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Musculoskeletal Disorders and Associated Healthcare Costs Among Family Members of Injured Workers

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Background *Research has infrequently looked beyond the injured worker when gauging the burden of occupational injury.*
Objectives *We explored the relationship between occupational injury and musculoskeletal disorders (MSDs) among family members of injured workers.*
Data and Methods *We used 2005 and 2006 Truven Health Analytics databases, which contain information on workers' compensation and family healthcare claims. We used descriptive analyses, and negative binomial and two-part models.*
Results *Family members of severely injured workers had a 15% increase in the total number of MSD outpatient claims and a 34% increase in the mean cost of MSD claims compared to family members of non-severely injured workers within 3 months after injury. Extrapolating cost results to the national level implies that severe occupational injury would be associated with between $29 and $33 million additional cost of family member outpatient MSD claims.*
Conclusion *Occupational injury can impose a formerly unrecognized health burden on family members of injured workers.* Am. J. Ind. Med. 58:1205–1216, 2015. Published 2015. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS: occupational injury; family health; musculoskeletal disorders; negative binomial; two-part model

INTRODUCTION

Most studies on the economic consequences of occupational injuries and illnesses concentrate on worker and workplace-specific economic impacts such as the cost of healthcare for the injured worker and the lost productivity of the injured worker due to disability, lost work days, or presenteeism. There is some evidence, however, that the effects of occupational injuries and illnesses can reach beyond the worker and the workplace and affect the family members of injured workers. Keogh et al. [2000] showed, for instance, that about half of Maryland workers' compensation claimants with upper extremity cumulative trauma disorders reported that their conditions had resulted in "family problems" when they were interviewed one to four years later, including 11% reporting separation from spouse or partner. As another example, Adams et al. [2002] examined the economic and social consequences of occupational injury through a series of in-depth case studies of severe occupational injuries and concluded that families of injured workers experienced emotional, mental, and financial problems, while some family members also suffered an increased physical burden of caring for injured workers. More recently, Brown et al. [2007] observed associations between occupational injury and family health and healthcare utilization, and Asfaw et al. [2012] observed

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associations between occupational injury and subsequent hospitalization of family members.

Severely injured workers may depend on their family members to perform many of their day-to-day activities such as walking and bathing [Miller, 1995; Morse et al., 1998; Boden, 2005], as well as other essential household chores [Hensler et al., 1991; Morse et al., 1998; Keogh et al., 2000; Weil, 2001; Strunin and Boden, 2004; Bianchi, 2005]. For instance, Hensler et al. [1991, pp 96–98] considered workers who suffered occupational injuries with cost consequences in the previous year, and found that family members had to provide care to 16% of these workers and to assume responsibility for at least a portion of the household chores of 38% of them. Physical demands associated with these new responsibilities may put family members at increased risk for musculoskeletal disorders (MSDs). These effects could be exacerbated by loss of income in families of injured workers, reducing their capacity to employ caretakers or household staff and adding to the physical burden falling upon family members. Several studies have shown that occupational injuries could significantly reduce the income of injured workers [Haveman and Wolfe, 1990; Miller and Galbraith, 1995; Burkhauser and Daly, 1996; Biddle et al., 1998; van der Sluis et al., 1998; Boden and Galizzi, 1999; Reville, 1999; Boden et al., 2001; Reville and Schoeni, 2001; Dembe, 2005; Brown et al., 2007; Leigh, 2011]. This economic effect could be aggravated if family members reduce their work hours in order to take care of injured workers [Weil, 2001].

Building on previous research, our study explored potential associations between the severity of occupational injury and subsequent MSDs among family members, as evidenced by the number of family members with at least one outpatient MSD claim, the total number of family member outpatient MSD claims, and the cost of these claims. We also examined associations between injury severity and a broader group of claims including MSD and slip, trip, and fall (STF) claims, and between injury severity and all other claims. For our main regression analyses, we focused on MSDs. We hypothesized that there would be no before-injury difference in outpatient MSD claims between family members of severely and non-severely injured workers, because we expected that their families would have similar characteristics. We further hypothesized that in the after-injury period, family members of severely injured workers would be more likely to suffer MSDs and to incur more outpatient MSD costs than family members of non-severely injured workers.

METHODS

Data

We used Truven Health Analytics (formerly known as Thomson Reuters) MarketScan data, collected from large employers and health insurers [Truven, 2012]. The MarketScan data are fully Health Insurance Portability and Accountability Act (HIPAA) compliant[1] and no Institutional Review Board approval was necessary because individual patients were not identifiable with the data. These data contain de-identified information on workers, their family members, employers, and insurance plans. We used the 2005 and 2006 Health and Productivity Management (HPM) and Commercial Claims and Encounter (CCE) databases. A total of 37 employers were represented in 2005 and 2006 in the HPM database. Of these, 31 were represented in the 2005 data with an average of 34,730 employees each, and 36 were represented in the 2006 data with an average of 30,003 employees each. The workers' compensation component of the HPM database included information on injured worker age and sex and whether they were paid hourly and belonged to a union, industry sector and geographic region of employment, health plan type, days away from work, as well as medical and total indemnity (wage replacement) payments associated with each claim. The CCE database included information on the number and cost of family member outpatient healthcare claims, and their medical diagnosis codes (International Classification of Diseases, 9th Revision, or ICD-9 codes). We linked CCE and HPM data using each covered worker's enrollment code that is available in both databases. This allowed us to track the incidence and cost of family member outpatient MSD healthcare claims before and after the incidence of occupational injury.

