Published in final edited form as:
J Safety Res. 2009 ; 40(4): 247–255. doi:10.1016/j.jsr.2009.05.001.

Work environment risk factors for injuries in wood processing

Christina A. Holcroft[a,b] and **Laura Punnett**[a,*]

[a]Department of Work Environment, University of Massachusetts Lowell, One University Avenue, Lowell, Massachusetts, 01854, USA

[b]Centre for Clinical Epidemiology and Community Studies, Jewish General Hospital, Montreal, Quebec, Canada

Abstract

Problem—The reported injury rate for wood product manufacturing in Maine, 1987–2004, was almost twice the state-wide average for all jobs.

Method—A case-control study was conducted in wood processing plants to determine preventable risk factors for injury. A total of 157 cases with injuries reported to workers' compensation and 251 controls were interviewed.

Results—In multivariable analyses, variables associated with injury risk were high physical workload, machine-paced work or inability to take a break, lack of training, absence of a lockout/tagout program, low seniority, and male gender. Different subsets of these variables were significant when acute incidents and overexertions were analyzed separately and when all injuries were stratified by industry sub-sector.

Impact on industry—Generalizability may be limited somewhat by non-representative participation of workplaces and individuals. Nevertheless, these findings provide evidence that many workplace injuries occurring in wood processing could be prevented by application of ergonomics principles and improved work organization.

Keywords

Ergonomics; Physical effort; Psychosocial strain; Safety programs; Sawmill

1. Background

Wood product manufacturing is a critical industry in forested regions like the state of Maine, in the northeastern United States. Excluding logging, wood product manufacturing includes sawmills and wood preservation, and veneer, plywood, and engineered wood product manufacturing. In 1987, lumber and wood product processing was the second largest major industry group in Maine, accounting for about 13% of the manufacturing workforce and about 10% of the gross value of production (Maine Department of Labor, 1989a). Although the industry has slowed somewhat, in 2004 it still comprised about 11% of the

*Corresponding author. Tel.: +1 978 934 3269; fax: +1 978 452 5711. Laura_Punnett@uml.edu (L. Punnett).

manufacturing workforce with 267 workplaces and a total of 6,785 employees (Bureau of Labor Statistics [BLS], 2006; Maine Department of Labor, 2006).

In addition to being economically important, wood product processing is a highly hazardous industry. Although the incidence rate of employer-reported injuries and illnesses in Maine has decreased from 29.1 cases per 100 worker-years in 1987 (OSHA Form 200) to 12.4 in 2004 (OSHA Form 300), the rate is still almost twice the average state-wide rate (BLS, 2006; Maine Department of Labor, 1989b). The rate of lost workday cases in wood product manufacturing in 2004 was 3.3 cases per 100 worker-years and the total number of cases represented 27% of reportable injuries (BLS, 2006).

Most of the injury research in wood product manufacturing has been conducted in the sawmill industry. Primarily, the literature has been descriptive with respect to the type of incidents and nature of injuries (Bode, Giwa, & Oke, 2001; Burridge, Marshall, & Laing, 1997; McPeek et al., 1976). Recent research in the British Columbia sawmill industry has focused on the accuracy of workers' compensation data, costs of work-related injuries, and changes in the psychosocial and physical work conditions as the industry has downsized, but the associations between work exposures and injuries have not been examined (Alamgir, Koehoorn, Ostry, Tompa, & Demers, 2006a,b; Alamgir, Tompa, Koehoorn, Ostry, & Demers, 2007a,b; Ostry et al., 2000).

In only a few studies of wood product manufacturing has the relationship between selected exposures in the work environment and the likelihood of injury been quantified. The processing of hard wood, temporary job assignment at the time of injury, and worker's age were significantly associated with days lost from work in Maine (Cooke & Blumenstock, 1979). In Alberta, heavy and repetitive work was higher, on average, in saw-filers with higher injury rates, although the trend was not statistically significant (Jones & Kumar, 2007). Forty percent of all sawmill injuries in California were associated with manual materials handling (lifting, pushing, pulling, and carrying), primarily of lumber and logs; the researchers additionally classified sawmill injuries as to whether or not they were preventable and judged that only 1% were random occurrences that could not have been prevented (O'Gara, 1978).

Ergonomic risk factors, both physical and organizational, in wood product manufacturing are as diverse as the size of tool handles, machine guard openings, and equipment reach requirements; the weight and location of manually handled loads; shift work and overtime; and work pace, repetitiveness, and machine-pacing. In general, heavy work and repetitive motions have been studied primarily with respect to musculoskeletal disorders or overexertions (National Research Council; Institute of Medicine, 2001). The effect of ergonomic factors on acute injuries is not as well documented and might be expected to have a different etiologic mechanism from the effect on musculoskeletal disorders. Acute injuries and near-misses have been linked inconsistently to fatiguing aspects of work organization such as rotating shifts, intensely paced work, and incentive wages, including some studies in the forestry industry (Caruso et al., 2006; Folkard & Lombardi, 2006; Lilley, Feyer, Kirk, & Gander, 2002; Sundstrom-Frisk, 1984).

