AMERICAN JOURNAL OF INDUSTRIAL MEDICINE 52:551–562 (2009)

Ergonomic and Socioeconomic Risk Factors for Hospital Workers' Compensation Injury Claims

Jon Boyer, ScD,[1]* Monica Galizzi, PhD,[2] Manuel Cifuentes, MD, ScD,[1] Angelo d'Errico, MD,[3] Rebecca Gore, PhD,[1] Laura Punnett, ScD,[1] Craig Slatin, ScD[4] and the Promoting Healthy Safe Employment (PHASE) in Healthcare Team

Background *Hospital workers are a diverse population with high rates of musculoskeletal disorders (MSDs). The risk of MSD leading to workers' compensation (WC) claims is likely to show a gradient by socioeconomic status (SES) that may be partly explained by working conditions.*

Methods *A single community hospital provided workforce demographics and WC claim records for 2003–2005. An ergonomic job exposure matrix (JEM) was developed for these healthcare jobs from direct observation of physical workload and extraction of physical and psychosocial job requirements from the O*NET online database. Occupational exposures and SES categories were assigned to workers through their O*NET job titles. Univariate and multivariate Poisson regression analyses were performed to estimate the propensity to file an injury claim in relation to individual factors, occupational exposures, and SES.*

Results *The jobs with the highest injury rates were nurses, semi-professionals, and semi-skilled. Increased physical work and psychological demands along with low job tenure were associated with an increase in risk, while risk decreased with psychosocial rewards and supervisor support. Both occupational and individual factors mediated the relationship between SES and rate of injury claims.*

Conclusions *Physical and organizational features of these hospital jobs along with low job tenure predicted WC injury claim risk and explained a substantial proportion of the effects of SES. Further studies that include lifestyle risk factors and control for prior injuries and co-morbidities are warranted to strengthen the current study findings.* Am. J. Ind. Med. 52:551–562, 2009. *© 2009 Wiley-Liss, Inc.*

KEY WORDS: occupational health disparities; musculoskeletal injuries; socioeconomic status; ergonomic exposures; workers' compensation claims; job exposure matrix; healthcare sector

INTRODUCTION

Hospital work is known to involve high ergonomic exposures and risks of musculoskeletal disorders (MSD) and other work-related injuries [Fuortes et al., 1994; Smedley et al., 1997; Engkvist et al., 2000; Goldman et al., 2000; Bureau of Labor Statistics, 2007a]. In addition, work environment exposures have recently begun to gain attention

[1]Department of Work Environment, University of Massachusetts Lowell, Lowell, Massachusetts
[2]Department of Economics, University of Massachusetts Lowell, Lowell, Massachusetts
[3]Department of Epidemiology, Local Health Unit ASL TO3, Grugliasco, Italy
[4]Department of Community Health and Sustainability, University of Massachusetts Lowell, Lowell, Massachusetts

Contract grant sponsor: US NIOSH; Contract grant numbers: R01-OH07381, T42-OH008416-02.

*Correspondence to: Jon Boyer, Department of Work Environment, University of Massachusetts Lowell, One University Avenue, Kitson Building, Room 200H, Lowell, MA 01854. E-mail: Jon_Boyer@uml.edu

Accepted 5 April 2009
DOI 10.1002/ajim.20702. Published online in Wiley InterScience (www.interscience.wiley.com)

among social and occupational epidemiologists as potential predictors of health disparities [Rosenberg et al., 2001; Krause et al., 2005; Lipscomb et al., 2006; Barbeau et al., 2007; Quinn et al., 2007]. Although early research in the area focused on cardiovascular disease [Marmot et al., 1998] and mental health outcomes [Wohlfarth, 1997], there are only a few studies of disparities in musculoskeletal health outcomes among working populations [Borg and Kristensen, 2000; Melchior et al., 2005]. In particular, workplace exposures to physical loads and psychosocial stress factors are suspected for their potential affects on the pathway between SES and musculoskeletal health but have rarely been examined in a specific industrial sector.

The healthcare industry setting is well suited for examining the complex relationships between socioeconomic status (SES) and musculoskeletal health outcomes. A major sector of the U.S. economy, its workforce encompasses a wide-range of occupations, physical and psychosocial exposures, educational levels, and incomes. The industry has high rates of work-related injuries, with strain/sprain and back injury rates being particularly high among a number of identified occupational groups in the healthcare sector [Jansen et al., 2004; Bureau of Labor Statistics, 2005; Waehrer et al., 2005].

In two recent studies of U.S. hospital workers, physical workload and psychosocial working conditions explained a greater proportion of risk of OSHA log injury reports [d'Errico et al., 2007] and self-reported musculoskeletal symptoms and physician diagnosed injuries [Gillen et al., 2007] than did SES. Dement et al. (2004) found that working conditions, African American race, and female gender were strong independent predictors of hospital nurses' compensation injuries but SES was not specifically examined in that study. These findings have improved our understanding about how working conditions are related to gradients between SES and ill health but additional studies are needed to clarify risk pathways between specific exposure types and health outcomes.

Injuries reported to workers' compensation (WC) systems are often used to estimate incidence of health outcomes and success of interventions in musculoskeletal epidemiology studies [Silverstein et al., 1997; Sorock et al., 1997; Evanoff et al., 1999; Goldman et al., 2000; Chhokar et al., 2005; Trinkoff et al., 2005]. Despite potential underreporting to passive surveillance systems, the increasing costs of epidemiologic studies, difficulty gaining direct access to working populations, and common availability of administrative data ensures that WC records will continue to be used as an important resource for occupational health and safety research.

This study was a component of a larger project focused on the health disparities of healthcare workers, Promoting Healthy and Safe Employment (PHASE) in Healthcare [Slatin et al., 2004]. The specific aims of this component were: (1) to describe the frequency of hospital WC claims for back injuries, strain & sprain injuries, and all injuries by SES; (2) to estimate the likelihood of WC claims associated with selected physical workload, work organization, and psychosocial exposures from a new healthcare industry job exposure matrix (JEM) developed for this study population; and (3) to explore the degree to which ergonomic exposures from the JEM explain differences in relative risk for reported injuries associated with socioeconomic SES.

MATERIALS AND METHODS

Data Collection and Management

Study setting and recruitment

The target population included all actively employed workers of 18 years or older (2003–2005) in a single hospital in northeastern Massachusetts, United States. The hospital was a privately owned 115-bed community hospital employing 1483 employees and providing the full range of traditional inpatient and outpatient services. The project was approved by the institutional review boards (IRB) of the University of Massachusetts Lowell and the facilities where the research was conducted.

Administrative data sources

Workforce rosters were obtained from the hospital from each year of the study period (2003–2005). Variables extracted were employee name, job title, hourly wage, type of contract (full-time, part-time, per diem, etc.), date of hire, gender, date of birth, race, and hours worked per week (Table I). Per diem workers were assumed to work 18.6 hr per week on average [Cifuentes et al., 2008]. WC data were obtained from the hospital's insurance company records for the same 3-year period.