We used occupational injury claim records in the workers' compensation component of the HPM database to define our study population. We excluded injured workers without family members or with multiple occupational injuries within a year. We also excluded workers who suffered occupational injuries within the first and last 3 months of 2005 and 2006 because we wanted to track the outpatient claims of family members 3 months before and 3 months after the occupational injuries we considered (See Fig. 1).

Classification of Occupational Injuries and Family Outpatient Claims

We divided injured workers into two groups: severely and non-severely injured. We considered as severely injured workers who received indemnity payments and were absent from work for at least 7 days, which equals or exceeds the minimum number of days absent to be eligible for indemnity payments in 49 states.

[1] See http://truvenhealth.com/your-healthcare-focus/analytic-research/marketscan-research-databases accessed on January 6, 2015.

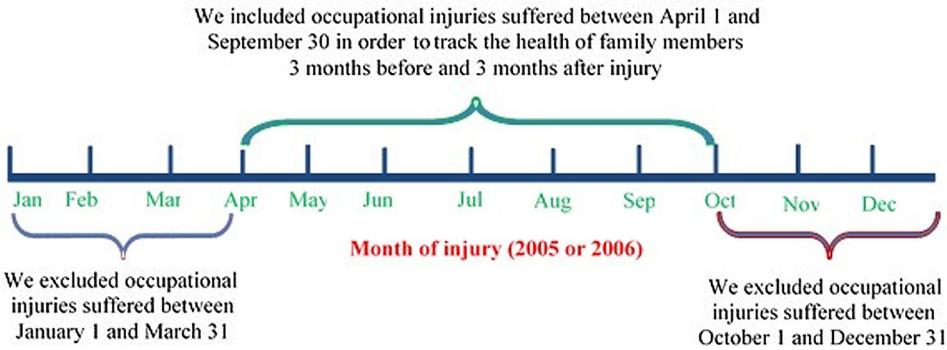

FIGURE 1. Time frame of the study

We used all primary and secondary ICD-9 codes appearing on family member outpatient claims to identify those that were likely to be associated with physical stress. We selected codes that corresponded to conditions that were likely caused or exacerbated by sudden exertion or prolonged use of force, awkward posture, repetitive motion, or vibration. We based this selection in part on expert opinion and in part on preliminary results from another NIOSH study in progress, conducted in collaboration with the Ohio Bureau of Workers' Compensation. In that study, ergonomics researchers classified a set of Ohio workers' compensation claims from 2001 to 2010 into three categories: MSD claims; STF claims; and all other claims. Classifications were based primarily on injury narratives. The family member outpatient MSD claims we used in the current study included the following 3-digit ICD-9 code groups: 354 (carpal tunnel and related), 550–553 (hernia), 717–719 (internal derangement of knee and other joint disorders), 721–724 (dorsopathies); 726–727 (peripheral enthesopathies; other disorders of synovium, tendon, and bursa), 728.7–728.8 (other fibromatoses; other disorders of muscle, ligament, and fascia), 729 (other disorders of soft tissues), and 840–848 (sprains and strains of joints and adjacent muscles).

The principal drawback to the use of ICD-9 codes to identify MSDs is that many of these codes represent conditions that also result from other causes. For example, codes for disc disorders and sprains also commonly appear on claims for another major category of injuries, STFs. While STFs were not central to our main hypothesis, we considered them to be another plausible outcome of caring for the injured worker and taking on more household chores. Therefore, we repeated all analyses with another set of ICD-9 codes that included MSDs as well as STFs (MSD + STF). Again, we consulted Ohio workers' compensation claims data, and determined the most commonly occurring ICD-9 codes in a pool of MSD + STF claims. Based on this information, we included family member outpatient claims for MSD and STF conditions with the following additional codes: 850.0–854.9 (intracranial injury), 800.0–829.1 (fracture), 920.0–924.9 (contusion), and 830.0–839.9 (dislocation). The frequency of MSD + STF ICD-9 diagnosis code groups in the pooled family member outpatient claims before and after occupational injury are presented in Appendix 1. To test whether any observed impacts of occupational injury on family outpatient claims were specific to MSDs alone or to MSDs and STFs, we also conducted an analysis using claims for conditions with ICD-9 codes not contained in the MSD + STF list. We referred to claims with these codes as "all other claims".

