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Surveillance of Work-Related Musculoskeletal Injuries Among Union Carpenters

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Combined data sources, including union administrative records and workers' compensation claims, were used to construct event histories for a dynamic cohort of union carpenters from Washington State during the period 1989–1992. Person-time at risk and the events of interest were stratified by age, sex, time in the union, and predominant type of carpentry work. Poisson regression techniques were used to identify subgroups at greatest risk of filing claims for a variety of musculoskeletal disorders defined by ANSI codes for body part injured and injury nature.

Distinguishing different kinds of musculoskeletal disorders, even crudely with ANSI codes, led to different conclusions about the effects of the explanatory variables. Among older workers, the rates of fractures of the foot were higher, while rates of contusions of the hand and foot were lower. Women had higher rates of sprain/strains and nerve conditions of the wrist/forearm. Higher rates of injuries to the axial skeleton were seen among carpenters who did predominantly light commercial and drywall work, while piledrivers had lower rates of these injuries. Drywall workers had higher rates of sprains to the ankle/lower leg. Workers who were members of the union as long as four years had lower risks for the vast majority of musculoskeletal disorders studied. Similar patterns were seen for more serious claims that resulted in paid lost time from work. Am. J. Ind. Med. 32:629–640, 1997. *© 1997 Wiley-Liss, Inc.*

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INTRODUCTION

Musculoskeletal disorders are a common cause of activity limitation, including temporary and permanent disability, in the United States [Frymoyer and Mooney, 1986; Cunningham and Kelsey, 1984]. A number of situations within the workplace are conjectured to contribute to the increasing magnitude of musculoskeletal impairments, including postural stress from prolonged sitting, standing, or kneeling, or holding an extremity in an uncomfortable or awkward position; stereotyped and repetitive tasks leading to chronic injury; peak overload injuries to the axial or peripheral skeleton; and environmental factors, including psychological stresses, job dissatisfaction, and complex social issues, such as compensation laws and disability systems [Frymoyer and Mooney, 1986].

Occupational injury rates in the construction trades, including carpentry, are high compared to the general workforce in the United States. The Bureau of Labor Statistics (BLS) [U.S. Department of Labor, 1995] reported an overall rate of lost time or medical injuries or illnesses of 8.4 per 100 full-time workers in 1994. During the same year, a rate of 11.8 per 100 full-time workers was reported among the construction trades as defined by Standard Industrial

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Classification codes 15 (building construction by general contractors), 16 (other construction by general contractors), and 17 (construction by special trade contractors) [Standard Industrial Classification Manual, 1987].

BLS data, the primary source of data on occupational disorders in the construction trades, are based on reports of Occupational Safety and Health Administration (OSHA) logs from a probability sample, rather than a census of the entire population. Employment statistics are used to calculate estimated rates of injury and illness per 100 full-time workers with full-time work defined as 2,000 hr/year. A cohort approach, using individual person-hours of work time as the denominator, revealed rates of medical cost or lost-time compensation claims of 43.7 per 200,000 work hours among union carpenters between 1989 and 1992—a rate much higher than BLS estimates [Lipscomb et al., 1996]. Among that same cohort, 45% of all workers' compensation claims filed were for musculoskeletal injuries and disorders.

Since there is no comprehensive database available in the United States for the surveillance of occupational disorders, there is interest in how existing databases might be used for surveillance purposes. This seems particularly relevant to construction workers with high rates of compensation claims and known exposures to potential risk factors for musculoskeletal disorders [Schneider and Susie, 1994]. Practical problems that affect the surveillance of construction workers, including changing employers, irregular and temporary employment, and often small and dispersed work sites, make the use of existing data sources particularly appealing for this occupational group.

Workers' compensation claims provide information about events that have been recognized to be related to the workplace, but alone they do not provide any information about the population from which the claims arose. We used combined administrative data sources to identify an historical cohort of union carpenters, their person hours at risk, and the compensation claims they filed. These pieces of data were used to construct event histories that could be used with survival techniques to identify subgroups at greater risk of filing claims for a variety of musculoskeletal disorders among this cohort.

MATERIALS AND METHODS

Data Sources

Health insurance eligibility files from the Carpenters Trusts of Western Washington were used to identify a cohort of 10,935 active union carpenters who worked at least 3 months of union time during 1989–1992. These files contained the hours worked by each individual for each month from January 1, 1989 through December 31, 1992, providing person-hours at risk as a union carpenter. Washington State and national union membership files of the United Brotherhood of Carpenters and Joiners of North America (UBC) provided dates of birth, sex, union local affiliation, and initiation date into the union for cohort members. No race information was available from these data sources. The Washington State Department of Labor and Industries (L&I) provided records of workers' compensation claims filed by these individuals during the period 1979–1992, including medical only claims, as well as those that resulted in lost work time. These data were used to identify the injury events of interest. A unique identifier was assigned to each individual by the Carpenters Trusts of Western Washington. Data were provided from all sources with this identifier to allow linkage of all data on an individual basis.

Definition of Events of Interest

For these analyses, the events of interest were defined by American National Standards Institute (ANSI) codes. Codes are provided for the part of the body injured, the nature of the injury, the type (mechanism) of injury, and the source (substance or object associated with the injury) of injury. These codes are included in the L&I data based on the first report of injury. Analyses presented in this report were based on cross-classifications of body part injured (e.g., back, neck, shoulder) and the injury nature (e.g., sprain, contusion). Only events that occurred in a month during which the individual had worked union hours were counted, so that events and time at risk were counted on the same basis for rate calculations. Work-related injuries did occur in months when no union hours were worked. These nonunion claims were not included, since no information was available regarding the type of work or number of hours worked in these months. We analyzed conditions for which the ANSI nature code was compatible with a musculoskeletal injury or disorder and for which there were 50 or more claims filed during this 4-year period. Initially, we included all claims that were filed by these carpenters, excluding those that were rejected for workers' compensation coverage. Later analyses were restricted to more serious claims that resulted in lost time with pay. In Washington State, an injured worker receives payment for lost time after 3 days of missed work. The musculoskeletal conditions we explored, as defined by ANSI codes, were largely sprains, but also included contusions, fractures, nerve conditions of the wrist/forearm, and ill-defined conditions of the back.

