Long-term mortality risk in individuals with permanent work-related impairment

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ABSTRACT

OBJECTIVES: Recent estimates indicate that at least one in five activity-limiting injuries occurs at work. Of individuals who suffer these injuries approximately 10% experience some degree of functional impairment. We were interested in investigating long-term mortality risk in individuals with permanent impairment from work injury and to examine whether work disability is a significant explanatory factor.

METHODS: We used a retrospective matched cohort methodology to examine differences in mortality rates between individuals with permanent impairment from a work injury and a group of non-injured controls over a 19-year period. We used a sample of impaired workers to investigate the impact of work disability on mortality risk using percentage of earnings recovery after injury as the key proxy measure. All analyses were stratified by sex.

RESULTS: Permanent impairment from a work injury was predictive of premature mortality in both male and female claimants, though the risk was slightly higher among women. Work disability was a key explanatory factor in the rate of death among impaired workers, the effects being more pronounced in men. We also found that higher impairment level was associated with mortality in men but not in women.

CONCLUSION: The study demonstrates the impact of permanent work-related impairment on longevity and identifies work disability as an important determinant of mortality risk. Given the disconnect between impairment ratings derived from standard diagnostic tools and labour-market activity after accident, more research is needed on the specific factors that contribute to work disability, particularly those related to psycho-social health and well-being.

KEY WORDS: Work injury; work disability; mortality; longitudinal methods

La traduction du résumé se trouve à la fin de l'article.

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Occupational injuries make up a substantial proportion of all injuries. Studies of the prevalence of activity-limiting injuries in employed people aged 18-75 estimate that between 18% and 28% of the most serious injuries occur at work.^{1,2} Of the individuals who report a work injury in Canada each year, approximately 10% experience some degree of permanent functional impairment. In Ontario, the proportion of workers experiencing impairment was 14% in 2010, exceeding the national rate of 11%.³ Disabling work injury is a devastating event that alters the course of an individual's work-life trajectory. Types of work injury commonly associated with some level of permanent impairment include musculoskeletal and traumatic injuries, such as strains, sprains, contusions, fractures and repetitive strain injuries of the shoulder and lower back.^{4,5} Studies show that individuals with acquired work-related impairments are prone to physical and psychosocial sequelae, such as pain and depression, that can have long-lasting effects on overall health and well-being.^{6,7} Furthermore, the level of physical impairment given by standard evaluative tools (e.g., the American Medical Association [AMA] *Guide to the Evaluation of Permanent Impairment*) can substantially underestimate the degree of disability experienced after injury.^{8,9} Consequently, impairment from work injury may affect longevity; yet prior research on mortality risk is focused on death from acute trauma.¹⁰⁻¹² A handful of studies have demonstrated elevated long-term mortality risk in individuals with severe injuries from all causes – including work injuries – though these studies offer little insight into possible mechanisms.¹³⁻¹⁵

The current study investigates the impact of permanent impairment from a work injury on long-term mortality risk with a focus on work disability as a key explanatory factor. Using a novel longitudinal database created from a linkage between administrative data from the Ontario Workplace Safety and Insurance Board (WSIB) and Statistics Canada's Longitudinal Administrative Databank (LAD), we employed a retrospective matched cohort methodology to examine differences in mortality rates between individuals with permanent impairment from a work injury and a group of non-injured controls over a 19-year period. We hypothesize that impaired workers will have a higher risk of death in the follow-up period relative to their non-injured counterparts; moreover, we expect that work disability will be a significant explanatory factor in elevated mortality risk.

