBA iterations on SSA mainframe computers, with the risk of losing our work if the computer was shut down for activities such as routine maintenance. Therefore, to reduce the time to run the QBA, we randomly sampled 25,000 each of the four groups with alive or unknown status (women medical-only, women lost-time, men medical-only, and men lost-time). Thus, the data set used in the QBA consisted of 100,000 living and 16,571 dead injured workers, which, when weighted by the inverse of their sampling probabilities, represents 653,762 living and 79,837 dead injured workers. We summarized this distribution using the median as a point estimate and the 2.5th to 97.5th percentile of the distribution as a 95% simulation interval to compare to our conventional analysis and 95% CI.

We then analyzed the sensitivity of our results to the major pre-injury depression estimates from the MarketScan data. We repeated the QBA, doubling these major depression prevalence estimates. We used Stata 16 for the study sample descriptive statistics and the MarketScan estimates of pre-injury major depression. We used SAS 9.4 for the survival analysis, including the QBA.

Though the primary objective of the present research was to compare the risk of suicide mortality for those with lost-time injuries to those with medical-only injuries after adjusting for pre-injury depression, we were also interested in understanding more about the pattern of suicide within characteristics of age, earnings, and industry, including which groups exhibited the greatest risk. In addition, we wanted our analyses to be informative and easily compared with other study populations. Therefore, we generated incidence rates within categories of the three characteristics (age, industry, pre-injury earnings). Neighboring categories of age and earnings were collapsed to allow for sufficient case numbers when estimates between categories were similar. We also generated sHRs and 95% CIs, both crude and adjusted, using the youngest age category and the highest income category as the reference. For industry, men and women exhibited different risks of suicide by industry and therefore, we chose the industry that would serve as the reference category within gender based on having enough cases and person-time and having a relatively low rate of suicide. For men, Nondurable Manufacturing was the reference group and for women, the reference group was Law, Education, and Social Services. Lastly, looking within strata of age, pre-injury earnings, or industry (covariates available in the data), we generated the sHRs and 95% CIs to estimate the association between lost-time injury and suicide within each stratum. We describe the results for industry strata in the Results section. The rest is in the Supporting Information Material.

TABLE 1 | Study population characteristics, Washington state workers compensation, 1994 through 2000.

Baseline characteristics	Men		Women	
	Lost-time injury $N^a = 152,378$	Medical-only injury $N^a = 308,310$	Lost-time injury $N^a = 84,527$	Medical-only injury $N^a = 188,385$
Age (years), %				
< 25	14.6	26.6	12.2	23.3
25–34	27.0	30.7	22.9	26.0
35–44	28.2	23.6	31.6	25.8
45–54	19.0	13.4	23.4	18.0
55–64	10.0	5.0	8.8	6.1
65+	1.3	0.7	1.2	0.9
Annual pre-injury earnings (2007$), %				
Less than $10,000	19.5	24.8	27.2	31.2
$10,000–$19,999	16.1	16.9	24.3	22.9
$20,000–$29,999	15.5	15.7	19.4	17.7
$30,000–$39,999	14.4	13.0	12.8	11.8
$40,000–$49,999	12.6	11.0	7.3	7.1
$50,000–$59,999	9.4	7.7	4.3	4.2
$60,000–$70,000	6.2	4.8	2.7	2.7
$70,000+	6.4	6.3	2.0	2.4
Industry, %				
Agriculture, forestry & fishing	4.4	4.2	2.3	2.4
Mining	0.5	0.3	0.0	0.0
Nondurable manufacturing	11.4	9.4	5.8	4.9
Durable manufacturing	12.0	12.4	6.8	5.5
Transportation	10.2	6.0	5.5	3.3
Wholesale	6.9	7.5	3.4	3.5
Finance, insurance & real estate	1.3	1.7	2.8	3.5
Services	8.3	10.2	10.0	9.9
Health	1.8	2.4	17.0	16.1
Government	6.1	4.9	4.8	4.3
Construction	19.2	16.2	1.8	1.7
Retail	13.2	19.6	25.2	28.4
Law, education & social services	4.7	5.3	14.6	16.5
Characteristics, end of follow-up				
Years follow-up, median (IQR)	20.8 (3.9)	20.9 (3.8)	20.8 (3.8)	20.8 (3.7)
Suicide deaths,[a] *n* (%)	1167 (0.77)	1625 (0.53)	223 (0.26)	391 (0.21)
Years between injury & suicide, median (IQR)	13.2 (12.0)	15.4 (12.2)	14.9 (9.8)	13.3 (11.2)

Abbreviation: IQR = interquartile range.
[a]Weighted to account for sampling of deaths. Subsamples do not add to 733,599 due to rounding of the weighted figures.