Definition of Time at Risk and Covariates

Person-hours of work as a union carpenter was used as the measurement of time at risk. The individual was considered to be at risk of filing a work-related claim at any time he was working, regardless of prior events. The occurrence of one injury did not remove workers from the risk set for a new event as long as they were still working. Although person-hours are used as the measurement of time at risk, the person-month is effectively the unit of analysis, since we do not know when the hours in any given month were accumulated. All hours worked in a month in which an injury occurred were counted as time at risk.

Covariates considered in these analyses included age, sex, time in the union, and predominant type of carpentry work. Our prior analyses of this cohort had shown that women and workers under the age of 30 had higher rates of filing all claims [Lipscomb and Dement, 1996]. Time in the union was dichotomized at four years in an attempt to separate apprentices from journeymen carpenters. To reach journeyman status, an inexperienced carpenter must be in the union at least 4 years and complete appropriate training. The union local affiliation was the only surrogate available for characterizing the type of work done by cohort members. The locals represented by this cohort were grouped into eight categories by the District Environmental Coordinator with the Carpenters' Health and Safety Fund based on the predominant type of carpentry work done by the locals. These categories included light commercial, heavy commercial, drywall, millwrighting, piledriving, cabinet and fixture work, residential, and a mixed category. Light commercial work involved construction on projects of 2–3 stories. Heavy commercial work involved high-rise buildings and interstate and freeway work. Millwrights are carpenters who work in industry and are often involved in repair and maintenance of heavy machinery. The mixed category includes those locals for which there was not a predominant type of work. Since there was no a priori low-risk group identified, deviation from the mean coding was used for the predominant types of carpentry work. This coding uses the overall cohort as the referent group, allowing comparisons of these predominant types of carpentry work to the overall group mean [Lemeshow and Hosmer, 1984].

Analyses

Crude incidence density rates were calculated for each of the ANSI definitions of musculoskeletal injuries. Using a customized program, each of the events of interest and person-time at risk was stratified by age, sex, time in the union, and predominant type of carpentry work for analyses with Poisson regression. The program treated age and time in the union as time-varying variables, allowing them to change appropriately throughout the 48-month follow-up period.

A popular application of Poisson regression concerns the modeling of failure rates for different subgroups [Kleinbaum et al., 1988]. In this case, it was used to determine whether the rates of specific types of musculoskeletal disorders, defined by ANSI codes, were significantly different across strata of age, sex, predominant job task, and time in the union. Multiple events were allowed for the same worker, of the same or different type, with each considered independent in the statistical analysis. A priori, it was decided that age and sex would be left in the models for descriptive purposes. A separate Poisson regression model was created for each of the defined musculoskeletal disorders or injuries. When limiting the analyses to more serious events which resulted in paid lost time from work, the data were more sparse. These models were limited to events which occurred at least 40 times over this 4-year period of time.

The generation of descriptive statistics, initial calculation of crude and stratified rates, and the data stratification were done using SAS [SAS Version 6.11]. Poisson regression analyses were done using EGRET [Statistics and Epidemiology Research Corporation, 1991].

RESULTS

Description of the Cohort, Hours at Risk, and Crude Rates of Filing Claims

A cohort of 10,935 active union carpenters was identified, each of whom had worked at least 3 months of union hours during 1989–1992. The cohort consisted of 10,847 men (98%) and 222 women (2%). Age at entry into the cohort ranged from 17 to 76, with a mean of 35 and a median of 34. Time in the union at entry into the cohort ranged from less than 1 year to 48 years with a mean of 6.2 years and a median of 1 year.

These individuals worked a total of 38,998,131 hours during the 4-year follow-up period. Workers present at the beginning and the end of follow-up, but who may not have worked every month averaged 1,700 hr/year, consistent with reports that construction workers in the United States work 1500–1800 hr/year [Report of the National Conference on Ergonomics, Safety and Health, 1993].

Claims Filed

Using the ANSI codes body part by injury nature, there were 16 categories of musculoskeletal injuries or disorders for which these carpenters filed 50 or more claims during the four year follow-up period. There were 3,050 claims filed for one of these 16 conditions, of which 1,162 (38%) resulted in paid lost time from work. The claims are defined in Table I, including the total number of claims filed for each disorder or injury, the number and percentage that resulted in paid lost time, and the crude rates (number of cases/200,000 hr worked) at which these events occurred. These events have been grouped according to injuries to the axial skeleton, the upper extremity, or the lower extremity. The highest overall

TABLE I. Number and Rates of Musculoskeletal Disorders and Injuries Defined by Cross-classification of ANSI Body Part Code and Nature Code Among Union Carpenters in Washington State, 1989–1992*