METHOD

Data

Data were derived from a linkage of two administrative data sources: workers' compensation claims records from Ontario's WSIB and federal tax file information from the LAD. The LAD is a 20%

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Table 1. Sample characteristics at baseline (year prior to injury event), men and women, 1986 to 1994, Ontario, Canada (N=106,208)

	N		SD
Men	72,627		
Mean age (years)		43.91	11.26
Mean individual labour-market income (CAD)		\$29,437	
Mean family/household income – adjusted for family size		\$29,144	
Proportion not married/single*		0.12	
Proportion rural residence†		0.18	
Proportion of age bracket 1 (25 to 39)		0.40	
Proportion of age bracket 2 (40 to 54)		0.37	
Proportion of age bracket 3 (55 to 64)		0.23	
Proportion impaired	13,697	0.19	
Proportion deceased	7380	0.10	
Women	33,581		
Mean age (years)		41.87	9.77
Mean individual labour-market income		\$15,835	
Mean family/household income – adjusted for family size		\$30,638	
Proportion not married/single*		0.12	
Proportion rural residence†		0.16	
Proportion of age bracket 1 (25 to 39)		0.45	
Proportion of age bracket 2 (40 to 54)		0.42	
Proportion of age bracket 3 (55 to 64)		0.13	
Proportion impaired	5625	0.17	
Proportion deceased	1500	0.04	

* Reference group is married/common-law union.

† Reference group is urban residence.

simple random sample of the T1 Family File (T1FF), a yearly cross-sectional database of all Canadian tax filers and their census families. Both the T1FF and the LAD have been created for every year from 1982 to 2010. The T1FF contains information on up to 95% of Canadians aged 18 years and older. Individuals are entered into the LAD through their social insurance number (SIN). Each year the LAD file is topped off with 20% of new tax filers in order to keep the file representative of the tax filing population. The files contain information on income sources and amounts, socio-demographic information and year of death where applicable.

The sample for this study consists of individuals aged 25 to 64 with workers' compensation claims for accidents occurring in Ontario from January 1, 1986, to December 31, 1994, that resulted in a permanent impairment. Because of the nature of the LAD sampling process (i.e., simple random sample) we would expect to identify, at an optimum, 20% of the claimant sample frame in the LAD. The linkage identified almost 19% of the sample frame, which suggests that the linkage was very successful. Information on the date of accident, type and amount of benefits received each year, percentage of permanent impairment, other claim details and a personal identifier (the individual's SIN) was extracted from WSIB for the entire frame. The information was then linked with the LAD through the SIN. The LAD was used to select a matched sample of control individuals without permanent impairment from a work injury, which was used for comparison with the sample of injured workers culled from the WSIB administrative data records and identified in the LAD.

Measures

The outcome variable for the statistical model was dichotomous, indicating whether or not the individual was deceased in a given calendar year (yes=1; no=0). Two key explanatory variables were investigated: 1) permanent impairment from work injury was a dichotomous variable identifying the individual as someone who was present in the claims data and had received a diagnosis of permanent impairment per the AMA guidelines (yes=1; no=0); and 2) percentage of labour-market earnings recovery was the

proportion of pre-injury earnings recovered by an individual in the period after a work injury. Four categories of labour-market earnings recovery were defined: <25% recovery of pre-injury earnings (reference category), 25% to <50%, 50% to <75% and ≥75%. This variable represents the key proxy for degree of labour-market engagement following an injury – i.e., work disability. All explanatory variables were based on information from the year prior to the outcome variable.

Other explanatory variables included in the analysis because of their potential association with the outcome variable and because these were of substantive interest in their own right were sex; age bracket at time of injury (three categories: 25-39, 40-54, 55-64); percentage/severity of impairment* (cases only: low impairment [<10% loss in bodily function]=0; high impairment [≥10% loss in bodily function]=1); family income (log, 1994 dollars, adjusted for family size); rural residence (yes=1; no=0); single/not married (yes=1; no=0); and calendar year (results for this variable not shown; available from the author upon request). All analyses were stratified by sex.

Control matching

To identify a comparison group of individuals who did not suffer a permanent impairment due to work injury (control group), we used a matching algorithm that selected up to 10 controls for each claimant of workers' compensation. The approach is known as the Nearest Available Mahalanobis Metric Matching within Calipers Defined by the Propensity Score.¹⁶ The matching technique has a robust history of application and development and is preferable to regression modeling techniques in some circumstances.¹⁷ In the current study, the procedure helped ensure that matched pairs were similar before the accident year on characteristics that bear

* We undertook a sensitivity analysis of the percentage/severity of impairment variable to determine whether different thresholds for low and high levels of impairment had differential effects on mortality risk. Our findings showed that a cut-point of <10% (low impairment) and ≥10% (high impairment) was the best predictor of significant differences in mortality risk over time (results available upon request). Hence, the 10% cut-point was retained in the duration models.