A 5-category SES classification scheme specific to the healthcare industry was developed for this study by the PHASE research team [d'Errico et al., 2007]. Facility job titles were classified according to their level of responsibility in the workplace hierarchy and education requirements (Table I). Nurses were classified as ''professionals'' but were treated separately in these analyses because they comprised such a large proportion of the study population, had known differences in exposure distributions compared to other jobs in the professional category, and were expected to have elevated injury risks compared to other job groups.

Exposure data source

Standard Occupational Codes (SOC) were assigned to each facility job title. A newly developed ergonomic JEM provided information about working conditions and was

TABLE I. Population Demographics, Scheduled Hours, Facility Tenure, and Socioeconomic Status of all Hospital Workers, and Those with Injury Claims, Employed from 2003 to 2005

Population descriptor	All hospital employees, n (%)	Employees with WC claims, n (%)
Study population		
All adult employees	1468 (100)	288 (19.6)
Non-white	132 (9.0)	23 (7.9)
Female	1180 (80.4)	230 (79.9)
Per diem	354 (24.1)	33 (11.4)
Tenure		
<2 years	113 (7.7)	79 (27.4)
2–10 years	785 (53.4)	108 (37.5)
11–20 years	273 (18.6)	50 (17.4)
>20 years	297 (20.3)	51 (17.7)
SES		
Administrators	55 (3.7)	3 (1.0)
Professionals	227 (15.5)	34 (11.8)
Nurses	358 (24.4)	105 (36.5)
Semi-professionals	276 (18.8)	62 (21.5)
Skilled workers	445 (30.3)	59 (20.4)
Semi-skilled workers	107 (7.3)	25 (8.7)
Population descriptor	All hospital employees mean (std)	Employees with WC claims mean (std)
Weekly hours scheduled		
All Employees	29.0 (10.8)	33.7 (8.7)
Regular	32.4 (10.3)	35.6 (7.2)
Per diem	18.6 (0.0)	18.6 (0.0)
Hourly rate	21.4 (12.7)	21.4 (8.3)
Age	42.2 (12.8)	42.3 (11.7)

constructed for this study from locally observed and nationally available data sources [Boyer, 2008b]. Healthcare workers from job titles within this and three other Massachusetts healthcare facilities were observed [Boyer, 2008a] with a modification of the PATH (Posture, Activities, Tools, and Handling) method [Buchholz et al., 1996] from 2003 to 2005. Each observed worker was a volunteer who gave individual written informed consent in a language of his/her choice. Proxy ergonomic exposure variables were extracted from the O*NET database [National Research Council, 1999] (http://www.onetcenter.org/database.html).

Average exposure estimates were computed for physical workload (manual handling, force requirements, bending and twisting, etc.) and organization factors (time pressure and safety hazards) for each JEM job code from matched exposure data from the PATH observations and the O*NET OnLine database. Psychosocial stress factors were extracted directly from O*NET and validated according to statistical methods described previously [Cifuentes et al., 2007]. These latter predictors were selected to approximate the factors of psychological demands, decision authority, job strain, and supervisor support from the job content questionnaire (JCQ) [Karasek et al., 1998] and rewards from the effort reward imbalance (ERI) Questionnaire [Siegrist, 1996]. For example, the O*NET rewards scale was approximated by extracting all the variables that conceptually matched the three sub-dimensions of the original rewards scale developed by Siegrist (representing employees' perceptions about: (1) levels of respect for the work they do; (2) job security; and (3) opportunities for promotion, increased income, and professional development).

Data management

Investigators coded the free text descriptions of the type of incident, nature, and agent of the injury, and body part injured. Workforce rosters and the WC database were matched on workers' names to produce a person-level database with the denominator of full-time employee equivalent (FTE) workers at risk and the number of claims filed by each individual during the study period. O*NET job codes had previously been assigned to all individuals in the population [Cifuentes et al., 2007; d'Errico et al., 2007]. Thus all ergonomic exposures were assigned to all cases and

non-cases by merging the WC and workforce rosters database with the JEM through O*NET job code.

Data Analysis

Spearman correlations were computed between all pairs of JEM variables and between selected exposures from the JEM database and SES. Cronbach's α was computed to assess the internal consistency of the various exposure scales.

Incidence rates per 100 FTE were estimated for all injuries, strains & sprains, and back body part by PHASE SES and for O*NET job codes with at least five total injuries. Univariate and multivariate relative risks and 95% confidence intervals were estimated for all injuries, strains & sprains, and back body part claims associated with SES, JEM exposures, and individual worker factors, in a prospective design, with ungrouped Poisson regression analyses. Risk models for the ''all injuries'' case group used the administrator SES job category as the reference. However, since there were no strain & sprain or back injuries in the administrator group, the next highest SES category (professionals other than nurses) served as referents when modeling risk estimates for those outcomes. Outcomes were entered as count data for each individual worker and JEM exposures were transformed to represent 10% increments in their standardized continuous exposure scales according to methods described by the O*NET online administrators (www.onetcenter.org).

Multivariate models were fit with SES entered into all models. JEM exposures were included in preliminary multivariate models if they had theoretical plausibility for predicting the outcome of interest; statistical significance in univariate analyses of ≤ 0.1; and if they were not highly correlated with other variables in the same model. Race, gender, and age were included in all models.

Variables were retained if they had a statistical significance of $P < 0.05$ or changed other variable coefficients by $\geq 15\%$ when removed. Model fit was assessed with the log-likelihood statistic. Dispersion of the Poisson distribution was evaluated with the χ^2 divided by degrees of freedom statistic (χ^2/df). All statistical operations were performed with SAS 9.1 software for Windows, Cary, N.C. Poisson models were produced from Proc Genmod with the log of FTE as the offset, Poisson distribution selected, and log link option chosen.

RESULTS

Population Characteristics

Hospital workforce rosters included information for 1468 employees (Table I). Employees were predominately female (80.4%) and white (91.0%) and had an average age of 43 (+/−19). Regular employees were scheduled to work an average of 32.4 h per week. Per-diem employees comprised 24% of the population. Average hospital tenure was around 10 years with around 8% being employed less than 2 years and over 20% being employed over 20 years. The largest SES category was skilled workers (30.3%), followed by nurses (24.4%), semi-professionals (18.8%), professionals other than nurses (15.5%), semi-skilled workers (7.3%), and administrators (3.7%). Not surprisingly, the mean job tenure was highest among high SES groups (Table I).

JEM Exposures

All physical exposures were strongly correlated with each other, excluding only repetitive motions (not shown but available upon request). Cronbach's αs for scales from the work organization and psychosocial domains ranged from 0.76 to 0.95 and were all statistically significant at $P < 0.05$. The weighted sum physical workload scale had a Cronbach α of 0.95 ($P < 0.000$).

Spearman correlations between SES and occupational exposures were mostly in the expected directions but many were weak. In contrast, psychological demands, decision latitude, and rewards were mostly strong and positively correlated with SES while job strain and supervisor support were negatively correlated.