Body part/ injury nature	No. filed	Rate[a]	No. with paid lost time (% with lost time)	Rate[a]
Axial skeleton				
Back sprain/strain	1,118	5.7	486 (40.7)	2.3
Back ill-defined symptoms	77	0.39	48 (62.5)	0.25
Neck sprain/strain	115	0.59	40 (34.8)	0.21
Back and neck sprain/strain	270	1.4	91 (33.7)	0.47
Upper extremity				
Shoulder sprain/strain	144	0.73	69 (47.9)	0.35
Elbow sprain/strain	92	0.47	29 (31.5)	0.15
Wrist/forearm sprain/strain	134	0.69	41 (30.6)	0.21
Hand/finger sprain/strain	66	0.34	18 (27.3)	0.09
Hand/finger contusion	175	0.90	11 (6.3)	0.06
Hand/finger fracture	151	0.77	51 (33.8)	0.26
Nerve condition of the wrist/ forearm	78	0.40	54 (69.2)	0.28
Lower extremity				
Knee sprain/strain	211	1.1	100 (47.4)	0.51
Ankle/lower leg sprain/strain	168	0.86	48 (29.6)	0.25
Knee contusion	73	0.37	15 (20.5)	0.08
Foot/toes contusion	102	0.52	12 (11.8)	0.06
Foot/toes fracture	76	0.39	49 (64.4)	0.25

*Sprain refers to sprain/strain. In defining body parts, hand and fingers are combined, as are foot and toes, wrist and forearm, and ankle and lower leg.
[a]Rates are per 200,000 hr worked as a union carpenter.

crude rate of claims occurred for back sprains (5.7), followed by sprains to the neck and back (1.4) and sprains of the knee (1.1). Restricting data to paid lost time revealed a similar pattern but with knee sprains (0.51) being second highest after back sprains (2.3).

These 3,050 claims were filed by 2,376 different individuals. The distribution of the number of claims per individual is shown in Table II. The number and percentage of repeat claims for the same individual for each event definition are presented in Table III. The largest percentages of repeat claims were seen for back sprains (11.6%) followed by sprains to the back and neck (7%) and knee (4.3%). An additional 209 claims (not included in analyses) for these musculoskeletal injuries or disorders were filed on nonunion hours, accounting for 6.4% of all claims filed by the cohort. The percentage ranged from less than 1% for sprains of the neck and ankle to 10% for ill-defined back disorders and sprains of the wrist.

The crude rates of filing claims for each of the 16 disorders defined by ANSI codes are presented by predominant type of work in Table IV. For each type of carpentry work, back sprains occurred at the highest rate. The rates for back sprains also varied more by task than for any other injury, ranging from 8.6 and 8.5 per 200,000 hr worked among workers doing drywall and residential work, respectively, to 1.4 per 200,000 hr worked among cabinet makers.

The results of the Poisson regression analyses on all claims filed are presented in Table V (axial skeleton), Table VI (upper extremity), and Table VII (lower extremity). Age was nonsignificant as a risk factor for 10 of the 16 musculoskeletal conditions examined when controlling for

TABLE II. Count of Claims Filed Per Individual Union Carpenters Washington State, 1989–1992

Claims	Individuals
1	1,856
2	401
3	94
4	20
5	2
6	1
7	2
Total Claims Filed	3,050

TABLE III. Percentage of Repeat Claims by ANSI Claim Definitions Union Carpenters Washington State, 1989–1992

	No. filed	No. of repeat claims (%)
Axial skeleton		
Back sprain	1,118	130 (11.6)
Back ill-defined symptoms	77	1 (1.2)
Neck sprain	115	4 (3.4)
Back and neck sprain	270	19 (7.0)
Upper extremity		
Shoulder sprain	144	0
Elbow sprain	92	2 (2.3)
Wrist/forearm sprain	134	2 (1.5)
Hand sprain	66	0
Hand contusion	175	3 (1.7)
Hand fracture	151	0
Nerve condition of the wrist/forearm	78	1 (1.3)
Lower extremity		
Knee sprain	211	9 (4.3)
Ankle/lower leg sprain	168	2 (1.2)
Knee contusion	73	1 (1.4)
Foot contusion	102	1 (1.0)
Foot fracture	76	1 (1.3)

TABLE IV. Crude Rates* and 95% Confidence Intervals† by Predominant Type of Work: Union Carpenters Washington State, 1989–1992