Table 2. Duration model of time to death in women, cases and controls, 1990 to 2009, Ontario, Canada (N=33,581)

Explanatory variables	Coefficient (95% CI)	Hazard ratio (95% CI)	Percent difference (95% CI)	Significance
Impaired	0.251 (0.127-0.375)	1.29 (1.13-1.45)	29% (13%-45%)	**
Age bracket (years)				
25 to 39 [reference group]				
40 to 54	1.383 (1.214 - 1.552)	3.99 (3.37 - 4.72)	399% (337% - 472%)	**
55 to 64	2.623 (2.456 - 2.790)	13.78 (11.65 - 16.29)	1378% (1165% - 1629%)	**
Rural residence	0.218 (0.085 - 0.351)	1.24 (1.09 - 1.42)	24% (9% - 42%)	**
Single/not married	0.138 (0.015 - 0.261)	1.15 (1.02 - 1.30)	15% (2% - 30%)	*
Total family/household income [log, 1994 dollars]	-0.068 (-0.128 - 0.008)	0.93 (0.88 - 0.99)	-7% (-12% - -1%)	*
Sample size	464,135 observation years			

* $p \leq 0.05$, ** $p \leq 0.01$.**Table 3.** Duration model of time to death in women, cases only, 1990 to 2009, Ontario, Canada (N=5625)

Explanatory variables	Coefficient (95% CI)	Hazard ratio (95% CI)	Percent difference (95% CI)	Significance
Age bracket (years)				
25 to 39 [reference group]				
40 to 54	0.940 (0.620 - 1.259)	2.56 (1.87 - 3.54)	256% (87% - 354%)	**
55 to 64	1.714 (1.334 - 2.093)	5.55 (3.80 - 8.11)	555% (380% - 811%)	**
Percentage impairment				
<10% [reference group]				
≥10%	-0.084 (-0.335 - 0.162)	0.92 (0.72 - 1.18)	-8% (-18% - 18%)	
Proportion earnings recovery				
<25% [reference group]				
25% to <50%	0.084 (-0.412 - 0.568)	1.09 (0.66 - 1.78)	9% (-34% - 78%)	
50% to <75%	-0.509 (-1.168 - 0.150)	0.60 (0.31 - 1.16)	-40% (-69% - 16%)	
≥75%	-0.321 (-0.666 - -0.024)	0.73 (0.51 - 1.02)	-27% (-49% - 2%)	*
Sample size	76,274 observation years			

* $p \leq 0.05$, ** $p \leq 0.01$.

on labour-market engagement. In this way, any substantive difference in the rate of mortality between cases and controls could be credibly attributed to the effects of a work injury resulting in permanent impairment. The essential criteria for candidate controls were as follows: that they were living in the province of Ontario in the injury year of the candidate-claimant match; they had wage and salary earnings in the injury year; and they were present in the database in at least one of the four years before the injury. The selection of controls for each claimant observation was based on two sets of characteristics. One set required an exact match of characteristics between the claimant and control, and the other required a match within some acceptable range. The exact match characteristics were province of residence, region of residence (urban/rural) and sex. The non-exact match characteristics were a propensity score ($\pm 25\%$ of the standard deviation of the logit propensity score); age ($\pm$ two years of the event); presence patterns in the database in each of the four years before injury year (both “present”=“present” and “not present”=“not present” were considered a match); and wage and salary earnings in each of the prior four years (wages and salaries within $\pm 20\%$ of event wage and salary level were considered acceptable). For candidate controls meeting the exact match criteria and having fulfilled the propensity score criteria, the following formula was used to calculate the weighted distance