Thus, although the wood product industry has high rates of both acute and chronic injuries to workers, there is only limited evidence regarding preventable risk factors for these injuries. An epidemiologic study was undertaken of reported injuries among workers in wood product manufacturing plants in Maine. The study objective was to identify ergonomic and other related work environment factors that were associated with injury occurrence and that offered the potential for prevention, especially by engineering controls. Secondary objectives were to compare risk factors for acute injuries and overexertions and to determine if risk factors varied by sector of wood product manufacturing.

2. Methods

2.1. Study Design and Sources of Data

The target population comprised all employees in Standard Industrial Classification (SIC) codes 242 (sawmills and planing mills), 243 (millwork, veneer, plywood, and structural wood members), 244 (wood containers), 245 (wood buildings and mobile homes), and 249 (wood products, not elsewhere classified) in the state of Maine from 1991 to 1994. (The classification of wood product processing has changed slightly since the study was carried out; in 2002 the North American Industry Classification System (NAICS) coding system replaced the 1987 SIC codes (U.S. Census Bureau, 2006; see footnotes in Table 2).

Using a prospective case-control study design, incident cases (workers reporting new injuries) were compared with controls (workers selected at random from the same or similar workplaces). Cases were identified from employers' First Reports of Injury (FRI) to the Maine Department of Labor, Bureau of Labor Standards (MBLS), beginning in early 1991. An injury was eligible for inclusion if it occurred on the employer's premises and was not a highway motor vehicle accident, and if the employee was employed in manufacturing, not in management, sales, or office work.

All identified wood processing companies in Maine, and locals of the United Paperworkers' International Union and the United Brotherhood of Carpenters and Joiners in those companies, were requested to provide access to worker/member rosters for control selection. Potential controls were randomly selected from the lists provided, with group matching to the SIC codes of the cases. Two controls were sought per case, although the number of participating workplaces limited the number of potential controls available. As for the cases, managers and office employees were excluded as controls.

Cases were originally to be selected only from workplaces where controls could also be recruited. However, in 1991 the criteria for reporting injuries changed so that First Reports of Injury were only to be filed for injuries that had resulted in one or more lost work days. Because the number of reported injuries dropped dramatically, we began sampling cases from a larger subset of companies. With the assistance of the Maine Department of Conservation, all firms in SIC 242-249 that were in the same categories of SIC and workforce size as the participating workplaces were identified and added to the list from which potential cases were drawn.

At the beginning of data collection, the variables coded routinely by the MBLS included nature of the injury, part of the body, and source and type of incident. While data collection was underway, in 1992, state budget cutbacks resulted in dropping these variables from computerized data entry. The case interview (see below) had already included a section to confirm the FRI data, so these questions were used to obtain the missing information.

In order to describe employer facility characteristics, injury reports and interviews were linked by employer identifier from MBLS to two supplementary sources of information. The 1990 Maine Manufacturing Directory provided data for the size of the work force, by building or production facility, of each employer in the state. The Maine Department of Conservation Directory of Roundwood Processors and Exporters (DRP) 1988 provided data for each sawmill and related wood processor on type of wood processed and annual production output by volume.

2.2. Interview Data

All participants were interviewed by telephone at their home or in a private area at the workplace. The interview was a standardized questionnaire developed from discussions with sawmill workers, supervisors, and health and safety professionals with experience in the industry. It was pilot tested and evaluated in individual telephone interviews with other sawmill workers, which led to refinements in survey wording. The study was approved by the UMass Lowell Institutional Review Board.

For cases, injury characteristics were collected and job information was obtained regarding the specific activity(ies) performed at the time of the injury (summary in Table 1). Controls were asked about their work activities on the last full day worked. Questions about the psychosocial work environment were taken from the Karasek-Theorell Job Content Questionnaire (JCQ) (Karasek & Theorell, 1990). Psychophysical measures of noise, work pace, lifting demands, and dynamic work were based on an adaptation (Punnett & van der Beek, 2000) of Borg’s Rating of Perceived Exertion (Borg, 1986).

2.3. Data Analysis

Differences in workplace characteristics were examined for companies that contributed both cases and controls, companies that contributed only cases, and companies that did not participate. Statistical comparisons of participating and non-participating companies were conducted using a Wilcoxon non-parametric test for continuous variables and a chi-square test of association for categorical variables.