	Predominant type of work							
Disorder	Light commercial n = 2,831 P/hr = 10,131,169	Heavy commercial n = 3,922 P/hr = 15,045,437	Drywall n = 1,525 P/hr = 5,695,264	Millwrighting n = 190 P/hr = 682,210	Piledriving n = 602 P/hr = 2,613,130	Cabinet/ fixture n = 72 P/hr = 282,295	Residential n = 282 P/hr = 516,021	Mixed n = 960 P/hr = 3,496,215
Axial skeleton								
Back sprain	5.9 (5.3, 6.6)	5.2 (4.7, 5.7)	8.6 (7.6, 9.8)	3.5 (1.8, 6.1)	3.0 (2.1, 4.1)	1.4 (1.7, 7.1)	8.5 (5.3, 12.8)	4.3 (3.4, 5.4)
Back ill-defined	0.39 (0.24, 0.6)	0.35 (0.23, 0.51)	0.45 (0.24, 0.77)	0.59 (0.07, 2.1)	0.23 (0.05, 0.67)	0.71 (0.02, 4.0)	0.77 (0.09, 2.8)	0.57 (0.28, 1.0)
Neck sprain	0.02 (0.01, 0.03)	0.41 (0.28, 0.59)	1.2 (0.84, 1.7)	0	0.38 (0.12, 0.89)	0	1.5 (0.41, 3.8)	0.17 (0.04, 0.50)
Back/neck sprain	1.3 (1.0, 1.7)	1.1 (0.88, 1.4)	2.5 (2.0, 3.2)	1.8 (0.66, 3.9)	0.46 (0.17, 1.0)	0	1.2 (0.25, 3.5)	1.4 (0.90, 2.1)
Upper extremity								
Shoulder sprain	0.59 (0.40, 0.84)	0.65 (0.48, 0.86)	1.5 (1.1, 2.0)	0	0.38 (0.12, 0.89)	0.71 (0.02, 4.0)	1.5 (0.41, 3.8)	0.46 (0.20, 0.91)
Elbow sprain	0.51 (0.33, 0.75)	0.44 (0.31, 0.61)	0.56 (0.32, 0.91)	0	0.23 (0.05, 0.67)	0.71 (0.02, 4.0)	0.77 (0.09, 2.8)	0.57 (0.28, 1.0)
Forearm sprain	0.81 (0.58, 1.1)	0.65 (0.48, 0.86)	0.70 (0.43, 1.1)	0.88 (0.18, 2.6)	0.15 (0.02, 0.54)	0	0.38 (0.01, 2.1)	0.74 (0.39, 1.3)
Hand sprain	0.30 (0.17, 0.50)	0.37 (0.25, 0.54)	0.53 (0.30, 0.87)	0	0.08 (0.002, 0.45)	0	0.38 (0.01, 2.1)	0.29 (0.09, 0.68)
Hand contusion	0.10 (0.01, 0.13)	0.87 (0.68, 1.1)	0.74 (0.46, 1.1)	1.2 (0.33, 3.1)	0.46 (0.17, 1.0)	0	2.7 (1.1, 5.6)	0.80 (0.44, 1.3)
Hand fracture	0.77 (0.55, 1.0)	0.76 (0.58, 0.99)	0.53 (0.30, 0.87)	0.88 (0.18, 2.6)	1.2 (0.69, 1.9)	1.4 (0.17, 5.1)	1.2 (0.25, 3.5)	0.86 (0.48, 1.4)
Nerve condition/ forearm	0.51 (0.33, 0.75)	0.27 (0.17, 0.42)	0.67 (0.40, 1.0)	0.29 (0.01, 1.6)	0.08 (0.002, 0.45)	0	0	0.51 (0.23, 0.97)
Lower extremity								
Knee sprain	1.2 (0.92, 1.6)	1.0 (0.80, 1.3)	1.3 (0.93, 1.8)	0.59 (0.07, 2.1)	1.0 (0.53, 1.7)	0	0	0.97 (0.57, 1.6)
Ankle sprain	0.73 (0.52, 0.99)	0.93 (0.73, 1.2)	1.3 (0.93, 1.8)	0.59 (0.07, 2.1)	0.38 (0.12, 0.89)	0	0.77 (0.09, 0.21)	0.74 (0.39, 1.3)
Knee contusion	0.39 (0.24, 0.60)	0.36 (0.24, 0.53)	0.56 (0.32, 0.91)	0.59 (0.07, 2.1)	0.31 (0.08, 0.79)	0	1.9 (0.62, 4.4)	0.11 (0.01, 0.40)
Foot contusion	0.47 (0.30, 0.70)	0.50 (0.36, 0.68)	0.56 (0.32, 0.91)	1.2 (0.33, 3.1)	0.38 (0.12, 0.89)	0	0	0.06 (0.03, 0.11)
Foot fracture	0.36 (0.21, 0.57)	0.36 (0.24, 0.53)	0.56 (0.32, 0.91)	0.59 (0.07, 2.1)	0.08 (0.002, 0.45)	0	0.77 (0.09, 0.21)	0.46 (0.20, 0.91)

*Rates are per 200,000 hours worked.
†Poisson confidence interval.
N, number of individuals; P/hr, person-hours.

the other variables in the model. Rate ratios decreased with increasing age for ankle sprains and contusions of the hand, foot, and knee. The effect of age went the other direction for fractures of the hand and foot. Those aged 30–44 years had a significant increase in the rate of fractures of the foot (rate ratio [RR] = 2.2). Those aged 30–44 years had more than twice the rate of elbow sprains of those less than 30 years of age.

No significant differences in rates were seen between men and women, except that women had 4.6 times the rate of wrist/forearm sprains of men and 3.7 times the rate of nerve conditions of the wrist/forearm. Among the latter, 80.8% (n = 63) had a specific ICD9 diagnosis of carpal tunnel syndrome (ICD9 354.0) attached to their medical claims. Other diagnoses for these nerve conditions of the wrist/forearm included enthesopathies, tenosynovitis, one ganglion (ICD9 727.43), and one diagnosis of cubital tunnel syndrome (ICD9 354.2).

Individuals whose predominant tasks were heavy commercial work, residential carpentry, or millwrighting did not have rates for any of these musculoskeletal disorders, which were significantly different from the overall mean. Individuals who did predominantly light commercial construction had 1.4 times the rate of back sprains compared to the overall group mean. Drywall workers had 1.8 times the rate of back sprains and simultaneous sprains to the back and neck and 1.6 times the rate of sprains to the lower leg/ankle compared to the overall mean. Piledrivers had a 28% lower rate of sprains to the back and a 37% reduction in rates of simultaneous sprains to the neck and back compared to the overall mean. Individuals affiliated with a local doing mixed tasks had 1.4 times the rate of wrist/forearm sprains compared to the overall group mean. To varying degrees, workers in the union long enough to reach journeyman status showed reduced claim rates for all events (RR = 0.42–0.89).