3 | Results

The distribution of characteristics at baseline for the Washington State workers' compensation data is provided in Table 1. Those with lost-time injury tended to be older than those with medical-only injury, a pattern observed for both men and women. The percentage of pre-injury annual earnings less than $10,000 was higher in the medical-only injury category, for both men and women. Transportation made up a higher percentage of the lost-time injury than medical-only injury for both men and women. The most represented industries among men, regardless of type of workers' compensation were Construction,

TABLE 2 | Association between lost-time injury and suicide in Washington State 1994 through 2018.

	Suicide deaths[a] *n*	At-risk person-years[b] per 100,000	Crude rate[c]	sHR[d] (95% CI)
Men				
Medical-only injury	1625	63.1	25.74	Reference
Lost-time injury	1167	30.5	38.29	1.49 (1.14–1.93)
Women				
Medical-only injury	391	38.7	10.10	Reference
Lost-time injury	223	17.2	12.96	1.30 (1.00–1.69)

Abbreviations: CI = confidence interval; sHR = subdistribution hazard ratio.
[a]Weighted to account for sampling of deaths.
[b]At-risk person-years weighted to account for sampling.
[c]Weighted rates per 100,000 person-years.
[d]Direct adjustment for age, pre-injury earnings, and industry.

TABLE 3 | Percentage of injured MarketScan population with pre-injury major depressive disorder.

	Men		Women	
	Lost-time	Medical-only	Lost-time	Medical-only
Full sample, %	1.77	1.76	3.90	3.43
Propensity score matched sample,[a] %	1.77	0.38	3.90	2.37

[a]We used a 1-to-1 matching of medical-only injuries to lost-time injuries within gender with propensity scores based on age, industry, and year of injury.

Retail, Durable and Nondurable Manufacturing, and Transportation. Among women, Retail made up a quarter of the study population, followed by Health and Law/Education/Social Services. Mining had very low representation in men and none in women. The percentage of suicide deaths among men with lost-time injuries was 0.77% and with medical-only injuries was 0.53%. For women, those percentages were 0.26% and 0.21%, respectively.

We examined the association between suicide and lost-time injury adjusted for age, pre-injury earnings, and industry (Table 2). Among men, there was an approximately 50% increased subdistribution hazard suicide rate among those with lost-time injury compared with medical-only injury (95% CI 1.14, 1.93). For women, there was a 30% increased subdistribution hazard rate (95% CI 1.00, 1.69).

The sHRs in overall models in Table 2 lacked adjustment for pre-injury depression. As described in the Methods section, a QBA requires adjusting for pre-injury depression in the Washington State workers' compensation data. To accomplish this, we first estimated the prevalence of pre-injury depression in those with lost-time injury and medical-only injury in the MarketScan data (Table 3). The propensity-score matched sample, matching on age, industry, and year of injury, yielded estimates of pre-injury depression of 1.77% in men with lost-time injury and 0.38% in men with medical-only injury. For women, the estimates were 3.90% and 2.37%, respectively.

After running 10,000 QBA regressions to generate a distribution of sHR estimates that adjust for pre-injury depression in the Washington State data, the median sHR for lost-time injury and suicide was attenuated for both men and women (Table 4). For men, the simulation interval excluded the null (median sHR = 1.33, simulation interval [1.18, 1.47]) while the simulation interval included the null for women (median sHR = 1.12, simulation interval [0.92, 1.33]). We performed a sensitivity analysis to accommodate for a potential underestimate of major depression in the MarketScan data. When we repeated the QBA after doubling the estimated major depression prevalence in both injury categories, the median sHR for men was 1.24 with a simulation interval of 0.99 to 1.43 and for women, the sHR was 1.07 (simulation interval of 0.76 to 1.86) (data not shown).