(closeness of the match) between an event and a candidate and control:

$$D_{ec} = w_1 |age_e - age_c| + \sum_{t=1}^4 w_2 (dummy_{ect}) + \sum_{t=1}^4 w_3 |\log(earnings_{et}) - \log(earnings_{ct})|;$$

where D_{ec} is the total distance between the event (e) and candidate control (c); w_1 is the weight given the age difference; w_2 is the weight given the matching of years; $dummy_{ect}$ is 0 if the presence pattern matches in year t and 1 otherwise; w_3 is the weight given earnings differences between claimants and controls; and $earnings_{et}$ and $earnings_{ct}$ are event and candidate control earnings in year t . The specific values used for the weights were as follows: $w_1=1$, $w_2=5$ and $w_3=50$. The largest weight was placed on the earnings difference, and the maximum allowable difference was 20%. The selection of controls was randomized without replacement. Final selection of controls was based on the smallest total distance between a claimant and control in accordance with the matching characteristics and the weight assigned to each characteristic. A maximum of 10 controls were selected for each claimant observation. The event-control matching was very successful; it resulted in a match of 5 to 10 controls for 97% of the claimant sample.

Statistical modeling

We used the complementary-log-log (c-log-log) function for continuous time processes to model the time from year of injury to

Table 4. Duration model of time to death in men, cases and controls, 1990 to 2009, Ontario, Canada (N=72,627)

Explanatory variables	Coefficient (95% CI)	Hazard ratio (95% CI)	Percent difference (95% CI)	Significance
Impaired	0.1958 (0.1428 - 0.2488)	1.22 (1.15 - 1.28)	22% (15% - 28%)	**
Age bracket (years)				
25 to 39 [reference group]				
40 to 54	1.5245 (1.4323 - 1.6167)	4.59 (4.19 - 5.04)	459% (419% - 504%)	**
55 to 64	2.7945 (2.7062 - 2.8828)	16.35 (14.97 - 17.86)	1635% (1635% - 1786%)	**
Rural residence	0.1077 (0.0489 - 0.1664)	1.11 (1.05 - 1.18)	11% (5% - 18%)	**
Single/not married	0.0836 (0.0196 - 0.1477)	1.09 (1.02 - 1.16)	9% (2% - 16%)	*
Total family/household income [log, 1994 dollars]	-0.1757 (-0.2111 - -0.1403)	0.84 (0.81 - 0.87)	-16% (-19% - -13%)	**
Sample size	961,482 observation years			

* $p \leq 0.05$, ** $p \leq 0.01$.**Table 5.** Duration model of time to death in men, cases only, 1990 to 2009, Ontario, Canada (N=13,697)

Explanatory variables	Coefficient (95% CI)	Hazard ratio (95% CI)	Percent difference (95% CI)	Significance
Age bracket (years)				
25 to 39 [reference group]				
40 to 54	1.367 (1.185 - 1.548)	3.92 (3.27 - 4.70)	392% (327% - 470%)	**
55 to 64	2.212 (2.023 - 2.401)	9.13 (7.56 - 11.03)	913% (756% - 1103%)	**
Percentage impairment				
<10% [reference group]				
≥10%	0.1222 (0.0137 - 0.2308)	1.13 (1.01 - 1.26)	13% (1% - 26%)	*
Proportion earnings recovery				
<25% [reference group]				
25% to <50%	-0.3148 (-0.5739 - -0.0556)	0.73 (0.56 - 0.94)	-27% (-44% - -6%)	*
50% to <75%	-0.1667 (-0.4052 - 0.0717)	0.85 (0.67 - 1.07)	-15% (-33% - 7%)	
≥75%	-0.4786 (-0.6169 - -0.3404)	0.62 (0.54 - 0.73)	-38% (-46% - -27%)	**
Sample size	184,735 observation years			

* $p \leq 0.05$, ** $p \leq 0.01$.

year of mortality. This approach treats the within-period hazard as constant (exponential) with an across-period baseline that takes the form of a step function with no pre-defined shape.¹⁸ For the data used in this study the within-period interval was a calendar year, and the across period intervals spanned the time from year of injury to year of death. Respondents were followed until 2009 (up to a maximum of 19 years from the date of injury). Like the Cox regression model, the c-log-log transformation invokes a proportionality assumption in hazards, not odds; as such, it provides a discrete time analog for the continuous time hazard model. Covariates were integrated into the c-log-log functional form using the proportional hazard approach. All models were run in SAS version 9.1 (SAS Institute, Cary, NC) using PROC GENMOD.