Univariate Analyses

First, we conducted a descriptive analysis and computed the statistical significance of differences between family members of severely and non-severely injured workers within the 3-month periods before injury, and within the 3-month periods after injury. We did this separately for three outcomes: the number of family members with at least one outpatient MSD claim, the total number of family member outpatient MSD claims, and the cost of family member outpatient MSD claims. Then, we tested the statistical significance of before-after injury differences in all 3 outcomes, both for severely and non-severely injured worker families. We repeated all of the above analyses for MSD + STF and for all other claims.

Regression Analyses

Number of family members with at least one outpatient claim

As explained in the introduction, the regression analyses compared families of severely and non-severely injured workers in the 3-month period after injury. We used a negative binomial model to estimate the effect of injury severity on the number of family members with at least one outpatient MSD claim. We determined that the Poisson model was not appropriate for our data because it assumes equal conditional mean and variance. We used severity of

injury as the main explanatory variable and included the following covariates in the model: number of family members with at least one outpatient MSD claim 3 months before occupational injury, injured worker age and sex, whether the worker belonged to a union and was paid hourly, industry sector and geographic region of employment, and health plan type. To facilitate the interpretation of the results, we presented incidence rate ratios (IRR) instead of the raw coefficients of the negative binomial model. IRR are the exponents of the regression coefficients and their interpretation is similar to that of the odds ratios of the logistic model. The IRR of a negative binomial regression shows the percentage increase ((IRR-1)*100 if IRR >1) or decrease ((1-IRR)*100 if IRR <1) with a unit increase in the dependent variable. We also used this model to estimate the effect of severity on the number of family members with at least one outpatient MSD + STF claim, and on the number of family members with at least one outpatient claim with all other diagnoses.

Total number of family member outpatient claims

We used an analogous negative binomial model to estimate the effect of injury severity on the total number of family member outpatient MSD claims. We also used this model to estimate the impact of injury severity on the total number of outpatient MSD + STF claims and on all other outpatient claims.

Cost of family member outpatient claims

For the analysis of outpatient MSD claim costs by injury severity, we used a two-part model because there were many family members of injured workers with no outpatient MSD claims within 3 months after injury (83%) [for details on this approach, see Mullahy, 1998; Tian and Huang, 2007; Asfaw and Souza, 2012]. In the first part of the model, we used logistic regression to estimate the probability that at least one family member of an injured worker would have an outpatient MSD claim within 3 months after occupational injury. In the second part, we used a log-linear regression to estimate the average cost of family member outpatient MSD claims for those families who had at least one MSD claim. In both the first and second parts of the model, we included a set of covariates analogous to those used in the negative binomial regressions described above, except that the before-injury cost variable was a binary indicator of whether the family had positive or zero outpatient MSD claim cost. We used this binary indicator because of the large dispersion and large number of zeros in before injury costs. In the final step, we estimated the average cost of outpatient MSD claims for all families by multiplying the results of the first and second parts of the model, as well as a smearing factor: (probability of any MSD claim) × (average costs for those families with MSD claims) × (smearing factor) (for details, see Asfaw and Souza, 2012). To estimate the effect of severe injury, we compared the model's mean predicted cost for all families that we derived by assuming they all had a severely injured worker, to the model's mean predicted cost for all families that we derived by assuming that all families had a non-severely injured worker. We repeated the cost analysis using MSD + STF claims.

Cost of family member outpatient claims on the national level

We constructed a rough estimate of the national costs implied by our family level estimate of the cost of outpatient MSD claims of severe injury. We started with the annual number of non-fatal occupational injuries reported by the U.S. Bureau of Labor Statistics in 2005–2006, 4.1 million [BLS, 2015], and assumed that the same percentage of these injuries met our criteria for severe injury as in this study. We then multiplied our estimate of the annual number of severe injuries in the U.S. by our estimate of the additional cost of family member outpatient MSD claims per severe injury. We made an additional adjustment for the fact that our study focused only on insured families of workers employed by large employers, and that their higher level of insurance coverage was likely to have increased their utilization of healthcare. We used estimates that 82.8% [Fronstin 2007, Fig. 6] – 84.5% [U.S. Census Bureau, 2015] of the nonelderly population had health insurance of any kind between 2005 and 2006, and assumed that on the national level all the insured would seek additional care at the rate observed in this study but that the uninsured would not seek additional care. Thus, we reduced our estimate by 15.5% -17.2%. We used the weights provided by Truven in the CCE database [see Schneider et al., 2014 for the details] to make the results somewhat more representative of the national insured population of workers their families. We expressed costs in 2013 dollars using a weighted average of indexes for physician services and paramedical services from the National Income and Product Accounts [U.S. Department of Commerce, 2015].

RESULTS

Descriptive Results and Univariate Analyses

We considered 17,238 injured workers, 16.2% of whom were severely injured, and 51,366 family members. Table I presents the descriptive statistics for all the variables used in the analyses by occupational injury severity. Before-injury worker and family characteristics were mostly similar.