In the Supporting Information Material, we present additional results, including an examination of suicide within industry. In our brief summary here, we highlight results for industries that comprised at least 10% of the overall person-time for either gender (the parenthetical values in the third column of Supporting Information: Tables S1a and S1b). For men, we estimated a doubling in the sHR for suicide when comparing lost-time injury with a medical-only injury in Durable Manufacturing (sHR 1.95 95% CI [0.97, 3.92]) and Retail (sHR 1.94 95% CI [1.04, 3.59]) (Supporting Information: Table S2a). Among women, the suicide rate in those with lost-time injuries was twice that of the medical-only injuries in the Services industry (sHR 2.09 95% CI [1.03, 4.25]) (Supporting Information: Table S2b).

4 | Discussion

We observed an increased risk of suicide among those who experienced a lost-time injury compared to those with a medical-only injury after adjusting for age, pre-injury earnings, and industry for both men and women. After including the indirect adjustment for pre-injury depression using a QBA, the association was attenuated for both men and women. In men, the association remained elevated and for women the association was not statistically significant.

TABLE 4 | Association between lost-time injury and suicide in Washington State 1994 through 2018 with indirect adjustment for pre-injury depression.

		Simulation interval	
	Median sHR[a,b]	2.5th percentile	97.5th percentile
Men			
Medical-only injury	Reference		
Lost-time injury	1.33	1.18	1.47
Women			
Medical-only injury	Reference		
Lost-time injury	1.12	0.92	1.33

Abbreviation: sHR = subdistribution hazard ratio.
[a]Direct adjustment for age, pre-injury earnings, and industry and indirect adjustment for major depressive disorder.
[b]Median of 10,000 iterations using simulated pre-injury major depression.

For the indirect adjustment, information regarding the prevalence of major depressive disorder in the 12 months before injury came from the MarketScan data. This data set has several advantages, including that we could look at prevalence among employed persons and separately for those who experienced lost-time and medical-only injuries. We can compare our prevalence estimates with other studies. Hasin et al. [31] reported prevalence of major depressive disorder in the National Epidemiologic Survey on Alcohol and Related Conditions III (NESARC-III, years 2012−2013), which indicated the 12-month prevalence of major depressive disorder was 7.2% in men and 13.4% in women for a US noninstitutionalized population. The 2021 National Survey on Drug Use and Health (NSDUH) found that prevalence of major depressive disorder in the past year was 6.2% in males and 10.3% in women [32, 33]. Both studies were based on interviews that directly asked questions that allowed assessment of the disorder based on the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) [34]. However, these other sources likely include persons who may not be working, and experiencing unemployment has been associated with an increase in depression [35]; therefore, it is possible studies using general population estimates of depression may not be appropriate. Nonetheless, a limitation of our MarketScan data was it is based on medical diagnoses. It is possible that this underestimates major depression if some members of that population did not seek treatment. In particular, men are less likely to report depressive feelings and seek treatment [36, 37]. In addition, the MarketScan data set represents a population of large, self-insured employers and, therefore, this external data set may not represent the experience of major depressive disorder for other types of injured workers. When we performed a sensitivity analysis, assuming the prevalence estimates of major depressive disorder were twice as high as we had observed, the association was attenuated for men with the CI including the null and the association for women was notably reduced and not statically significant.

There are other challenges to consider in regard to controlling for depression when examining suicide. For example, our indirect adjustment was for major depressive disorder, but other mental health disorders, including bipolar disorder or anxiety disorder may also increase risk of suicide [30, 38]. While we used the QBA to control for pre-injury depression, the actual relationship between a workplace injury and subsequent suicide is likely more complex. Our underlying assumption in this analysis was that pre-injury depression increased risk of suicide and lost-time injury. However, we may need to consider if the true causal relationship involves no direct relationship between pre-injury depression and lost-time injury. Instead, perhaps lost-time injury may influence subsequent depression which is also influenced by pre-injury depression, which may itself be a risk factor for suicide. If we adjust for pre-injury depression, this would effectively block the direct effect of lost-time injury on suicide. Thus, although we do make an effort to control for pre-injury depression, we acknowledge that the relationship between injury, depression, and suicide has additional challenges that could be explored in future research. Other studies that present results with and without pre-injury depression, as we have done here, may provide additional insight since this relationship may differ across industries. Ideally, future studies that look to control for depression or mental health could have a more direct estimate for the primary study population.