RESULTS

Table 1 presents descriptive statistics for the sample used in the statistical modeling. The male and female samples comprised 72,627 and 33,581 individuals respectively. The average age of respondents was 44 years. Men reported slightly higher labour-market earnings than women (mean log of individual income 10.3 [\$29,437] and 9.7 [\$15,835] respectively). Nineteen percent of men and 17% of women were permanently impaired from a work injury. Among impaired people (N=19,322), a slightly greater percentage of women than men were highly impaired (54% and 50%

respectively). A total of 7,380 men and 1,500 women were deceased by the end of the observation period. The rate of death among impaired men was 55% higher than their non-impaired counterparts (14% versus 9% respectively). For women, the rate of death among impaired people exceeded the rate among non-impaired individuals by 50% (6% versus 4% respectively).

Table 2 presents the results from the duration modeling for female cases and controls. Women with permanent impairment from a work injury were almost 30% more likely to die than their non-impaired counterparts (coefficient: 0.251, hazard ratio [HR]=1.29; $p < 0.01$). Further tests revealed the presence of an interaction between impairment status and age of onset of impairment, women who had sustained injuries at younger ages being at higher risk of mortality (coefficient: 0.80, HR=2.23; $p < 0.01$). Other covariates predictive of higher mortality risk in women were older age bracket, rural residence, being single/not married and low family income. A comparison of survival curves between claimants and controls showed that the death rate diverged significantly at approximately 13 years after injury, suggesting that the elevated risk of death from disabling injury in women persists over decades.

We also tested a duration model on female claimants only to examine whether both level of impairment and percentage of earnings recovery after injury (i.e., work disability) affect mortality risk in this group (Table 3). The model was adjusted for the effect

of age bracket. No significant differences in mortality risk were found between women with high- versus low-level of impairment. There were, however, differences in mortality risk based on degree of work disability. Women with impairments who had low or no work disability (high earnings recovery, i.e., $\geq 75\%$ of pre-injury earnings) were 27% less likely to die during follow-up compared with their counterparts with high work disability (earnings recovery $< 25\%$).

Table 4 presents duration modeling results for male cases and controls. Men with impairments had a greater risk of death (coefficient: 0.20, HR=1.22; $p < 0.01$), though the risk was slightly lower than that observed in women. Further tests of the models based on age of onset of impairment revealed that younger age was predictive of higher mortality risk in men (coefficient: 0.45, HR=1.57; $p < 0.01$). Other covariates predictive of increased mortality risk in men were older age bracket, rural residence, being single/unmarried and low family income. Survival plots showed that death rates among male claimants and controls diverged significantly around year 15 of follow-up.

Statistical tests of the male impaired sample (Table 5) found that men with high impairment were more at risk of dying than those with low impairment (coefficient: 0.12, HR=1.13; $p < 0.05$). Furthermore, a higher degree of labour-market engagement after injury modified the risk of death in impaired men. Specifically, for men with moderate work disability the rate of mortality was reduced by a factor of 0.27; for those with low or no work disability the death rate was modified even further by a factor of 0.38.

DISCUSSION

Permanent impairment from a work injury is a devastating experience with adverse implications for individual health and longevity. Studies of death from work injury typically focus on the increased incidence from different types of physical trauma, though a handful of studies have found that risk of death can persist well beyond the acute phase.¹³ We have little knowledge, however, as to the specific mechanisms underlying long-term mortality risk after injury. In the current study, we found evidence to support the hypothesis that an increased risk of death due to disabling work injury can persist for several years after injury. Our findings also indicate that work disability plays a key role in mortality risk. Risk of premature death from work disability appears to be more salient in men than women, men being more susceptible to premature mortality at lower levels of work disability. For both women and men, the onset of impairment at younger ages is associated with greater risk of death. Another key finding from the analysis is that higher level of physical impairment affects mortality in men but not in women.

A key strength of the study is the large, powerful longitudinal dataset we have assembled through a linkage of two administrative data sources. Also, the rigorous cohort-control matching on key characteristics plus a propensity score helped to ensure that claimants and controls were similar at baseline, such that divergences in death rates could be credibly attributed to permanent impairment from work injury. The matching method has been tested in prior studies with good success.^{9,19,20} Another strength is the study's use of a duration model for continuous time processes that corrects for error arising from multiple observations on each person, improving the precision of the results.