TABLE I. Descriptive Statistics: MSD and MSD + STF Claims by Injury Severity

	Non-severely injured	Severely injured
Number of injured workers and family members		
Total number of injured workers	14,450	2,789
Total number of family members (excluding injured worker)	43,017	8,349
Number of family members with at least one outpatient claim (Mean)		
Number of family members with at least one outpatient MSD claim:		
3 months before injury	0.20	0.21
3 months after injury	0.19	0.23
Number of family members with at least one outpatient MSD+STF claim:		
3 months before injury	0.24	0.25
3 months after injury	0.23	0.27
Total number of family member outpatient claims (Mean)		
Total number of family member outpatient MSD claims: 3 months before injury	0.54	0.55
Total number of family member outpatient MSD claims: 3 months after injury	0.56	0.63
Total number of family member outpatient MSD+STF claims:3 months before injury	0.66	0.66
Total number of family member outpatient MSD+STF claims:3 months after injury	0.68	0.77
Cost of outpatient claims (Mean)		
Cost of outpatient MSD claims: 3 months before injury	$150	$162
Cost of outpatient MSD claims: 3 months after injury	$155	$202
Cost of outpatient MSD+STF claims: 3 months before injury	$192	$193
Cost of outpatient MSD+STF claims: 3 months after injury	$196	$250
Demographic variables		
Sex of injured workers (1 if male, 0 if female) (%)	75.5	79.8
Mean age of injured workers	43.5	44.3
Job classification of injured workers (1 if paid hourly, 0 otherwise) (%)	85.2	89.5
Union status of injured workers (1 if union member, 0 otherwise) (%)	58.7	52.4
Industry (%)		
Manufacturing durables	37.3	40.0
Manufacturing non-durables	27.4	21.7
Transportation	20.0	33.2
Finance	0.6	0.1
Services	14.8	5.0
Health plan type (%)		
Comprehensive	9.6	7.1
Health Maintenance Organization (HMO)	6.6	6.4
Point of Service (POS)	21.0	35.2
Preferred Provider Organization (PPO)	62.2	50.9
Region (%)		
Northeast	12.1	18.2
North central	33.6	27.1
South	39.4	36.3
West	14.9	18.5

Figures 2 and 3 summarize some of the information in Table I by expressing severely-non-severely injured differences and before-after injury differences in percentages, and indicating their significance. Before-after increases in all three MSD outcomes were statistically significant for families of severely injured workers (panel (a) of Fig. 2), while increases were relatively small and not consistently significant for families of non-severely injured workers. Results for MSD + STF claims (panel (b) of Fig. 2) were similar to those for MSD claims alone.

As we hypothesized, before-injury differences in MSD outcomes between severely injured and non-severely injured worker families were relatively modest and non-significant. After-injury differences were much larger and statistically significant, with more severely injured worker family claims and higher costs (panel (c) of Fig. 3). After-injury results for MSD+STF claims were similar to those for MSD claims alone (panel (d) of Fig. 3).

We reported results for claims with all other diagnoses (excluding MSD + STF) in Appendices 2 and 3. They

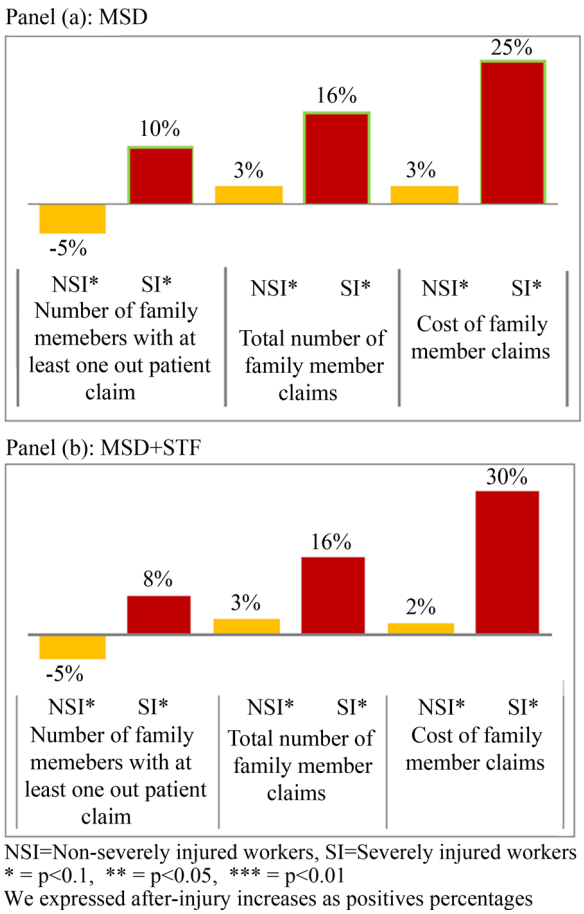

FIGURE 2. Percentage change in after-injury period compared to before-injury period and paired *t* test results.