We observed differences in suicide rates between men and women. Consistent with what has been reported previously in the United States, men had higher suicide rates than women (for both lost-time and medical-only injuries). Also, the association between lost-time injury and suicide appeared stronger for men. Unemployment and disability may influence suicide risk [39–41]. However, it is not clear that injured men suffer greater economic impacts than injured women. A study of Washington State injuries found that post-injury lost earnings as a proportion of pre-injury earnings were similar for men and women [42], and an earlier study in Wisconsin found that women had greater losses than did men [43]. On the other hand, the impact of similar levels of unemployment and disability on mental health may differ by gender. In a study that examined predictors of suicide among men and women, injuries (examined by location of injury) were found to be a predictor of suicide for men but not for women [41]. In our prior study which used a similar methodology to the present study but was based in New Mexico, the associations for men and women were similar to each other [19].

Another difference between men and women in the Washington State workers' compensation data was the distribution of

industries. It is possible that male and female workers may not be represented equally in those industries or that the types of jobs held and thereby the risk of more severe injury on subsequent employment may differ by gender. In other words, in this study population, it may be that we did not see a stronger association in women because perhaps women were not working in jobs where more severe injuries occur. In addition, industries may differ with respect to health insurance and job security, and that may, in turn, have an impact on mental health outcomes. In the Supporting Information Material, we provided industry-specific results on the relationship between lost-time injuries and suicide.

The timeframe for the injuries examined implies a tradeoff between relevance to current injury patterns and the length of time for follow-up. We chose 1996−2000 injuries for this study, which allowed for long follow-up. This longer follow-up meant better alignment with other studies. The choice of comparison group also involves tradeoffs. The comparison group for our study was workers with medical-only injuries in the workers' compensation data. While it might be assumed that a non-injured worker population would be the preferred comparison group and perhaps the relationship with lost-time injuries and suicide may be stronger, there may be concerns with respect to comparability. These may include whether non-injured workers have the same level of injury risk, access to workers' compensation, or insurance as those identified as injured.

Other factors may influence the relationship between lost-time injury and suicide. A recent paper described how chemical, physical, and psychosocial exposures as well as access to means of suicide at work may increase risk of suicide [44]. Also, workplace factors have been shown to influence mental health. Shift work, high job demand, low job control, effort-reward imbalance, job insecurity, bullying, and low social support in the workplace have been shown to be related to poor mental health [45, 46]. In addition, long-term mental health post-injury can be affected by repeated occupational injuries and unemployment [47]. Similarly, a work-related injury may increase job insecurity, which may increase suicidal ideation [44]. Moreover, filing a complaint with the workers' compensation system due to the work injury may increase stress and suicidality [44]. These point to a number of areas in which employers could develop strategies to intervene on contributors to poor mental health or to prevent injuries. In addition, the literature points to approaches, including offering mental health benefits, to reduce workplace-related suicide [45, 48].

Future research should emphasize prevention to mitigate suicide risk. More information on workers' perceptions about the work environment (e.g., to determine perceptions about job security and high-demand jobs), the role of the workers' compensation insurance process, and impact of different prevention programs would be useful to identify the most effective intervention strategies, which may differ by state and by industry. Attention to the impact of severity of injury could also be important to study as severity and disability may impact future earnings and well-being. Those with the most severe injuries may need additional types of support to better cope with life post-injury.

5 | Conclusions

An association between workplace injuries and suicide has a complex relationship with depression. Further research on injury, depression before and after injury, and suicide within a population of workers would be beneficial to understanding these relationships. Even before improving our understanding of those relationships, emphasis in practice should be on improving workplace safety and well-being to prevent depression and injury and to identify optimal programs among employers and insurers to support injured workers to mitigate suicide risk.

Author Contributions

Katie M. Applebaum: conceptualization, methodology, writing draft and revisions. **Abay Asfaw:** conceptualization, methodology, analysis and producing tables, writing revisions. **Paul K. O'Leary:** conceptualization, methodology, analysis, writing revisions. **Matthew P. Fox:** methodology, analysis, writing revisions. **Yorghos Tripodis:** analysis, writing revisions. **Andrew Busey:** analysis, writing revisions. **Jaimie L. Gradus:** interpretation, writing. **Leslie I. Boden:** funding acquisition, conceptualization, methodology, writing revision.