Injury Rates

There were 381 total WC claims from the hospital workforce during the 3-year study period. Two hundred eighty-eight employees (20%) reported at least one injury with the range of 0–4 injuries per worker, and 26% of all injured workers (5% of all workers) reporting more than one injury.

The incidence rate for the full study period was 11.9 (95%CI 10.8–13.2) per 100 FTEs for all reported injuries linkable to the workforce roster (Table II). Strain & sprain and back injuries were 3.0 (95%CI 2.4–3.6) and 1.4 (95%CI 1.0–1.9) per 100 FTEs, respectively. Per-diem workers had only 7.9 injuries compared to 12.7 per 100 FTEs for permanent workers.

Incidence rates for all injuries were highest among nurses and semi-skilled workers and lowest among administrators (Table II). Strain & sprain injury rates were highest among nurses and semi-professionals, and lowest among administrators who had no cases reported. Back injury rates were highest in semi-skilled workers and nurses, and lowest among administrators.

Poisson Models of Injury Claims

Multivariate models

The best final multivariate Poisson model for risk of reporting of any WC injury included the physical workload

TABLE II. Incidence Rates for All Injuries, Strains & Sprains, and Back Injuries by Socioeconomic Status (SES): 1468 Massachusetts Hospitals Workers, 2003–2005

SES	SES label	n workers	All injuries rate per 100 FTEs* (95%CI)	Strain & sprain injuries rate per 100 FTEs* (95%CI)	Back injuries rate per 100 FTEs* (95%CI)
6	Administrators	55	2.6 (.97–6.9)	0.0 (no cases)	0.0 (no cases)
5	Professionals	227	8.8 (6.6–11.7)	2.7 (1.6–4.5)	1.3 (.64–2.8)
4	Nurses	358	18.5 (15.7–21.8)	4.6 (3.4–6.4)	2.1 (1.3–3.4)
3	Semi-professionals	276	12.7 (10.1–15.8)	4.1 (2.8–6.1)	1.9 (1.1–3.3)
2	Skilled	445	8.1 (6.4–10.2)	1.4 (.77–2.4)	.45 (.17–1.2)
1	Semi-skilled	107	16.6 (12.1–22.8)	3.5 (1.7–7.0)	2.2 (.91–5.2)
Totals	All SES categories	1468	11.9 (10.8–13.2)	3.0 (2.4–3.6)	1.4 (1.0–1.9)

Full time employee equivalence (FTEs) (scheduled weekly work hours for each employee/40 hours) × number of years employed during followup.

scale, psychological demands, psychosocial rewards, and supervisor social support from the JEM, worker tenure less than 2 years, age, non-white race from workforce rosters, and SES as significant predictor variables (Table III). Gender was kept in the model but had no significant effects on other retained variables.

There was approximately 23% greater chance of reporting any WC injury per 10% increase in the physical workload scale, a 20% increase associated with each increment of psychological demands, and 20 and 30% reductions in reporting for each increment in social support and rewards, respectively. There was also a 4.8 times greater chance of reporting any injury for workers with less than 2 years of tenure. There was almost 10% increase in risk per year of age. Non-white workers were around 40% less likely to report any WC injury than white workers.

Although only the point estimate for semi-professionals was statistically significant in the final multivariate model for all cases, SES was significant in the model overall. Semi-professionals had over three times greater chance of reporting an injury than administrators. Point estimates indicated that all other SES categories were over twice as likely to report an injury as administrators but these estimates were not significant in the final model. Further, the inverse trend in univariate claim risk by SES was much less distinct in the multivariate model. Of all SES categories, the univariate point estimates for nurses and semi-skilled workers were attenuated the most in the final multivariate model (Table III). Removal of the SES from the all case final model resulted in a slight strengthening of all predictors, a minimal decrease in overdispersion, and a moderate improvement in model fit (not shown but available upon request).

The final multivariate Poisson model for strain & sprain injuries included manual handling, race, gender, age, and tenure (Table IV). There was a 38% increase in risk of a strain & sprain for every decile of increase in manual handling. The point estimates for race, gender, and age were similar to those for all injury reporting but the reporting risk associated with low tenure decreased from 4.8 to 3.9 times.

The final model for risk of back injuries contained the same set of variables as for the strains & sprains, except that bending and twisting of the body replaced manual handling as the best representative physical workload variable (Table IV). The relative risk of a back injury was increased 2.3 per decile increase in exposure to bending and twisting of the body. Further, the risk associated with work tenure less than 2 years was almost five times greater than for employees with more seniority. The point estimates for nurses, semi-professionals, and skilled workers were attenuated by 30–50% and by 10% for semi-skilled workers compared to univariate models. Back injury risk models were all slightly under-dispersed and generated point estimates that were 50–80% greater than for all injuries and 20–60% greater than observed in strain & sprain models.

The differences in SES reference group (Administrators-Table III vs. Professionals Table IV) and outcome measures (all injuries, strains & sprains, back segment) affected the magnitude of risk estimates and patterns of attenuation between univariate and final models. For both all injury (Table III) and back segment (not shown but available upon request) reports, the risk estimates followed an expected trend of reduced SES effect after controlling for working conditions and individual factors. The attenuation was also greater in those SES job categories with less favorable working conditions, nurses, and semi-skilled workers.

DISCUSSION

Among employees of a single Massachusetts hospital, incidence rates for all WC injuries, strains & sprains, and back cases were generally highest among nurses and workers in the lowest two SES categories. Increased physical workload and psychological demands along with low job

TABLE III. Selected Univariate and Final Multivariate Poisson Models of Relative Risk (RR) for any Injury Claim: 1468 Hospital Workers, 2003–2005

Exposure or risk factor	Univariate models RR (95%CI)[a]	Final multivariate model RR (95%CI)[a]
Physical workload		
Manual handling[b]	1.22 (1.11–1.33)	—
Force requirements[b]	1.35 (1.21–1.49)	—
Bending and twisting[b]	1.53 (1.36–1.72)	—
Physical work scale[b,c]	1.41 (1.27–1.58)	1.23 (1.04–1.45)
Work organization		
Time pressure[b]	1.01 (0.90–1.13)	—
Hazardous conditions[b]	1.36 (1.25–1.48)	—
Psychosocial factors		
Psychological demands[d]	1.21 (1.08–1.35)	1.20 (1.02–1.40)
Decision latitude[d]	0.91 (0.84–0.98)	—
Supervisor social support[d]	0.74 (0.64–0.86)	0.78 (0.58–0.97)
Rewards[d]	0.79 (0.69–0.90)	0.68 (0.52–0.89)
Individual factors		
Race (0/1 = non-white)[e]	0.79 (0.53–1.17)	0.57 (0.38–0.87)
Gender (0/1 = female)[e]	1.00 (0.77–1.28)	0.84 (0.63–1.11)
Age in years[e]	1.05 (0.99–1.11)	1.09 (1.03–1.16)
Age^2 in years[e]	0.99 (0.98–1.00)	0.99 (0.98–1.00)
Tenure (0/1 = <2 years)[e]	4.64 (3.71–5.80)	4.83 (3.80–6.14)
SES job groups		
Administrators (Reference)	1.0	1.0
Professionals	3.41 (1.23–9.46)	2.22 (0.79–6.26)
Nurses	7.16 (2.65–19.33)	2.82 (0.99–8.03)
Semi-professionals	4.92 (1.80–13.43)	3.18 (1.13–8.98)
Skilled	3.13 (1.14–8.58)	2.11 (0.72–6.20)
Semi-skilled	6.42 (2.29–17.98)	2.59 (0.80–8.33)

[a]Represents the change in risk for every 10% increase in exposure for each variable except for individual factors and PHASE SES where they are compared as indicated.
[b]Weighted sum of manual handling, force requirements, and bending and twisting of the body.
[c]Weighted average JEM composites from PATH observations and O*NET database values.
[d]Variables computed or extracted directly from the O*NET OnLine database.
[e]From workforce rosters.

tenure were associated with an increase in claim likelihood, while risk decreased with psychosocial rewards and supervisor support. Both occupational and individual factors appeared to mediate the relationship between SES and rate of injury claims.