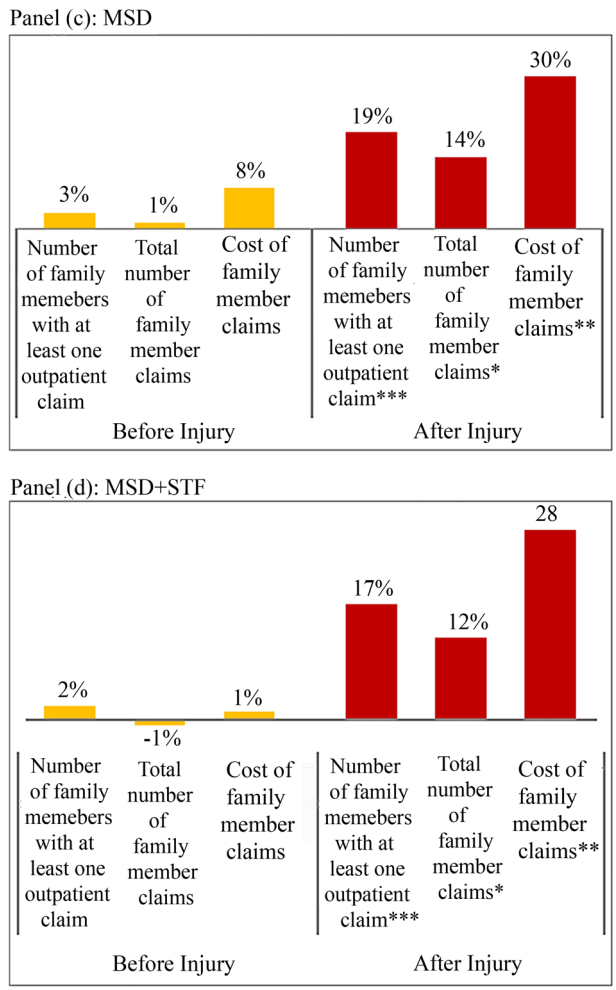

FIGURE 3. Differences between severely and non-severely injured worker families in before-injury and after-injury periods: Percentage of non-severely injured estimates and paired *t* test results

showed before-after decreases rather than increases in outcomes for both severely injured and non-severely injured worker families, most of them statistically significant. We found no statistically significant differences between outcomes for severely injured and non-severely injured worker families in either the before-injury or after-injury periods (Appendix 3).

Regression Analyses

Number of family members with at least one outpatient claim

As shown in Table II, our main explanatory variable, severity of occupational injury, took the expected positive sign and the effect was statistically significant ($P < 0.01$) for MSD claims. Controlling for all covariates, the expected number of family members of severely injured workers treated for outpatient MSD was 17% higher than the number of family members of non-severely injured workers treated for MSD within 3 months after injury.

Results were also statistically significant for several covariates. For example, an additional family member with before-injury outpatient MSD claims would increase by 101% ($P < 0.01$) the expected number of family members with after-injury outpatient MSD claims. If the injured worker was male, the expected number of family members with outpatient MSD claims would be 20% higher ($P < 0.01$). The expected number of family members with outpatient MSD claims for families with comprehensive health plan was 19% lower than for families with PPO health plan (the reference category) holding the other variables constants.

As also shown in Table II (last column), results for MSD + STF claims together were similar to those for MSD claims alone. The coefficients of most of the covariates were also similar to the MSD only regression. Results for all other claims (excluding MSD + STF) showed no significant

TABLE II. Number of Family Members With at Least One Outpatient MSD or MSD+STF Claim within 3 Months Following Occupational Injury: Incidence Rate Ratios (IRR) From Negative Binomial Regression

Variables	MSD	MSD+STF
Severity of occupational injury	1.17[a]	1.15[a]
Family member outpatient claim 3 months before injury	2.01[a]	1.88[a]
Sex of injured worker (1 if male)	1.20[a]	1.16[a]
Age of injured worker	1.01[a]	1.01[a]
Job classification of injured worker (1 if paid hourly)	1	1.03
Union status of injured worker (1 if union member)	1.06	1.06
Region (Northeast reference)		
North central	1.09	1.09
South	1	0.944
West	1.03	1.03
Industry (Manufacture-durable reference)		
Manufacture nondurable	1.05	1.03
Transport	0.98	0.93
Finance	0.67	0.76
Service	1.03	0.95
Health plan type (PPO reference)		
Comprehensive	0.81[a]	0.85[a]
HMO	1.20[a]	1.16[a]
POS	1.04	1.06
Other	0.88	0.83
Constant (intercept)	0.06[a]	0.1
Observations	17,239	17,239

[a] $P < 0.01$.