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Ethics Statement

The Boston University Medical Center Institutional Review Board (number H-32401) and the Washington State Institutional Review Board (number D-110618-L) approved this study. Data use agreements have been signed by Boston University and the Social Security Administration for the use of data from the National Center for Health Statistics, and the Washington State Department of Labor and Industries. This study did not involve informed consent as a waiver was granted by the Boston University Medical Center Institutional Review Board.

Data Availability Statement

US Social Security Administration data are not available for non-SSA employees. Washington State workers' compensation data may be available with a data use agreement and approval by the Washington State Institutional Review Board. National Death Index data are available upon approval by the NDI.

References

1. "The Surgeon General's Call to Action to Implement the National Strategy for Suicide Prevention," Office of the Surgeon General," 2021, https://www.hhs.gov/sites/default/files/sprc-call-to-action.pdf.

2. S. Curtin, M. Garnett, and F. Ahmad, *Provisional Estimates of Suicide by Demographic Characteristics: United States, 2022. Vital Statistics Rapid Release*, Number 034 (Centers for Disease Control and Prevention, 2023), https://www.cdc.gov/nchs/data/vsrr/vsrr034.pdf.

3. L. I. Boden and M. Galizzi, "Ecnomic Consequences of Workplace Injuries and Illnesses: Lost Earnings and Benefit Adequacy," *American Journal of Industrial Medicine* 36, no. 5 (1999): 487–503.

4. R. T. Reville, "The Impact of a Disabling Workplace Injury on Earnings and Labor Force Participation," *Creation and Analysis of Employer-Employee Matched Data* 241 (1999): 147–173.

5. C. Woock, "Earnings Losses of Injured Men: Reported and Unreported Injuries," *Industrial Relations: A Journal of Economy and Society* 48, no. 4 (2009): 610–628.

6. J. M. Sears, B. A. Schulman, D. Fulton-Kehoe, and S. Hogg-Johnson, "Workforce Reintegration After Work-Related Permanent Impairment: A Look at the First Year After Workers' Compensation Claim Closure," *Journal of Occupational Rehabilitation* 31 (2020): 1–13.

7. R. T. Reville and R. F. Schoeni, "The Fraction of Disability Caused at Work," *Social Security Bulletin* 65, no. 4 (2003): 31–37.

8. P. O'Leary, L. I. Boden, S. A. Seabury, A. Ozonoff, and E. Scherer, "Workplace Injuries and the Take-Up of Social Security Disability Benefits," *Social Security Bulletin* 72, no. 3 (2012): 1–17.

9. L. Strunin and L. I. Boden, "Family Consequences of Chronic Back Pain," *Social Science & Medicine* 58, no. 7 (2004): 1385–1393.

10. J. J. Ho, J. S. Hwang, and J. D. Wang, "Life-Expectancy Estimations and the Determinants of Survival After 15 Years of Follow-Up for 81 249 Workers With Permanent Occupational Disabilities," *Scandinavian Journal of Work, Environment & Health* 32, no. 2 (2006): 91–98.

11. H. Scott-Marshall and E. Tompa, "The Health Consequences of Precarious Employment Experiences," *Work* 38, no. 4 (2011): 369–382.

12. S. H. Lin, H. Y. Lee, Y. Y. Chang, Y. Jang, and J. D. Wang, "Estimation of Life Expectancies and Loss-of-Life Expectancies for Workers With Permanent Occupational Disabilities of the Extremities: A 21-Year Follow-Up Study," *Scandinavian Journal of Work, Environment & Health* 38, no. 1 (2012): 70–77.

13. L. I. Boden, P. K. O'Leary, K. M. Applebaum, and Y. Tripodis, "The Impact of Non-Fatal Workplace Injuries and Illnesses on Mortality," *American Journal of Industrial Medicine* 59, no. 12 (2016): 1061–1069.

14. C. J. Martin, C. Jin, S. J. Bertke, J. H. Yiin, and L. E. Pinkerton, "Increased Overall and Cause-Specific Mortality Associated With Disability Among Workers' Compensation Claimants With Low Back Injuries," *American Journal of Industrial Medicine* 63 (2020): 209–217.