Physical workload factors were consistently among the strongest predictors for all multivariate models. Manual handling, trunk bending and twisting, and hazardous safety conditions from the JEM predicted elevated multivariate risk ratios for all WC claims which were even higher for strains & sprains and back injuries. Increased psychological job demands, low psychological rewards, and low supervisor support increased the all injury claim likelihood. But none of the psychosocial factors remained significant in final strain & sprain or back models. Although multi-colinearity among predictors and SES limited our ability to examine them all simultaneously, the large proportion of significant exposure variables from different ergonomic domains indicates the acceptable predictive validity of the newly developed JEM for use with hospital WC claim outcomes in epidemiology studies.

Despite our hypothesis of higher injury rates with decreasing SES, nurses, semi-skilled workers, and semi-professionals consistently had the highest rates for all injuries, strains & sprains, and back cases. If nurses and skilled workers were removed from analyses, a more distinct inverse gradient emerged for injury risks.

Over one-half (57%) of the skilled group comprised clerical workers (transcriptionists, medical secretaries, billing representative, etc.). Clerical workers are commonly exposed to chronic static postures and highly repetitive motions of the upper extremity, and often have excess chronic musculoskeletal morbidity, but this is likely to be missing from WC claims data [Morse et al., 1998]. On the other hand,

TABLE IV. Selected Univariate and Final Multivariate Poisson Model Relative Risks (RR) for Reporting a Strain & Sprain Injury (SS) or Back Injury to WC from Ergonomic, Individual, and Socioeconomic Risk Factors Among 1413 Massachusetts Hospital Workers Identified from Case Records and Workforce Rosters During Reporting Years 2003–2005

Exposure or risk factor	Univariate SS models RR (95%CI)[a]	Final multivariate SS model RR (95%CI)[a]	Univariate back models RR (95%CI)[a]	Final multivariate back model RR (95%CI)[a]
Physical workload				
Manual handling[b]	1.27 (1.07–1.52)	1.38 (1.13–1.68)	1.48 (1.18–1.86)	—
Force requirements[b]	1.24 (1.00–1.54)	—	1.63 (1.24–2.15)	—
Bending and twisting[b]	1.74 (1.37–2.20)	—	2.16 (1.53–3.05)	2.30 (1.55–3.40)
Physical work scale[b,c]	1.47 (1.18–1.83)	—	1.80 (1.36–2.39)	—
Work organization				
Time pressure[b]	1.24 (0.98–1.58)	—	1.13 (0.80–1.58)	—
Hazardous conditions[b]	1.48 (1.24–1.76)	—	1.79 (1.37–2.36)	—
Psychosocial factors				
Psychological demands[d]	1.22 (0.98–1.54)	—	1.20 (0.86–1.68)	—
Supervisor social support[d]	0.67 (0.50–0.89)	—	0.61 (0.40–0.94)	—
Rewards[d]	0.96 (0.74–1.26)	—	0.92 (0.62–1.35)	—
Individual factors				
Race (0/1 = non-white)[e]	0.47 (0.17–1.29)	0.41 (0.15–1.14)	0.79 (0.24–2.54)	0.67 (0.20–2.22)
Gender (0/1 = female)[e]	0.63 (0.35–1.14)	0.46 (0.24–0.88)	0.89 (0.41–1.91)	0.56 (0.25–1.26)
Age in years[e]	1.11 (0.99–1.25)	1.14 (1.01–1.28)	1.12 (0.94–1.33)	1.17 (0.98–1.40)
Age^2 in years[e]	0.99 (0.98–1.00)	0.99 (0.98–1.00)	0.99 (0.98–1.00)	0.99 (0.98–1.00)
Tenure (0/1 = <2 years)[e]	3.37 (2.08–5.47)	3.89 (2.35–6.43)	4.45 (2.29–8.65)	4.94 (2.47–9.90)
SES job groups				
Professionals (reference)	1.0	—	1.0	—
Nurses	1.71 (0.92–3.18)	—	1.57 (0.64–3.81)	—
Semi-professionals	1.54 (0.81–2.95)	—	1.42 (0.56–3.62)	—
Skilled	0.50 (0.23–1.09)	—	0.34 (0.09–1.15)	—
Semi-skilled	1.30 (0.55–3.11)	—	1.63 (0.52–5.13)	—

[a]Represents the change in risk for every 10% increase in exposure for each variable except for individual factors and PHASE SES where they are compared as indicated.
[b]Weighted sum of manual handling, force requirements, and bending and twisting of the body.
[c]Weighted average JEM composites from PATH observations and O*NET database values.
[d]Variables computed or extracted directly from the O*NET OnLine database.
[e]From workforce rosters.

they are unlikely to experience forceful manual handling, extreme trunk postures or exposure to hazardous machinery, or work environments that would be more likely to lead to acute traumatic injuries and WC claims.

Radiologic technologists were another healthcare professional group with higher than expected injury rates compared to other jobs in that SES group. They had the highest rates of strain & sprain injury reports (4.5 per 100 FTEs) and the fifth highest rate for back segment injuries (2.5 per 100 FTEs) of all 107 hospital job codes. These increased claim rates for shoulder and back cases were likely associated with frequent patient handling (transferring and repositioning) and prolonged seated image review, editing, and documentation with shoulder elevation. Since professionals exposed to high physical workload factors were used as the SES reference category for analyses of strains & sprains and back outcomes, risk among lower SES groups for these outcomes was diluted.

The elevated univariate risks associated with SES for any injury were strongly attenuated when adjusted by physical workload, psychological demands, and work tenure. The attenuation pattern for physical workload was replicated for back injuries, but not in analyses of strains & sprains, contrary to our study hypothesis. These strain & sprain results were contrary to our study hypothesis. Unfortunately, the necessary use of professionals as the reference category for strain and sprain and back cases limited the strength and precision of the models that included SES. Consequently, the best reported final multivariate models for those outcomes do not include SES.