The back sprains among individuals affiliated with locals doing predominantly light commercial and drywall were most commonly described as overexertion injuries (>80%). In light commercial work, they were associated

TABLE V. Poisson Regression Results: Injuries to the Axial Skeleton: All Nonrejected Claims Filed by Union Carpenters Washington State, 1989–1992

	Type of event			
Covariates	Back sprain n = 1,118 RR (95%CI)	Neck sprain n = 115 RR (95%CI)	Back and neck sprain n = 270 RR (95%CI)	Back ill-defined n = 77 RR (95%CI)
Age[a]				
<30	1	1	1	1
30–44	1.0 (0.85, 1.2)	1.6 (0.93, 2.7)	0.90 (0.66, 1.2)	1.1 (0.58, 2.1)
>45 and	0.86 (0.70, 1.1)	1.0 (0.49, 2.1)	0.73 (0.48, 1.1)	1.4 (0.66, 2.9)
Sex				
Men	1	1	1	
Women	1.3 (0.82, 2.1)	1.8 (0.57, 5.7)	0.58 (0.14, 2.3)	—
Time in the union[a]				
<4 years	1	1	1	1
≥4 years	0.73 (0.64, 0.84)[c]	0.43 (0.28, 0.67)[c]	0.56 (0.43, 0.75)[c]	0.83 (0.50, 1.4)
Predominant task[b]				
Light commercial	1.4 (1.1, 1.7)[c]	—	1.2 (0.84, 1.6)	0.84 (0.49, 1.5)
Heavy commercial	1.2 (0.95, 1.5)	—	0.83 (0.61, 1.1)	0.68 (0.40, 1.2)
Drywall	1.8 (1.4, 2.3)[c]	—	1.8 (1.3, 2.5)[c]	1.0 (0.55, 1.9)
Millwright	0.88 (0.52, 1.5)	—	1.6 (0.79, 3.4)	1.2 (0.33, 4.2)
Piledriver	0.72 (0.51, 1.0)[c]	—	0.43 (0.21, 0.89)[c]	0.49 (0.17, 1.4)
Cabinet/fixture	0.38 (0.11, 1.3)	—	—	1.5 (0.25, 8.4)
Residential	1.5 (0.92, 2.3)	—	0.80 (0.30, 2.2)	1.7 (0.46, 6.0)
"Mixed"	0.95 (0.73, 1.2)	—	1.0 (0.93, 1.4)	1.2 (0.25, 5.9)

[a]Time-varying covariates.
[b]Deviation from mean coding used, comparisons to overall mean.
[c]Significant at $P = 0.05$.

most frequently with timber or slabs (23.5%), bodily motion (7.1%), structural metal (6.8%), and wood items (6.8%). Among drywall workers, back sprains were most commonly associated with sheetrock (43.2%), followed by bodily motion (6.6%), and timber and slabs (5.7%). Simultaneous sprains to the back and neck in drywall were most often the result of overexertion (73%), although 19% were the result of a fall. In addition, 46% of the ankle sprains in drywall workers resulted from a fall. The most common cause of forearm sprains in carpenters doing mixed tasks was overexertion (61.5%), and they are frequently associated with a hammer (23.1%) or a power drill (15.4%).

Predominant task was not able to be included in all the models. The distribution of observations did not allow the estimation of rate ratios (failure to converge) in models for nerve conditions of the forearm, contusions to the foot, and sprains to the neck, shoulder, elbow, hand, and knee. Thus, coefficients for predominant task are not included in the summary results of these models. In addition, there were only 72 individuals whose union local's predominant task was cabinet making. These 72 individuals were deleted from models for all conditions or injuries, except back sprains and ill-defined back conditions, because the models would not converge.

Claims Resulting in Lost Time With Pay

The number of claims was reduced significantly when analyzing only lost-time claims. The results of the Poisson regression models for the events that resulted in paid lost time from work (modeled if more than 40 events) are presented in Table VIII. Time in the union remained protective for all these events. Drywall workers had significantly higher rates of filing claims for back sprains that resulted in paid lost time than the rates for the overall group mean (RR = 1.8; 95%CI = 1.2, 2.5). These injuries were similar in mechanism and source to all back sprains among

TABLE VI. Poisson Regression Results: Injuries to the Upper Extremity: All Nonrejected Claims Filed by Union Carpenters Washington State, 1989–1992

	Type of event						
Covariates	Shoulder sprain n = 144 RR (95%CI)	Elbow sprain n = 92 RR (95%CI)	Forearm sprain n = 134 RR (95%CI)	Hand sprain n = 66 RR (95%CI)	Hand contusion n = 175 RR (95%CI)	Hand fracture n = 151 RR (95%CI)	Nerve condition forearm n = 78 RR (95%CI)
Age[a]							
<30	1	1	1	1	1	1	1
30–44	1.0 (0.67, 1.6)	2.2 (1.1, 4.5)[c]	1.0 (0.67, 1.6)	0.79 (0.44, 1.4)	0.63 (0.44, 0.90)[c]	0.79 (0.51, 1.2)	1.0 (0.55, 1.9)
≥45	0.86 (0.49, 1.5)	1.5 (0.67, 3.5)	0.54 (0.28, 1.1)	0.48 (0.20, 1.2)	0.42 (0.24, 0.72)[c]	1.3 (0.79, 2.2)	1.0 (0.49, 2.2)
Sex							
Men	1		1	1	1	1	1
Women	1.3 (0.41, 4.1)	—	4.6 (2.3, 9.2)[c]	0.90 (0.13, 6.5)	1.3 (0.49, 3.6)	1.3 (0.42, 4.2)	3.7 (1.3, 10.3)[c]
Time in the union[a]							
<4 years	1	1	1	1	1	1	1
≥4 years	0.43 (0.32, 0.67)[c]	0.75 (0.47, 1.2)[c]	0.44 (0.30, 0.66)[c]	0.51 (0.29, 0.91)[c]	0.42 (0.29, 0.61)[c]	0.58 (0.40, 0.86)[c]	0.65 (0.39, 1.1)[c]
Predominant task[b]							
Light commercial	—	—	1.5 (0.95, 2.5)	—	1.2 (0.82, 1.6)	0.94 (0.62, 1.4)	—
Heavy commercial	—	—	1.1 (0.70, 1.8)	—	0.93 (0.67, 1.3)	0.99 (0.68, 1.4)	—
Drywall	—	—	1.2 (0.67, 2.0)	—	0.67 (0.43, 1.1)	0.63 (0.37, 1.1)	—
Millwright	—	—	2.0 (0.72, 5.7)	—	1.6 (0.67, 4.0)	1.1 (0.41, 3.0)	—
Piledriver	—	—	0.31 (0.09, 1.1)	—	0.61 (0.29, 1.2)	1.5 (0.89, 2.5)	—
Cabinet/fixture	—	—	—	—	—	—	—
Residential	—	—	0.57 (0.10, 1.6)	—	1.6 (0.71, 3.5)	0.90 (0.27, 3.0)	—
''Mixed''	—	—	1.4 (1.2, 1.7)[c]	—	0.90 (0.32, 3.1)	1.1 (0.69, 1.8)	—