15. A. Asfaw and K. Souza, "Incidence and Cost of Depression After Occupational Injury," *Journal of Occupational & Environmental Medicine* 54, no. 9 (2012): 1086–1091.

16. J. Kim, "Depression as a Psychosocial Consequence of Occupational Injury in the US Working Population: Findings From the Medical Expenditure Panel Survey," *BMC Public Health* 13, no. 1 (2013): 303.

17. V. Gerasimaviciute, U. Bültmann, P. M. Diamond, et al., "Reciprocal Associations Between Depression, Anxiety and Work-Related Injury," *Injury Prevention* 26, no. 6 (2020): 529–535.

18. A. M. Jones, M. Koehoorn, U. Bültmann, and C. B. McLeod, "Prevalence and Risk Factors for Anxiety and Depression Disorders in Workers With Work-Related Musculoskeletal Strain or Sprain in British Columbia, Canada: A Comparison of Men and Women Using Administrative Health Data," *Occupational and Environmental Medicine* 78 (2021): 500–508.

19. K. M. Applebaum, A. Asfaw, P. K. O'Leary, A. Busey, Y. Tripodis, and L. I. Boden, "Suicide and Drug-Related Mortality Following Occupational Injury," *American Journal of Industrial Medicine* 62, no. 9 (2019): 733–741.

20. S. H. Lin, H. Y. Lee, Y. Y. Chang, Y. Jang, P. C. Chen, and J. D. Wang, "Increased Mortality Risk for Workers With a Compensated, Permanent Occupational Disability of the Upper or Lower Extremities: A 21-Year Follow-Up Study," *American Journal of Epidemiology* 171, no. 8 (2010): 917–923.

21. L. I. Boden, A. Asfaw, A. Busey, et al., "Increased All-Cause Mortality Following Occupational Injury: A Comparison of Two States," *Occupational and Environmental Medicine* 79 (2022): 816–823.

22. A. Busey, A. Asfaw, K. M. Applebaum, et al., "Mortality Following Workplace Injury: Quantitative Bias Analysis," *Annals of Epidemiology* 64 (2021): 155–160.

23. "Service to Epidemiological Researchers to Provide Vital Status Data on Subjects of Health Research," US Social Security Administration, 2024, https://www.ssa.gov/policy/about/epidemiology.html.

24. M. P. Fox, R. F. MacLehose, and T. L. Lash, *Applying Quantitative Bias Analysis to Epidemiologic Data* (Springer Science & Business Media, 2021).

25. S. B. Patten, J. V. Williams, D. H. Lavorato, and M. Eliasziw, "Major Depression and Injury Risk," *Canadian Journal of Psychiatry* 55, no. 5 (2010): 313–318.

26. J. Kubo, B. A. Goldstein, L. F. Cantley, et al., "Contribution of Health Status and Prevalent Chronic Disease to Individual Risk for Workplace Injury in the Manufacturing Environment," *Occupational and Environmental Medicine* 71, no. 3 (2014): 159–166.

27. L. Hansen, *The Truven Health MarketScan Databases for Life Sciences Researchers* (Truven Health Analytics IBM Watson Health, 2017).

28. J. P. Fine and R. J. Gray, "A Proportional Hazards Model for the Subdistribution of a Competing Risk," *Journal of the American Statistical Association* 94, no. 446 (1999): 496–509.

29. M. P. Fox, R. F. MacLehose, and T. L. Lash, "SAS and R Code for Probabilistic Quantitative Bias Analysis for Misclassified Binary Variables and Binary Unmeasured Confounders," *International Journal of Epidemiology* 52, no. 5 (2023): 1624–1633.

30. M. Moitra, D. Santomauro, L. Degenhardt, et al., "Estimating the Risk of Suicide Associated With Mental Disorders: A Systematic Review and Meta-Regression Analysis," *Journal of Psychiatric Research* 137 (2021): 242–249.

31. D. S. Hasin, A. L. Sarvet, J. L. Meyers, et al., "Epidemiology of Adult DSM-5 Major Depressive Disorder and Its Specifiers in the United States," *JAMA Psychiatry* 75, no. 4 (2018): 336–346.