Job Exposure Estimates

JEMs are an increasingly used grouping tool for organizing and characterizing employment history and exposure information in the field of occupational epidemi-

ology [Coughlin and Chiazze, 1990; Stewart and Mustafa, 1994; Kauppinen et al., 1998; Weiderpass et al., 1999; Quinn et al., 2001; Le Moual et al., 2005]. JEMs have been used to characterize risk of multiple simultaneous exposures for occupational disease [Blanc et al., 2005], work organization [Johnson and Stewart, 1993], physical ergonomic [Blanc et al., 1996; Carmona et al., 1998; Dement et al., 2004], and combined psychosocial and biomechanical [Kauppinen et al., 1998] exposures to estimate risks for cardiovascular disease, MSDs and back injury claims, and carpal-tunnel surgery disability outcomes, respectively. The current JEM contains qualitative and quantitative estimates of healthcare worker exposures to physical, psychosocial, and organizational conditions relevant MSD risk over a 3-year period.

Although JEMs can provide a flexible exposure database and reduce self-report and common methods bias, their infrequent use may be due to the labor-intensive nature of JEM development or concerns about their validity and generalizability [ACGIH-AIHA, 1996; Coughlin and Chiazze, 1990]. Validation studies of cancer risk factor JEMs have been conducted [Siemiatycki et al., 1989; Bouyer and Hemon, 1993] but the results are not necessarily generalizable from one JEM to another.

In this instance, we first examined the reliability of PATH observation data inputs [Park et al., 2009] and agreement between observational and O*NET metrics from physical workload [Boyer, 2008b] and between psychosocial factors from questionnaire and O*NET [Cifuentes et al., 2007]. Qualitative evaluation of their face validity and job sample representativeness also helped to reduce the chance of exposure misclassification and increase predictive validity. More work is needed to expand the content of the current JEM to include factors for co-worker support and ERI, to determine its predictive validity with other health outcomes, and to evaluate its generalizability to other populations.

Comparison with Other Studies

The injury rates in this study were similar to other published reports. For example, nursing and plant maintenance have been reported in other studies to be among the hospital job titles with the highest WC claim rates [Fuortes et al., 1994; Goldman et al., 2000]. Hospital and medical center cleaning staff have been identified as having high rates of OSHA recordable injury rates [Sarri et al., 1991; d'Errico et al., 2007]. However, the high rates of occupational injuries among hospital radiology technicians and security guards identified in this study have not been well described in the literature. Another exception was nursing aides in this population, who had overall injury rates similar to national BLS statistics [Bureau of Labor Statistics, 2007b] but were ranked only 13th, 5th, and 5th for all injuries, strains & sprains, and back cases, respectively. Other studies have reported nursing aides as having the highest rates of musculoskeletal and other injuries among all hospital workers due to frequent participation in patient handling tasks [Fuortes et al., 1994; Engkvist et al., 2000].

Physical workload factors such as manual handling, forceful exertions, and trunk bending and twisting have been established as important risk factors for musculoskeletal and other injuries in hospital workers [Lagerstrom et al., 1998; Institute of Medicine, 2001]. A large proportion of the WC claim records in this study indicated associations with physical ergonomic exposures and involved the musculoskeletal system. Manual handling activities in general, and patient care and handling in particular, were important in the reporting of strains & sprains, back, and other body segment injuries in this population of healthcare workers.

Other studies of hospital workers have identified decreased job control (strongly correlated with rewards in this study), increased psychological demands, and physical workload as associated with increased risk of reporting of work-related MSDs [Koehoorn et al., 2006; d'Errico et al., 2007] and physical and social disability from back and neck pain [Shannon et al., 2001]. Our results, where likelihood of WC claims decreased as rewards increase, were consistent with another study which found an increased risk of MSDs from increased ERI [Gillen et al., 2007]. Rewards were also positively correlated with SES in the current study.

This evidence, along with previous exposure assessments in the population [Boyer, 2008a], indicates that with the exception of nurses and some other patient care professionals, the jobs with the lowest rewards and control may also have had the highest physical workload exposures. Workers with more control over job demands and higher perceived rewards may have been less likely to get injured and/or been more able to manage symptoms to prevent progression to severity levels that required medical treatment, lost time, and claims reporting.

Low supervisor support was a consistently strong predictor of increased WC injury in multivariate models for all cases. Workers with low job estimates of supervisor support may have received less training in hazard awareness, had less access to advanced work methods, tools, and protective equipment. These could lead to increased exposures, injury occurrence, and elevated WC claim rates in low support jobs [Gershon et al., 1999; Felknor et al., 2000; Kaila-Kangas et al., 2004]. However, there is contrasting evidence from other studies which suggest that low supervisor support reduces the likelihood of injury reporting and WC claim filing due to decreased administrative guidance and management dis-incentives to report injuries [Pransky et al., 1999; Azaroff et al., 2002]. Further studies are needed to clarify the apparent contradiction.

Employees with tenure less than 2 years were 3–5 times more likely to report strains & sprains, back, and all injuries compared to workers with greater seniority and the effect of

low tenure was greatest for back injuries. Three other hospital studies have reported similar findings [Fuortes et al., 1994; Yassi et al., 1995; Weddle, 1996]. Workers with less tenure often have less training in hazard awareness, have not yet adapted physically to their jobs, may feel less job security, and may not understand the administrative processes for reporting an injury [Yassi et al., 1995], all factors which could increase the chance of getting injured and decrease the chance of reporting. There is also evidence that workers with more experience have better coping skills and more social attachments to the workplace which help them avoid disability after work-related injuries [Pransky et al., 2005].

Added confidence in the current study results can be gleaned from the similarities with other studies conducted in this and other hospital populations which identified similar risk factors and found large attenuation of SES risks by ergonomic working conditions, despite using different study designs and having different measures of exposures, health outcomes, and SES [d'Errico et al., 2007; Gillen et al., 2007].

Study Limitations

The inability to match all WC cases for the study period with individuals in the hospital rosters resulted in a known loss of 83 cases comprised mostly of cuts and lacerations to the distal upper extremity and serious multiple body segment injuries that often involved the back and lower extremities. It was not possible to determine the job titles or SES categories in which the lost cases occurred.

The current study did not have access to information about individual factors other than age, race, gender, and tenure. Prior injuries and symptoms, in particular, have been identified as important risk factors for injury occurrence and reporting of WC claims [Fuortes et al., 1994; Engkvist et al., 2000; Galizzi and Boden, 2003; Linton et al., 2005; Videman et al., 2005]. Co-morbidities and risk factors like being overweight, smoking [Ryan et al., 1992; Ostbye et al., 2007], and leisure-time physical activities were also not measured [Hoogendoorn et al., 1999; Hoogendoorn et al., 2000; Miranda et al., 2001a; Miranda et al., 2001b; Miranda et al., 2002]. Unmeasured confounding due to these factors cannot be ruled out, because they are also likely to be correlated with social class [Shi and Stevens, 2005], but only prior injuries would be expected to have an effect on occupational injury risk.

The lack of strain & sprain and back cases within the SES reference group (administrators) limited the study's ability to construct regression models of the SES gradient or of its combined effect with ergonomic risk factors among hospital workers.