[a]Time-varying covariates.
[b]Deviation from mean coding used, comparisons to overall mean.
[c]Significant at $P = 0.05$.

drywall workers, with the majority described as overexertion injuries (85%) most commonly involving sheetrock (47.8%). Lost-time injury rates increased with increasing age for injuries to the peripheral skeleton that we examined, while lost-time injuries to the axial skeleton decreased after the age of 45. However, these age differences were not statistically significant. The rate ratio for women remained elevated for nerve conditions of the forearm (RR = 4.1; 95%CI = 1.3, 13.4). No women filed claims for knee sprains or foot fractures that resulted in paid lost time.

DISCUSSION

These analyses were accomplished by defining an historical cohort of union carpenters and constructing event histories for them through the use of combined administrative data sources. This allowed the analysis of the data using a cohort approach. Despite censored observations we were able to make use of all the available data, something of particular importance when studying a dynamic cohort. Rate ratios for different types of musculoskeletal injuries or conditions were calculated by age, sex, time in the union, and, in some instances, predominant type of carpentry work, using Poisson regression. Distinguishing different kinds of musculoskeletal events, even crudely with ANSI codes, led to different conclusions about the effects of the explanatory variables.

Rate ratios decreased with increasing age for ankle sprains and contusions of the hand, foot, and knee, while the effect of age went in the other direction for fractures of the hand and foot. Those aged 30–44 years had more than twice the rate of elbow sprains of those less than 30 years of age. Women had significantly higher rates than men for sprain/strains and nerve conditions of the forearm. Individuals who did predominantly light commercial construction or drywall had higher rates of back sprains compared to the overall group mean. Drywall workers also had higher rates of simultaneous sprains to the back and neck, and sprains to the

TABLE VII. Poisson Regression Results: Injuries to the Lower Extremity: All Nonrejected Claims Filed by Union Carpenters Washington State, 1989–1992

	Type of event				
Covariates	Knee sprain n = 211 RR (95%CI)	Ankle sprain n = 168 RR (95%CI)	Knee contusion n = 73 RR (95%CI)	Foot contusion n = 102 RR (95%CI)	Foot fracture n = 76 RR (95%CI)
Age[a]					
<30	1	1	1	1	1
30–44	1.0 (0.67, 1.5)	0.74 (0.51, 1.1)	0.48 (0.27, 0.86)[c]	0.50 (0.31, 0.81)[c]	2.2 (1.0, 4.5)[c]
≥45	1.5 (0.96, 2.3)	0.54 (0.32, 0.92)[c]	0.57 (0.27, 1.2)	0.49 (0.26, 0.93)[c]	2.6 (1.1, 6.2)[c]
Sex					
Men	1	1	1	1	1
Women	0.70 (0.17, 2.8)	1.5 (0.58, 4.3)	3.1 (0.96, 10.1)	0.60 (0.08, 4.3)	1.1 (0.15, 7.8)
Time in the union[a]					
<4 years	1	1	1	1	1
≥4 years	0.66 (0.48, 0.91)[c]	0.67 (0.48, 0.96)[c]	0.89 (0.52, 1.5)	0.62 (0.39, 0.99)[c]	0.53 (0.32, 0.89)[c]
Predominant task[b]					
Light commercial	—	1.1 (0.70, 1.6)	1.1 (0.62, 1.8)	—	0.99 (0.55, 1.8)
Heavy commercial	—	1.2 (0.85, 1.8)	0.84 (0.50, 1.4)	—	0.96 (0.56, 1.6)
Drywall	—	1.6 (1.0, 2.4)[c]	1.4 (0.79, 2.5)	—	1.4 (0.76, 2.6)
Millwright	—	0.92 (0.27, 3.1)	1.6 (0.47, 5.6)	—	1.5 (0.43, 5.3)
Piledriver	—	0.57 (0.26, 1.3)	0.82 (0.33, 2.1)	—	0.22 (0.04, 1.2)
Cabinet/fixture	—	—	—	—	—
Residential	—	0.93 (0.28, 3.2)	2.0 (0.57, 6.9)	—	1.8 (0.52, 6.4)
‘‘Mixed’’	—	0.96 (0.81, 1.2)	0.59 (0.27, 1.3)	—	1.2 (0.93, 1.7)

[a]Time-varying covariates.
[b]Deviation from mean coding used, comparisons to overall mean.
[c]Significant at $P = 0.05$.

lower leg/ankle compared to the overall mean. Piledrivers had reduced rates of injuries to the axial skeleton compared to the overall mean. Workers in the union for as long as 4 years demonstrated reduced rates for all disorders studied. When analyzing only claims that resulted in paid lost time from work, we had reduced power to detect differences in rates, but the overall patterns were not dissimilar to those seen when looking at all claims filed.

Among construction workers, safety practices have been reported to increase with age [Dedobbeleer and German, 1987]. Consistent with that finding, our crude results indicated that those less than 30 years old had significantly higher rates of all claims [Lipscomb et al., 1996]. However, when controlling for the other variables, the effect of age was nonsignificant as a risk factor for 10 of the 16 musculoskeletal conditions.