32. "Major Depression," National Institute of Mental Health, accessed April 26, 2024, https://www.nimh.nih.gov/health/statistics/major-depression.

33. "2021 National Survey on Drug Use and Health (NSDUH): Methodological summary and definitions," Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration 2022, Rockville, MD, accessed July 3, 2024, https://www.samhsa.gov/data/release/2021-national-survey-drug-use-and-health-nsduh-releases.

34. American Psychiatric Association D, Association AP, *Diagnostic and Statistical Manual of Mental Disorders: DSM-5*, Vol 5 (Washington, DC: American Psychiatric Association, 2013).

35. C. Henking and D. Gondek, "Social Determinants of Mental Health Trajectories During Midlife: A Prospective British Birth Cohort Study," *Lancet* 402 (2023): S48.

36. M. E. Addis, "Gender and Depression in Men," *Clinical Psychology: Science and Practice* 15, no. 3 (2008): 153–168.

37. R. F. Levant, "Toward the Reconstruction of Masculinity," *Journal of Family Psychology* 5, no. 3–4 (1992): 379–402.

38. A. Høye, B. K. Jacobsen, J. G. Bramness, R. Nesvåg, T. Reichborn-Kjennerud, and I. Heiberg, "Total and Cause-Specific Mortality in Patients With Personality Disorders: The Association Between Comorbid Severe Mental Illness and Substance Use Disorders," *Social Psychiatry and Psychiatric Epidemiology* 56 (2021): 1809–1819.

39. M. Pompili, M. Innamorati, C. Di Vittorio, et al., "Unemployment as a Risk Factor for Completed Suicide: A Psychological Autopsy Study," *Archives of Suicide Research* 18, no. 2 (2014): 181–192.

40. C. Peterson, A. Sussell, J. Li, P. K. Schumacher, K. Yeoman, and D. M. Stone, "Suicide Rates by Industry and Occupation—National Violent Death Reporting System, 32 States, 2016," *MMWR. Morbidity and Mortality Weekly Report* 69, no. 3 (2020): 57–62.

41. J. L. Gradus, A. J. Rosellini, E. Horváth-Puhó, et al., "Prediction of Sex-Specific Suicide Risk Using Machine Learning and Single-Payer Health Care Registry Data From Denmark," *JAMA Psychiatry* 77, no. 1 (2020): 25–34.

42. S. A. Seabury, E. Scherer, P. O'Leary, A. Ozonoff, and L. Boden, "Using Linked Federal and State Data to Study the Adequacy of Workers' Compensation Benefits," *American Journal of Industrial Medicine* 57, no. 10 (2014): 1165–1173.

43. L. I. Boden and M. Galizzi, "Income Losses of Women and Men Injured at Work," *Journal of Human Resources* 38, no. 3 (2003): 722–757.

44. A. D. LaMontagne, M. Åberg, S. Blomqvist, et al., "Work-Related Suicide: Evolving Understandings of Etiology & Intervention," *American Journal of Industrial Medicine* 67, no. 8 (2024): 679–695.

45. S. B. Harvey, M. Modini, S. Joyce, et al., "Can Work Make You Mentally Ill? A Systematic Meta-Review of Work-Related Risk Factors for Common Mental Health Problems," *Occupational and Environmental Medicine* 74, no. 4 (2017): 301–310.

46. I. Niedhammer, H. Sultan-Taïeb, A. Parent-Thirion, and J.-F. Chastang, "Update of the Fractions of Cardiovascular Diseases and Mental Disorders Attributable to Psychosocial Work Factors in Europe," *International Archives of Occupational and Environmental Health* 95 (2022): 233–247.

47. W.-S. Chin, J. S.-C. Shiao, S.-C. Liao, C.-Y. Kuo, C.-C. Chen, and Y. L. Guo, "Depressive, Anxiety and Post-Traumatic Stress Disorders at Six Years After Occupational Injuries," *European Archives of Psychiatry and Clinical Neuroscience* 267 (2017): 507–516.

48. N. Hallett, H. Rees, F. Hannah, L. Hollowood, and C. Bradbury-Jones, "Workplace Interventions to Prevent Suicide: A Scoping Review," *PLoS One* 19, no. 5 (2024): e0301453.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.