None of the Poisson analyses performed for the current paper included the full ERI ratio. Although an ERI proxy was available from previous work [Cifuentes et al., 2007], it was produced from a ratio of O*NET psychological demands over O*NET rewards because no O*NET items properly represented the ''effort'' component of the model. Thus, it was decided that testing of the individual JCQ and ERI subscales for predictive power would be a more valid and informative analysis strategy. In accordance with this decision, only the 3-item O*NET rewards scale was included from the ERI model.

Social relationships may play an important role in the complex risk profile of workplace incidents in the healthcare sector [Myers et al., 2007]. However, valid measurement of social factors is a challenging endeavor in any sector. In the current study, the O*NET proxy estimate for JCQ co-worker support was derived from only one O*NET item asking: ''Are co-workers easy to get along with?'' In addition, it did not correlate well with the actual JCQ scale estimates collected from survey results in the same population [Cifuentes et al., 2007], had low variation across current study job titles, and had a strong positive Spearman correlation with O*NET rewards. Although some previous studies have found co-worker support from the JCQ to be an important modifier of musculoskeletal symptom reporting [Ariens et al., 2001; Hoogendoorn et al., 2001], the questionable validity of our indicator and its high correlation with other better characterized variables led to its exclusion from Poisson analyses. Consequently, the O*NET supervisor support variable, derived from questions about supervisors' provision of adequate technical training and human resources support, was the only social support proxy used in this study.

Concerns about biased injury risk estimates arise where differential magnitude of underreporting could occur among exposure groups. In the current study, differential under-reporting by high SES job groups would lead to over-estimates of risk in lower SES categories. However, since reporting barriers have been shown to be more common among low-wage or low status workers [Rosenman et al., 2000; Strunin and Boden, 2000; Boden and Ruser, 2003; Azaroff et al., 2004; Tait et al., 2004; Scherzer et al., 2005], it appears more likely that the rates and relative risks of low SES workers would be underestimated in the current study.

Although there may have been some underreporting of injuries in the current study population, the rates appear higher than national statistics and rates from other studies for all injuries and similar to national statistics for back injuries and strains & sprains. Therefore, it does not appear that underreporting in the current study should reduce generalizability of findings to other hospitals providing a similar range of services.

Study Strengths

The multiple prospective collection methods and data sources strengthen the current study because they reduce the likelihood of misclassification or common methods bias and increase generalizability of findings. Objective data were

obtained from workforce rosters, WC records, direct observations of the workforce, and a national database representing probable exposures. In particular, the study benefited from detailed objective collection of ergonomic exposures within the healthcare facility from which WC claims were filed.

CONCLUSION

Physical workload factors were associated with greater risk of strain & sprain and back injuries than work organization or psychosocial factors in this population of Massachusetts hospital workers. Together, these hospital job features along with individual worker factors, predicted WC injury risk and explained some, but not all, of the effects of SES. The consistently higher relative risks among nurses, other healthcare professionals, and semi-skilled workers were attenuated by physical workload, hazardous safety conditions, and psychosocial factors. This indicates the importance of working conditions over SES as predictors of injury among hospital employees. The high prevalence of physical workload exposures across diverse jobs was a likely contributor to the irregular trends in risk by SES observed but unmeasured non-work confounding cannot be ruled out. Elevated injury claim risk underscores the importance of surveillance and ergonomic exposure reduction interventions for low status and tenure workers performing facilities maintenance and repair, housekeeping and janitorial, diagnostic imaging, and clinical lab work, along with the commonly recognized patient care tasks.

ACKNOWLEDGMENTS

We thank Jody Lally and Petra Miesmaa for facility liaison and assistance with data collection, Joan Handstad and Mary Ellen Davis for facilitating data collection, Maggie Y Hood for Standard Occupational Classification coding of job titles, the PHASE Exposure Assessment Team for PATH data collection, and Lu Yuan and Ioana Crisan for cleaning and coding of WC files. This investigation was made possible by Grants No. R01-OH07381 and T42-OH008416-02, from the U.S. National Institute of Occupational Safety and Health (NIOSH). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the NIOSH.

REFERENCES

ACGIH-AIHA JTG. 1996. Data elements for occupational exposure databases: guidelines and recommendations for airborne hazards and noise. Appl Occup Environ Hyg 11:1294–1311.

Ariens GA, Bongers PM, Hoogendoorn WE, Houtman IL, van der Wal G, van Mechelen W. 2001. High quantitative job demands and low coworker support as risk factors for neck pain: results of a prospective cohort study. Spine 26:1896–1901. Discussion 1902–1903.

Azaroff LS, Lax MB, Levenstein C, Wegman DH. 2004. Wounding the messenger: the new economy makes occupational health indicators too good to be true. Int J Health Serv 34:271–303.

Azaroff LS, Levenstein C, Wegman DH. 2002. Occupational injury and illness surveillance: conceptual filters explain underreporting. Am J Public Health 92:1421–1429.

Barbeau EM, Hartman C, Quinn MM, Stoddard AM, Krieger N. 2007. Methods for recruiting white, black, and hispanic working-class women and men to a study of physical and social hazards at work: the United for Health study. Int J Health Serv 37:127–144.

Blanc PD, Eisner MD, Balmes JR, Trupin L, Yelin EH, Katz PP. 2005. Exposure to vapors, gas, dust, or fumes: assessment by a single survey item compared to a detailed exposure battery and a job exposure matrix. Am J Ind Med 48:110–117.

Blanc PD, Faucett J, Kennedy JJ, Cisternas M, Yelin E. 1996. Self-reported carpal tunnel syndrome: predictors of work disability from the National Health Interview Survey Occupational Health Supplement. Am J Ind Med 30:362–368.

Boden LI, Ruser JW. 2003. Workers' compensation "reforms," choice of medical care provider, and reported workplace injuries. Rev Econ Stat 85:923–929.

Borg V, Kristensen TS. 2000. Social class and self-rated health: can the gradient be explained by differences in life style or work environment? Soc Sci Med 51:1019–1030.

Bouyer J, Hemon D. 1993. Comparison of three methods of estimating odds ratios from a job exposure matrix in occupational case-control studies. Am J Epidemiol 137:472–481.

Boyer J. 2008a. Ergonomic exposures, socioeconomic status, and musculoskeletal disorder risk among healthcare workers: chapter 2. Ergonomic exposure assessment to back disorder risk factors among healthcare workers: a description and comparison of hospitals and nursing homes. *Doctoral Dissertation*, University of Massachusetts Lowell.

Boyer J. 2008b. Ergonomic exposures, socioeconomic status, and musculoskeletal disorder risk among healthcare workers: chapter 3 Development of an ergonomic job exposure matrix for the healthcare sector. *Doctoral Dissertation*, University of Massachusetts Lowell.

Buchholz B, Paquet V, Punnett L, Lee D, Moir S. 1996. PATH: a work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work. Appl Ergon 27:177–187.

Bureau of Labor Statistics. 2005. Lost-Worktime Injuries and Illnesses: Characteristics and Resulting Days Away From Work, 2003. Washington, DC: United States Department of Labor, p. 11.