TABLE III. Total Number of Family Member Outpatient MSD or MSD+STF Claims Within 3 Months Following Occupational Injury: Incidence Rate Ratios (IRR) From Negative Binomial Regression

Variables	MSD	MSD+STF
Severity of occupational injury	1.15[b]	1.09
Family member outpatient claim 3 months before injury	1.46[a]	1.37[a]
Sex of injured worker (1 if male)	1.44[a]	1.33[a]
Age of injured worker	1.02[a]	1.02[a]
Hourly/salary status (1 if paid hourly)	0.94	0.94
Union status of injured worker (1 if union member)	1.07	1.02
Region (Northeast reference)		
North central	1.01	1.04
South	0.94	0.88
West	0.95	0.96
Industry (Manufacture-durable reference)		
Manufacture nondurable	1.1	1.04
Transport	1.07	0.97
Finance	0.52	0.61
Service	1.17	1.03
Health plan type (PPO reference)		
Comprehensive	0.76[a]	0.80[a]
HMO	1.12	1.08
POS	0.97	0.99
Other	0.88	0.73
Constant	0.10[a]	0.18[a]
Observations	17,239	17,239

[a] $P < 0.01$.
[b] $P < 0.05$.

difference between severely injured and non-severely injured worker families (See Appendix 4).

Total number of family member outpatient claims

Results are presented in Table III. Severe occupational injury was associated with 15% more family MSD claims after injury ($P < 0.05$). Results for all MSD and STF claims together showed a smaller, 9% increase for severe injury that was statistically non-significant. Results for all other claims, reported in Appendix 5, showed that injury severity was not associated with the number of claims after injury.

Total cost of family member outpatient claims

Cost results are presented in Table IV. Expected family member outpatient MSD costs were \$206 and \$154 after severe and non-severe injury, respectively. The difference between the two (34% or \$53) was statistically significant ($P < 0.01$). The difference in outpatient MSD+STF costs was lower in percentage terms but similar in absolute terms (24% or \$48) ($P < 0.01$).

Cost of family member outpatient claims on the national level

Our data showed that 16.2% of occupational injuries were classified as severe. As a point of comparison, using BLS and other data Leigh [2011] classified 18% of injuries as non-medical only (indemnity claims), although non-medical-only claims include those with 3–7 days away from work, which we excluded. The results of our two-part model

TABLE IV. Expected Mean Cost of Family Member Outpatient MSD or MSD+STF Claims Within 3 Months Following Occupational Injury by Injury Severity

Injury severity	MSD	MSD + STF
Severely injured	\$206 [\$204, \$208]	\$245 [\$243, \$247]
Non-severely injured	\$154 [\$152, \$155]	\$197 [\$196, \$199]
Difference	\$53 [\$52, \$53]	\$48 [\$47, \$48]
Percentage difference (%)	34	24
t	191	242
Pr(|T| > |t|)	0.000	0.000

Note: Some numbers do not add up due to rounding.

showed $53 additional cost per severe injury of family MSD claims in the 3 months after injury. Using these values and the 82.8–84.5% insurance coverage rate, we estimated that the annual, national outpatient healthcare cost of additional MSD claims of family members associated with severe injury could be between $29.1 million (0.162 × 4.1 million × 0.828 × $53) and 33.1 million ((0.18 × 4.1 million × 0.845 × $53) in 2005-2006 (2013 dollars). The additional cost observed in the regression analysis of MSD+STF claims ($48 per injury) would yield a slightly lower estimate.

DISCUSSION

Overall, results were in agreement with our study hypothesis. There was little before-injury difference in the number of family members with outpatient MSD claims or in the total number of MSD claims for family members of severely and non-severely injured workers (Table I and Figs. 2 and 3). Yet in the 3 months after injury, family members of severely injured workers were more likely to suffer MSDs than family members of non-severely injured workers. The negative binomial regression analysis showed that, controlling for the before-injury number of family members with MSD claims and other covariates, severity of occupational injury was associated with a 17% higher number of family members with outpatient MSD claims within 3 months after-injury (Table II). Severe occupational injury was also associated with a 15% higher total number of MSD claims after injury (Table III). These estimates were close to the percentage differences observed in the descriptive analysis. The findings suggest that the health impact of occupational injuries might not be limited to injured workers, extending as well to increased likelihood that family members suffer from MSD.

Results appeared generally similar when the category of claims examined was expanded to include STFs, suggesting that severe injuries might also be associated with this type of outcome. However, since only 19% of claims in the MSD+STF group had one of the added STF ICD-9 codes, the modest differences between the MSD and MSD+STF results implied that association of severity with these types of STF claims was considerably lower than for claims in the MSD set of codes (which also includes some STFs). In fact, regression results for total number of outpatient MSD claims (15% higher for SI) and MSD + STF claims (9% higher for SI) actually imply a lower number of claims with the added STF codes for severely injured worker families, rather than higher (Table III). Thus, the association of severe injury with family member claims appears to exist mainly or exclusively for those conditions associated with overexertion, excessive force, and awkward postures, rather than for more discrete events such as STFs. The statistically non-significant coefficient of the severity variable in the analysis of other claims (not MSD or STF) (Appendices 4 and 5) also suggested that injury severity may not be positively associated with most other types of claims.