Few epidemiologic studies have examined differences in injury rates for men and women. This is especially true in construction work. Female electric utility workers have been reported to have higher overall injury rates [Kelsh and Sahl, 1996]. Consistent with our findings, discrepancies between women and men were seen for injuries to the wrist and very little difference was seen for back injuries. Among these electric workers, the greatest effect of sex was for lower-extremity injuries. This finding is different from those seen among these carpenters—likely a reflection of differences in job exposures.

Among the cross-classifications of ANSI codes for nature and body part that we evaluated, the designation nerve condition of the wrist/forearm is the closest approximation of carpal tunnel syndrome, and 81% of these claims had an ICD9 code specific to carpal tunnel syndrome. Although all these claims cannot be assumed to be carpal tunnel syndrome, the higher rate among women is consistent with sex differences reported for carpal tunnel syndrome based on self-report in the general population [Tanaka et al., 1994] or

TABLE VIII. Poisson Regression Results: Claims That Resulted in Paid Lost Time Filed by Union Carpenters Washington State, 1989–1992

	Type of event						
Covariates	Back sprain n = 456 RR (95%CI)	Back/neck sprain n = 91 RR (95%CI)	Shoulder sprain n = 69 RR (95%CI)	Hand fracture n = 51 RR (95%CI)	Nerve condition Forearm n = 54 RR (95%CI)	Knee sprain n = 100 RR (95%CI)	Foot fracture n = 49 RR (95%CI)
Age[a]							
<30	1	1	1	1	1	1	1
30–44	1.2 (0.94, 1.6)	1.0 (0.61, 1.9)	1.1 (0.60, 2.2)	0.91 (0.43, 1.9)	1.0 (0.50, 2.2)	1.5 (0.78, 2.7)	1.9 (0.80, 4.9)
≥45	0.94 (0.67, 1.3)	0.70 (0.32, 1.6)	1.4 (0.61, 3.0)	1.2 (0.47, 2.9)	1.3 (0.53, 3.2)	2.0 (1.0, 4.1)	2.7 (0.97, 7.5)
Sex							
Men	1	1	1	1	1	1	
Women	1.5 (0.76, 2.9)	0.75 (0.10, 1.6)	0.98 (0.14, 7.1)	1.3 (0.18, 9.8)	4.1 (1.3, 13.4)[c]	—	—
Time in the union[a]							
<4 years	1	1	1	1	1	1	1
≥4 years	0.55 (0.44, 0.69)[c]	0.45 (0.27, 0.75)[c]	0.43 (0.25, 0.74)[c]	0.59 (0.31, 1.1)	0.52 (0.28, 0.97)[c]	0.56 (0.35, 0.88)[c]	0.50 (0.27, 0.93)[c]
Predominant task[b]							
Light commercial	1.4 (0.98, 1.9)	—	—	0.70 (0.36, 1.4)	—	—	—
Heavy commercial	1.3 (0.91, 1.8)	—	—	0.89 (0.50, 1.6)	—	—	—
Drywall	1.8 (1.2, 2.5)[c]	—	—	0.74 (0.33, 1.7)	—	—	—
Millwright	1.2 (0.54, 2.5)	—	—	1.0 (0.18, 5.6)	—	—	—
Piledriver	0.66 (0.37, 1.1)	—	—	1.1 (0.44, 2.9)	—	—	—
Cabinet/fixture	0.51 (0.09, 2.9)	—	—	—	—	—	—
Residential	0.98 (0.43, 2.2)	—	—	2.3 (0.43, 1.9)	—	—	—
''Mixed''	1.2 (0.78, 1.8)	—	—	0.79 (0.55, 1.2)	—	—	—

[a]Time-varying covariates.
[b]Deviation from mean coding used, comparisons to overall mean.
[c]Significant at $P = 0.05$.

for occupational cases [Tanaka et al., 1988; Franklin et al., 1991]. The model for nerve conditions of the forearm is one in which predominant type of work could not be included so this model is not adjusted in even a crude way for the type of work done.

Strengths and Limitations

For some occupational injuries or disorders, including a number of musculoskeletal problems, time of onset of a particular episode and case definitions can be difficult to determine. The use of workers' compensation claims as the events of interest made defining episodes easy for these analyses, assuming that a new claim represents a new episode. The ANSI code definitions that we used are crude. These codes are based on the first report of injury, and they cannot necessarily be assumed to represent comparable International Classification of Disease codes.

We identified events of interest based on the ANSI codes assigned at the time of the first report of injury. In the state of Washington, medical only claims from employers who self-insure for work-related injuries and illnesses are not consistently coded, and claims, including those that result in the loss of time from work, do not have to be reported to the Department of Labor and Industries until the case is closed. While it is likely that we captured most paid lost time claims that occurred while working for self-insured employers, we could not capture all less serious self-insured claims filed by these carpenters. However, we did capture the time at risk for those individuals. If self-insured employers were more likely to hire individuals affiliated with certain types of work, this could result in biased results.

It is important to recognize that we studied claims that were filed and not health events. While this made counting of events easy, anything that influences whether a person chooses to file a workers' compensation claim will influence our results. We do not presume to have captured all musculoskeletal disorders related to the workplace among these carpenters. What we captured were events that the carpenter, employer, or care provider considered related to the workplace. This approach is likely to more completely capture acute traumatic events than events that may be the result of cumulative trauma, as the latter may be less likely to be counted as work related in compensation files.

For analyses of workers' compensation claims filed by these construction workers with variable work hours and sporadic employment, we felt that person-hours at work as a union carpenter was a more appropriate unit of measurement of time at risk than calendar time. For these analyses, we did not control in any manner for calendar time, assuming that there would not have been a change in risk of musculoskeletal injuries over the 4-year time period we were observing.