Bureau of Labor Statistics. 2007a. Workplace Injuries and Illnesses in 2006. Washington, DC: United States Department of Labor.

Bureau of Labor Statistics. 2007b. Nonfatal Occupational Injuries And Illnesses Requiring Days Away From Work, 2006. Washington, DC: United States Department of Labor. p Table 11. Number, incidence rate and median days away from work of occupational injuries and illnesses with days away from work involving musculoskeletal disorders by selected occupations, All United States, private industry, 2006.

Carmona L, Faucett J, Blanc PD, Yelin E. 1998. Predictors of rate of return to work after surgery for carpal tunnel syndrome. Arthritis Care Res 11:298–305.

Chhokar R, Engst C, Miller A, Robinson D, Tate RB, Yassi A. 2005. The three-year economic benefits of a ceiling lift intervention aimed to reduce healthcare worker injuries. Appl Ergon 36:223–229.

Cifuentes M, Boyer J, Gore R, d'Errico A, Scollin P, Tessler J, Lerner D, Kriebel D, Punnett L, Slatin C. 2008. Job strain predicts survey response in healthcare industry workers. Am J Ind Med 51:281–289.

Cifuentes M, Boyer J, Gore R, d'Errico A, Tessler J, Scollin P, Lerner D, Kriebel D, Punnett L, Slatin C. 2007. Inter-method agreement between O*NET and survey measures of psychosocial exposure among healthcare industry employees. Am J Ind Med 50:545–553.

Coughlin SS, Chiazze L Jr. 1990. Job-exposure matrices in epidemiologic research and medical surveillance. Occup Med 5:633–646.

Dement JM, Pompeii LA, Ostbye T, Epling C, Lipscomb HJ, James T, Jacobs MJ, Jackson G, Thomann W. 2004. An integrated comprehensive occupational surveillance system for health care workers. Am J Ind Med 45:528–538.

d'Errico A, Punnett L, Cifuentes M, Boyer J, Tessler J, Gore R, Scollin P, Slatin C. 2007. Hospital injury rates in relation to socioeconomic status and working conditions. Occup Environ Med 64:325–333.

Engkvist IL, Hjelm EW, Hagberg M, Menckel E, Ekenvall L. 2000. Risk indicators for reported over-exertion back injuries among female nursing personnel. Epidemiology 11:519–522.

Evanoff BA, Bohr PC, Wolf LD. 1999. Effects of a participatory ergonomics team among hospital orderlies. Am J Ind Med 35:358–365.

Felknor SA, Aday LA, Burau KD, Delclos GL, Kapadia AS. 2000. Safety climate and its association with injuries and safety practices in public hospitals in Costa Rica. Int J Occup Environ Health 6:18–25.

Fuortes LJ, Shi Y, Zhang M, Zwerling C, Schootman M. 1994. Epidemiology of back injury in university hospital nurses from review of workers' compensation records and a case-control survey. J Occup Med 36:1022–1026.

Galizzi M, Boden LI. 2003. The return to work of injured workers: evidence from matched unemployment insurance and workers' compensation data. Labor Econ 10:311–337.

Gershon RR, Karkashian CD, Vlahov D, Kummer L, Kasting C, Green-McKenzie J, Escamilla-Cejudo JA, Kendig N, Swetz A, Martin L. 1999. Compliance with universal precautions in correctional health care facilities. J Occup Environ Med 41:181–189.

Gillen M, Yen IH, Trupin L, Swig L, Rugulies R, Mullen K, Font A, Burian D, Ryan G, Janowitz I, Quinlan PA, Frank J, Blanc P. 2007. The association of socioeconomic status and psychosocial and physical workplace factors with musculoskeletal injury in hospital workers. Am J Ind Med 50:245–260.

Goldman RH, Jarrard MR, Kim R, Loomis S, Atkins EH. 2000. Prioritizing back injury risk in hospital employees: application and comparison of different injury rates. J Occup Environ Med 42:645–652.

Hoogendoorn WE, Bongers PM, de Vet HC, Houtman IL, Ariens GA, van Mechelen W, Bouter LM. 2001. Psychosocial work characteristics and psychological strain in relation to low-back pain. Scand J Work Environ Health 27:258–267.

Hoogendoorn WE, van Poppel MN, Bongers PM, Koes BW, Bouter LM. 1999. Physical load during work and leisure time as risk factors for back pain. Scand J Work Environ Health 25:387–403.

Hoogendoorn WE, van Poppel MN, Bongers PM, Koes BW, Bouter LM. 2000. Systematic review of psychosocial factors at work and private life as risk factors for back pain. Spine 25:2114–2125.

Institute of Medicine. 2001. Musculoskeletal Disorders and the Workplace. Washington, DC: National Research Council, p. 492.

Jansen JP, Morgenstern H, Burdorf A. 2004. Dose-response relations between occupational exposures to physical and psychosocial factors and the risk of low back pain. Occup Environ Med 61:972–979.

Johnson JV, Stewart WF. 1993. Measuring work organization exposure over the life course with a job-exposure matrix. Scand J Work Environ Health 19:21–28.

Kaila-Kangas L, Kivimaki M, Riihimaki H, Luukkonen R, Kirjonen J, Leino-Arjas P. 2004. Psychosocial factors at work as predictors of hospitalization for back disorders: a 28-year follow-up of industrial employees. Spine 29:1823–1830.

Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. 1998. The Job Content Questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. J Occup Health Psychol 3:322–355.

Kauppinen T, Toikkanen J, Pukkala E. 1998. From cross-tabulations to multipurpose exposure information systems: a new job-exposure matrix. Am J Ind Med 33:409–417.

Koehoorn M, Demers PA, Hertzman C, Village J, Kennedy SM. 2006. Work organization and musculoskeletal injuries among a cohort of health care workers. Scand J Work Environ Health 32:285–293.

Krause N, Scherzer T, Rugulies R. 2005. Physical workload, work intensification, and prevalence of pain in low wage workers: results from a participatory research project with hotel room cleaners in Las Vegas. Am J Ind Med 48:326–337.

Lagerstrom M, Hansson T, Hagberg M. 1998. Work-related low-back problems in nursing. Scand J Work Environ Health 24:449–464.

Le Moual N, Siroux V, Pin I, Kauffmann F, Kennedy SM. 2005. Asthma severity and exposure to occupational asthmogens. Am J Respir Crit Care Med 172:440–445.

Linton SJ, Gross D, Schultz IZ, Main C, Cote P, Pransky G, Johnson W. 2005. Prognosis and the identification of workers risking disability: research issues and directions for future research. J Occup Rehabil 15:459–474.

Lipscomb HJ, Loomis D, McDonald MA, Argue RA, Wing S. 2006. A conceptual model of work and health disparities in the United States. Int J Health Serv 36:25–50.

Marmot MG, Fuhrer R, Ettner SL, Marks NF, Bumpass LL, Ryff CD. 1998. Contribution of psychosocial factors to socioeconomic differences in health. Milbank Q 76:403–448, 305.