Severe occupational injury was associated with increased outpatient MSD costs as well. The descriptive statistics showed that the average outpatient MSD costs of family members of severely injured workers increased by 25% compared to 3% for family members of non-severely injured workers, and a similar difference (30%) was observed in the comparison of severely injured and non-severely injured worker families in the after-injury period (Fig. 2). The estimates of the two-part regression model suggested that this comparison did not overstate the difference associated specifically with severe injury, since, controlling for several other factors, severe injury was associated with 34% higher outpatient MSD costs of family members in the 3 months following injury (Table IV). Our cost estimates are low for the following reasons. First, we considered only outpatient claims, excluding pharmacy and inpatient costs. Second, we did not consider the impact of non-severe occupational injuries (relative to non-injury) that could also trigger MSD for family members, although the observed post-injury increases in the case of non-severe injury were small and statistically non-significant (Fig. 2). Third, the 3 month after-injury period was arbitrary, and might be too short to fully capture all the MSD costs of family members. Fourth, costs of injuries that went untreated due to high out-of-pocket costs, lack of insurance, or other reasons, were not included. Costs of alternative treatment modalities not resulting in medical claims were also not captured. Finally, cost estimates did not capture the pain and suffering of family members of injured workers.

Our national estimate implies that severe occupational injury imposed formerly unrecognized economic burden of between $29 million and $33 million in terms of outpatient MSD claims upon family members of severely injured workers. This estimate is low for the reasons just stated, and also because BLS underestimates the actual number of non-fatal occupational injuries [Leigh et al., 2004; Dong et al., 2011].

Limitations and Strengths

This study has several limitations. First, the 3-month observation periods captured only short run impacts of work injury, and only outpatient claims were included. We limited the follow up period to 3 months after injury to obtain sufficient observations and to be consistent with the study of Asfaw et al. [2012]. Second, we excluded workers who suffered occupational injury during the first and last 3 months of each year we examined. This could have produced biased results if there were systematic differences between injuries occurring within the included periods and injuries occurring

within the excluded periods. Third, we excluded workers with multiple occupational injuries which might have resulted in an underestimate of injury severity. Fourth, the database we used was restricted to large employers who were clients of Thomson Reuters, and to workers who obtained health insurance for themselves and their dependents through their employers. Truven-provided weights from the CCE database could make the results only somewhat more representative of the national, insured population. Fifth, we included only occupational injuries resulting in workers' compensation claims, although many occupational injuries do not result in workers' compensation claims [CDC, 2010].

This study also has several strengths. First, the injuries we examined occurred over a range of dates, and the periods we examined before and after injury were shorter than those examined by Brown et al. [2007] and, therefore, the results were less likely to have been influenced by trends affecting healthcare use. Second, our focus on only injured workers helped us to create comparable groups of families. As shown in Figure 2, we did not observe a statistically significant difference between families of severely and non-severely injured workers in the number of family members with outpatient MSD claims 3 months before injury. Had we compared injured to non-injured workers, who might have been different, for example, in terms of their socio-economic status, we might have found major differences in the before-injury health status of their family members. In addition to creating comparable groups of families, we controlled for influences of covariates including before-injury family member outpatient MSD claims and other characteristics of injured workers. Third, we used doctor-diagnosed health problems instead of self-reported symptoms to measure the health status of family members.

CONCLUSION

While the scope of economic research in the area of occupational safety and health has broadened from direct economic impacts to wide-ranging social and economic consequences of occupational injuries and illnesses, most impact assessment studies have not examined consequences beyond the injured worker. This study added a new dimension in occupational injury research by providing empirical evidence on the impact of occupational injury on the MSDs suffered by family members. Our findings support the need for a greater focus on the secondary effects of occupational injury on the families of injured workers in order to more fully understand the burden of injury at work. These types of indirect health effects of occupational injuries should be taken into account when considering the value of interventions to prevent injuries at work.

It is also worthwhile to consider that the impact of occupational injury on family members might not be limited to MSDs. Family members of severely injured workers might be more likely to experience increases in other physical and emotional problems in both the short and longer terms, especially if family income decreases substantially. We are working to explore these effects. In addition, it would be useful to examine the impact of different types, natures, and extent of specific injuries (e.g., body part injured) on family member health, and potential differences in the health impacts of occupational injuries on different family members (e.g., spouses vs. children).

AUTHOR CONTRIBUTIONS

Abay Asfaw conceived the study and all authors participated in the design of the study. Abay Asfaw and Tim Bushnell performed the analyses, and all the authors participated in the interpretation of the results and writing the manuscript. Regina Pana-Cryan, Seven Sauter, and Tim Bushnell critically reviewed and edited the final manuscript draft.