We had no information on hours these individuals may have worked, or even the type of work they may have done, aside from their union work. In an attempt to avoid overestimating rates, we only analyzed events which occurred in a month in which the individual worked union hours. This omitted only 6.4% of all claims filed by the cohort during the appropriate time period. However, exposures in nonunion work, as well as these other injuries that occurred on nonunion time, could have had an impact on the musculoskeletal disorders and injuries which we have described.

Our classification of predominant work is a crude aggregate measure. The groupings are not mutually exclusive with regard to predominant type of carpentry work. Even though a local may perform predominantly one task, this does not mean that is the only type of work done by members of that local, and there might actually be quite a bit of overlap in the nature of the tasks performed by people from different locals. No personal exposure information is available and no exposure information at all is available for these individuals before 1989 or when they entered the carpenter cohort. Our goal with these data sources was to identify groups that appeared to be at greater risk, and we were able to accomplish that goal to some extent. However, we have not controlled for individual work exposures. The models which would not converge with the variable for predominant job task included are not adjusted in even a crude way for job exposure; this should be kept in mind in interpreting and comparing the results for these different definitions of musculoskeletal disorders.

The dichotomization of time in the union at 4 years was done in an attempt to separate apprentices, still in training, from journeymen carpenters. However, it is not uncommon for individuals with prior carpentry experience to come into the union at the level of journeyman. In interpreting the findings related to this variable, it is important to recognize that this is only measuring time in the union and is not a clear separation of apprentices from journeymen or a measure of total carpentry experience.

Possible Interpretations of Results and Recommendations

The mechanism of fractures and contusions to the same body part could be theorized to be similar—perhaps only varying in the degree of force—making the increasing rate of fractures and decreasing rate of contusions with age difficult to explain. It seems unlikely that the explanation would relate to physiologic differences in bone densities among a cohort of predominantly male workers who do physical work, although perhaps this should be a consideration. Others have also reported older workers to be more likely to sustain fractures on the job than younger workers [Abraham et al., 1996]. The patterns of risk for these fractures and contusions are different across different types of predominant work task, suggesting perhaps that different exposures are responsible for these different types of injuries. Older workers could have delayed reaction time making them more likely to sustain fractures, although you would expect a similar rise in contusions as well if this were the case. It is possible that these findings are a reflection of differences in what people seek care for, or report to workers' compensation, based on age. Older workers could be less likely to report a contusion, which is less likely to result in loss of time from work, on workers' compensation than younger workers which could result in the diminished rate ratios for contusions with age. This hypothesis contrasts though with the finding that younger workers are more likely to seek emergency room care than older workers, but less likely to file a workers' compensation claim [Fingar et al., 1992].

Little is documented on health hazards of women carpenters. There are concerns about possible effects of peer pressure to perform comparably to men, lack of fit of basic tools due to smaller body habitus, and reduced upper body strength compared to men [Carpenter Focus Group, 1996]. The two events for which women had significantly higher rates than men are both conditions of the wrist/forearm—sprains and nerve conditions—raising questions about physiologic mechanisms related to the forearm. Sex may be a surrogate measure for physical size or strength. Since we did not have access to any data on personal exposures, it is also possible that the exposures of men and women are different. If the differences we saw were related to differences in health care-seeking behavior, we would expect a more universal effect. The differences seen between men and women warrant further investigation, even though women represent a small percentage of this cohort, making the rates for women more unstable.

The rate ratios for the different predominant types of carpentry work are diminished by using the overall group mean as the referent group, as opposed to having used an a priori determined low-risk group. This makes the modestly elevated rate ratios seen for drywall workers and light commercial workers of greater concern.

Elevated rates of ankle sprains were seen among drywall workers, as were all back sprains and more serious claims resulting in paid lost time from work and simultaneous sprains to the back and neck. Exposures that increase the risk of occupational low back pain are clearly documented among drywall workers, including handling heavy and awkward loads, consistent with the description of most of these injuries as overexertion injuries associated with sheetrock. It is not uncommon for drywall workers to put sheets of drywall on their heads to hold them in place as they are attached to the ceiling. These workers also describe a competitive atmosphere oriented towards very fast paced output [Carpenter Focus Group, 1996]. The finding that simultaneous back and neck injuries and ankle sprains among these workers are often caused by falls warrants further exploration. These workers should be targets for further assessment and possible intervention trials. More information on the seriousness of the events would also help provide information on the potential public health impact if interventions on behalf of these workers were successful.

Union workers may have safer work practices which are learned over time or in training even among individuals who enter the union as journeymen, with nonunion carpentry experience explaining the fact that having been in the union for 4 years or more was clearly protective for all events. Dedobbeleer et al. [1990] reported that unionized construction workers were more likely to use recognized safety practices, but this was largely explained by age. Among this cohort, this is not a function of age. It might be a reflection of different job assignments, with the less skilled workers receiving the more dangerous or physically taxing tasks. Individuals with union seniority would be more likely to work as foremen, perhaps performing more supervisory roles with less prolonged exposures. This could also reflect survivorship in the trade of the more fit individuals who did not drop out of the construction industry or different patterns of filing compensation claims based on time in the union. The behavior of these individuals who have been in the union less than 4 years and their work assignments should be assessed to avoid failing to recognize high risk exposures due to the attribution of risk to inexperience.

These data provide information that is useful for surveillance purposes, documenting rates and allowing internal comparisons for a group of construction workers at known high risk of musculoskeletal disorders who are difficult to survey from a practical standpoint. The continued use of these methods with an updated cohort will provide data that can be useful in monitoring trends of musculoskeletal disorders among these union carpenters and will provide additional power to evaluate more serious events. Several high-risk groups have been identified that should be targets for further investigation and possible interventions; the data presented here also provide a benchmark against which the effect of interventions can be measured.

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