Melchior M, Krieger N, Kawachi I, Berkman LF, Niedhammer I, Goldberg M. 2005. Work factors and occupational class disparities in sickness absence: findings from the GAZEL cohort study. Am J Public Health 95:1206–1212.

Miranda H, Viikari-Juntura E, Martikainen R, Takala EP, Riihimaki H. 2001a. A prospective study of work related factors and physical exercise as predictors of shoulder pain. Occup Environ Med 58:528–534.

Miranda H, Viikari-Juntura E, Martikainen R, Takala EP, Riihimaki H. 2001b. Physical exercise and musculoskeletal pain among forest industry workers. Scand J Med Sci Sports 11:239–246.

Miranda H, Viikari-Juntura E, Martikainen R, Takala EP, Riihimaki H. 2002. Individual factors, occupational loading, and physical exercise as predictors of sciatic pain. Spine 27:1102–1109.

Morse TF, Dillon C, Warren N, Levenstein C, Warren A. 1998. The economic and social consequences of work-related musculoskeletal disorders: the Connecticut Upper-Extremity Surveillance Project (CUSP). Int J Occup Environ Health 4:209–216.

Myers DJ, Kriebel D, Karasek R, Punnett L, Wegman DH. 2007. The social distribution of risk at work: acute injuries and physical assaults among healthcare workers working in a long-term care facility. Soc Sci Med 64:794–806.

National Research Council. 1999. The Changing Nature of Work, Implications for Occupational Analysis. Washington, DC: National Research Council, National Academy. of Sciences.

Ostbye T, Dement JM, Krause KM. 2007. Obesity and workers' compensation: results from the Duke Health and Safety Surveillance System. Arch Intern Med 167:766–773.

Park J, Boyer J, Tessler J, Casey J, Gore R, Punnett L. 2009. Inter-rater reliability of PATH observations for assessment of ergonomic risk factors in hospital work. Ergonomics (in press).

Pransky GS, Benjamin KL, Savageau JA, Currivan D, Fletcher K. 2005. Outcomes in work-related injuries: a comparison of older and younger workers. Am J Ind Med 47:104–112.

Pransky G, Snyder T, Dembe A, Himmelstein J. 1999. Under-reporting of work-related disorders in the workplace: a case study and review of the literature. Ergonomics 42:171–182.

Quinn MM, Sembajwe G, Stoddard AM, Kriebel D, Krieger N, Sorensen G, Hartman C, Naishadham D, Barbeau EM. 2007. Social disparities in the burden of occupational exposures: results of a cross-sectional study. Am J Ind Med 50:861–875.

Quinn MM, Smith TJ, Youk AO, Marsh GM, Stone RA, Buchanich JM, Gula MJ. 2001. Historical cohort study of US man-made vitreous fiber production workers: VIII. Exposure-specific job analysis. J Occup Environ Med 43:824–834.

Rosenberg BJ, Barbeau EM, Moure-Eraso R, Levenstein C. 2001. The work environment impact assessment: a methodologic framework for evaluating health-based interventions. Am J Ind Med 39:218–226.

Rosenman KD, Gardiner JC, Wang J, Biddle J, Hogan A, Reilly MJ, Roberts K, Welch E. 2000. Why most workers with occupational repetitive trauma do not file for workers' compensation. J Occup Environ Med 42:25–34.

Ryan J, Zwerling C, Orav EJ. 1992. Occupational risks associated with cigarette smoking: a prospective study. Am J Public Health 82:29–32.

Sarri C, Eng E, Runyan C. 1991. Injuries among medical laboratory housekeeping staff: incidence and worker perceptions. J Occup Med 33:52–56.

Scherzer T, Rugulies R, Krause N. 2005. Work-related pain and injury and barriers to workers' compensation among Las Vegas hotel room cleaners. Am J Public Health 95:483–488.

Shannon HS, Woodward CA, Cunningham CE, McIntosh J, Lendrum B, Brown J, Rosenbloom D. 2001. Changes in general health and musculoskeletal outcomes in the workforce of a hospital undergoing rapid change: a longitudinal study. J Occup Health Psychol 6:3–14.

Shi L, Stevens GD. 2005. Vulnerability and unmet health care needs. The influence of multiple risk factors. J Gen Intern Med 20:148–154.

Siegrist J. 1996. Adverse health effects of high-effort/low-reward conditions. J Occup Health Psychol 1:27–41.

Siemiatycki J, Dewar R, Richardson L. 1989. Costs and statistical power associated with five methods of collecting occupation exposure information for population-based case-control studies. Am J Epidemiol 130:1236–1246.

Silverstein BA, Stetson DS, Keyserling WM, Fine LJ. 1997. Work-related musculoskeletal disorders: comparison of data sources for surveillance. Am J Ind Med 31:600–608.

Slatin C, Galizzi M, Melillo KD, Mawn B. 2004. Conducting interdisciplinary research to promote healthy and safe employment in health care: promises and pitfalls. Public Health Rep 119:60–72.

Smedley J, Egger P, Cooper C, Coggon D. 1997. Prospective cohort study of predictors of incident low back pain in nurses. BMJ 314:1225–1228.

Sorock GS, Smith GS, Reeve GR, Dement J, Stout N, Layne L, Pastula ST. 1997. Three perspectives on work-related injury surveillance systems. Am J Ind Med 32:116–128.

Stewart PA, Mustafa D. 1994. A bibliography for occupational exposure assessment for epidemiologic studies. Am Ind Hyg Assoc J 55:1178–1187.

Strunin L, Boden LI. 2000. Paths of reentry: employment experiences of injured workers. Am J Ind Med 38:373–384.

Tait RC, Chibnall JT, Andresen EM, Hadler NM. 2004. Management of occupational back injuries: differences among African Americans and Caucasians. Pain 112:389–396.

Trinkoff AM, Johantgen M, Muntaner C, Le R. 2005. Staffing and worker injury in nursing homes. Am J Public Health 95:1220–1225.

Videman T, Ojajarvi A, Riihimaki H, Troup JD. 2005. Low back pain among nurses: a follow-up beginning at entry to the nursing school. Spine 30:2334–2341.

Waehrer G, Leigh JP, Miller TR. 2005. Costs of occupational injury and illness within the health services sector. Int J Health Serv 35:343–359.

Weddle MG. 1996. Reporting occupational injuries: the first step. J Safety Res 27:217–223.

Weiderpass E, Pukkala E, Kauppinen T, Mutanen P, Paakkulainen H, Vasama-Neuvonen K, Boffetta P, Partanen T. 1999. Breast cancer and occupational exposures in women in Finland. Am J Ind Med 36:48–53.

Wohlfarth T. 1997. Socioeconomic inequality and psychopathology: are socioeconomic status and social class interchangeable? Soc Sci Med 45:399–410.

Yassi A, Khokhar J, Tate R, Cooper J, Snow C, Vallentyne S. 1995. The epidemiology of back injuries in nurses at a large Canadian tertiary care hospital: implications for prevention. Occup Med (Lond) 45:215–220.