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Appendix 1

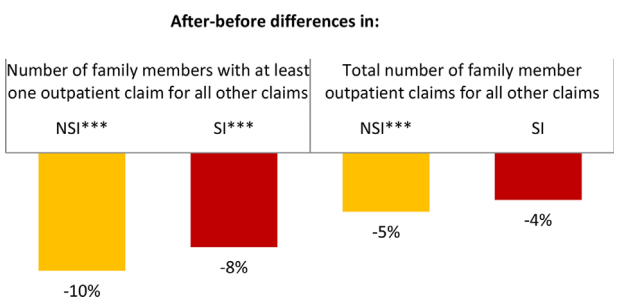
Frequency and Selected MSD or STF ICD-9 Diagnosis Codes Among Outpatient Claims of Family Members of Injured Workers Within 3 Months Before and After Occupational Injury

Diagnoses	ICD-9 code range	Number of claims[a]
Carpal tunnel and related	354.0–354.9	569
Hernia	550.0–553.9	417
Internal derangement of knee	717.0–717.9	842
Other joint disorders	718.0–719.9	7,945
Dorsopathies	721.0–724.9	15,156
Peripheral enthesopathies and Other disorders of synovium, tendon, and bursa	726.0–72.79	3,826
Other fibromatoses and Other disorders of muscle, ligament, and fascia	728.7–728.8	1,102
Other disorders of soft tissues	729.0–729.9	3,730
Fracture	800.0–829.1	4,032
Dislocation	830.0–839.9	3,270
Sprain	840.0–848.9	6,889
Intracranial injuries	850.0–854.9	465
Contusion	920.0–924.9	1,468

[a]Claims were counted more than once if they contained codes in more than one range.

Appendix 2

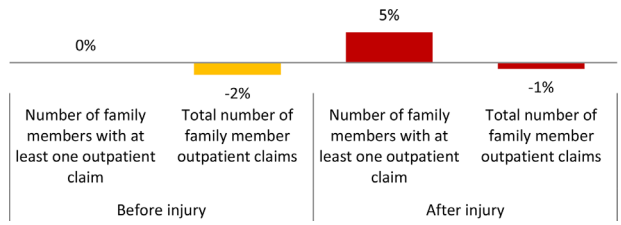
Differences between Before-Injury and After-Injury Periods for All Other Claims: Percentage of Before-Injury Estimates and Paired *t* Test Results



NSI, Non-severely injured workers; SI, Severely injured workers.
Note: We expressed after-injury increases as positive percentages.
$^{*}P < 0.10$.
$^{**}P < 0.05$.
$^{***}P < 0.01$.

Appendix 3

Differences Between SI and NSI Worker Families in Before-Injury and After-Injury Periods for All Other Claims: Percentage of Non-Severely Injured Estimates and Paired *t* Test Results.



NSI, Non-severely injured workers; SI, Severely injured workers.
Note: We expressed higher values for families of severely injured workers as positive percentages.
$^{*}P < 0.10$.
$^{**}P < 0.05$.
$^{***}P < .01$.

Appendix 4

Number of Family Members With at Least One Outpatient Claim With All Other Diagnoses (Except MSD + STF) Within 3 Months Following Occupational Injury: Incidence Rate Ratios (IRR) from Negative Binomial Regression

Variables	IRR
Severity of occupational injury	1.01
Family member outpatient other claim 3 months before injury	1.23[a]
Sex of the injured worker	1.28[a]
Age of the injured worker	0.99[a]
Union status of the injured worker	1.07[a]
Hourly/salary status (1 if paid hourly)	1.06[b]
Region (Northeast reference)	
North central	0.95[b]
South	0.93[a]
West	0.95[b]
Industry (Manufacture-durable reference)	
Manufacture nondurable	1.02
Transport	1.04
Finance	1.04
Service	1.05[c]
Health plan type (PPO reference)	
Comprehensive	0.91[a]
HMO	1.06[a]
POS	1.08[b]
Other	0.79
Constant	1.12
Observations	17,238

[a]$P < 0.01$.
[b]$P < 0.05$.
[c]$P < 0.10$.

Appendix 5

Total Number of Family Member Outpatient Claims With All Other Diagnosis Codes (Except MSD + STF) Within 3 Months Following Occupational Injury: Incidence Rate Ratios (IRR) From Negative Binomial Regression

Variables	IRR
Severity of occupational injury	0.10
Family member outpatient other claim 3 months before injury	1.12[a]
Sex of the injured worker	1.34[a]
Age of the injured worker	0.99[a]
Union status of the injured worker	1.09[a]
Hourly/salary status (1 if paid hourly)	1.07[b]
Region (Northeast reference)	
North central	1.00
South	0.98
West	0.97
Industry (Manufacture-durable reference)	
Manufacture nondurable	1.01
Transport	1.00
Finance	1.03
Service	1.00[c]
Health plan type (PPO reference)	
Comprehensive	0.94[b]
HMO	1.05
POS	1.04
Other	0.66[a]
Constant	1.73[a]
Observations	17,238

[a] $P < 0.01$.
[b] $P < 0.05$.
[c] $P < 0.10$.

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