We also acknowledge some limitations of the study. First, the database lacked information on educational attainment, type of work injury and specific work characteristics, including occupation, although we did have a broad range of socio-demographic, health and earnings information. In a similar vein, health information was limited to the presence of work injury; therefore, we cannot be certain that the health status of cases and controls was equivalent at baseline. Furthermore, the sample comprises workers from the province of Ontario, which might raise questions as to the generalizability of the findings. For example, it is possible that labour-market conditions in other jurisdictions could have a different impact on labour-market engagement and work disability after injury.

These limitations notwithstanding, our focus in this study (Ontario workers' compensation claimants) can be viewed as a first case study of the longer-term impact of health impairments arising from work injury. The study makes an important contribution to the occupational health literature by providing evidence that work disability is a key explanatory factor in risk of premature mortality after impairment. Future investigations into the health and longevity consequences of work injury should begin to account for the factors associated with labour-market engagement in impaired workers. These factors include not just the physical consequences of work injury, such as mobility limitations and pain, but also a myriad of other adverse psychosocial impacts such as anxiety, coping and stigma. These "softer" psychosocial impacts may be more difficult to evaluate precisely, though they no doubt play a key role in work disability. Prior research finds that work disability is often underestimated in populations with less severe impairments.^{9,21,22} Identifying the key mechanisms underlying work disability requires that rehabilitation researchers go beyond physical assessments of work limitations to consider the impact of injury on an individual's sense of self, coping and adaptability, and other factors – such as age at which the impairment occurs – that can present significant barriers to successful labour-market re-entry. A better understanding of the social psychology of work disability can help rehabilitation services design programs that more effectively assist workers with labour-market re-engagement after injury with implications for improved longevity and overall well-being.

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RÉSUMÉ

OBJECTIFS : Selon des estimations récentes, au moins un traumatisme sur cinq limitant les activités se produit au travail. Environ 10 % des personnes qui subissent ces traumatismes éprouvent une certaine incapacité fonctionnelle. Nous avons voulu étudier les risques de mortalité à long terme chez les personnes atteintes d'une incapacité permanente à la suite d'un accident du travail et déterminer si l'incapacité professionnelle en est un facteur explicatif important.

MÉTHODE : À l'aide d'un modèle d'étude de cohorte rétrospective appariée, nous avons examiné sur une période de 19 ans les différences dans les taux de mortalité de sujets atteints d'une incapacité permanente à la suite d'un accident du travail et d'un groupe témoin n'ayant pas subi de traumatisme. Nous avons utilisé un échantillon de travailleurs ayant une incapacité pour étudier l'impact de l'incapacité professionnelle sur le risque de mortalité en utilisant le pourcentage de récupération des gains après le traumatisme comme variable substitutive clé. Toutes nos analyses ont été stratifiées selon le sexe.

RÉSULTATS : Une incapacité permanente à la suite d'un accident du travail était une variable prédictive de mortalité prématurée tant chez les hommes que chez les femmes ayant présenté une demande d'indemnisation, bien que le risque ait été légèrement supérieur chez les femmes. L'incapacité professionnelle était un facteur explicatif clé du taux de décès des travailleurs ayant une incapacité, les effets étant plus prononcés chez les hommes. Nous avons aussi constaté qu'un niveau d'incapacité supérieur était associé à la mortalité chez les hommes, mais non chez les femmes.

CONCLUSION : Cette étude montre l'impact d'une incapacité professionnelle permanente sur la longévité et identifie l'incapacité professionnelle comme étant un important déterminant du risque de mortalité. Étant donné le décalage entre les taux d'incapacité dérivés des outils de diagnostic standard et l'activité sur le marché du travail après un accident, il faudrait pousser la recherche sur les facteurs précis qui contribuent à l'incapacité professionnelle, surtout ceux qui sont liés à la santé et au bien-être sur le plan psychosocial.

MOTS CLÉS : accidents du travail; incapacité professionnelle; mortalité; méthodes longitudinales