The questionnaire included 14 items on different aspects of physical workload; these were examined in factor analysis with maximum likelihood fitting, orthogonal rotation, and Spearman nonparametric correlation coefficients. Three physical effort factors were identified that described heavy work, awkward positions, and postural stress frequency (see Table 1 for constituents, scales and Cronbach alpha coefficients for each factor). The factor scores were constructed as unweighted averages of components and were each scaled from 1 to 4. The three factors were only moderately associated with each other (heavy work and awkward positions $r=0.5$; heavy work and postural stress $r=0.4$; and awkward positions and postural stress $r=0.3$). In order to further reduce the number of covariates considered in multivariable modeling, an interaction term was created by multiplying the heavy work and awkward positions factors and rescaling the range from 1 to 4.

A composite score for safety hazards was created from five safety questions from the Job Content Questionnaire (JCQ; Table 1), excluding noise level which did not fit well into the safety hazards factor. Three items on perceived effectiveness of the health and safety program and employer's commitment to health and safety were combined into a "perceived safety climate" factor.

Pre-defined exposure scores from the JCQ included decision latitude, psychological job demands, social support from coworkers and supervisors, job insecurity, and skill utilization (Karasek & Theorell, 1990). The job-strain ratio was calculated as psychological job demands divided by job decision latitude. A binary variable called "isostrain" was created for the combination of high job demands, low decision latitude, and low social support from coworkers and supervisors versus all other combinations (Landsbergis, Schnall, Warren, Pickering, & Schwartz, 1994). Job demands and decision latitude were dichotomized at the mean values for the U.S. male working population (30.67 and 65.92, respectively; Karasek et al., 1998); social support was dichotomized at 24.0, which was the median value of study participants.

Associations between injury occurrence and risk factors were estimated crudely for dichotomous exposure variables by the odds ratio with test-based 95% confidence limits, the chi-square statistic for categorical variables, and for continuous variables by the Student t-test (if normally distributed) or the Wilcoxon non-parametric test (otherwise). Associations were estimated both for all injuries combined and for injuries subdivided into qoverexertionq (strain/sprain) and qacute incidentq (e.g., fall, struck against or by, caught in or between).

Multivariable logistic regression modeling was used to estimate simultaneous associations and to control for potential confounding (Checkoway, Pearce, & Kriebel, 2004). Because there were differing participation rates of cases and controls by SIC, conditional logistic regression modeling was also used to control for sector (two SIC strata: 242/243 vs. 249). Confounding was defined as a change of 20% or more in the odds ratio. Collinearity between covariates was checked using Spearman pairwise correlations. Selection of independent variables for qbest fitq models was based on a stepwise fitting procedure to determine the model that provided the largest model chi-square per degrees of freedom with all independent variables significant at $p \leq 0.05$. All analyses were conducted in SAS v.8 (SAS, 2001).

In the stepwise selection process, some significant variables were not included in the final models. Specifically, wood type was removed from the conditional logistic models because it was not independent of SIC (softwood was almost exclusively used in SIC 242). Only variables with a plausible mechanism of effect were included (e.g., neither lockout/tagout program or noise for overexertions). The perceived safety climate factor was significant in some models but was ultimately removed because of concern about potential reporting bias among injured workers.

3. Results

3.1. Company Participation

Originally, 30 companies and three union locals agreed to provide workforce or membership rosters for identification of potential controls; rosters were actually obtained from 20 companies and all three union locals. Cases and controls were selected from these 20 workplaces for the entire duration of the study. In 1992, an additional 31 companies were identified that were judged comparable to one or more of the originally participating workplaces and whose employers agreed to provide access to cases but not controls.

All 51 participating companies were compared to the other 202 non-participating workplaces in SIC 242-249. As a group, in 1990, the participating facilities employed more workers, had higher gross annual sales and a higher injury rate, processed more board feet in 1998, were more likely to come from SIC 242 (sawmills), and were more likely to process hard wood (Table 2).

3.2. Participation of Cases and Controls etc

The participation rate was 53% among all potential cases (eligible FRI's) and 64% among all potential controls. Only about 12% of all individuals contacted refused to be interviewed, but a larger group of potential participants could not be located, specifically in that about 30% of cases were no longer at the address given on the First Report of Injury. A total of 408 participants were interviewed at least partially; 391 interviews were completed. Comparing the workplaces of participating and non-participating cases, the average total injury rate in 1990 did not differ between the workplaces (280 vs. 286 injuries per 1,000 workers per year; t-test p=0.8). However, the average injury rate was more than twice as high at the workplaces of non-participating controls compared to those of participating controls (593 vs. 269 injuries per 1,000 workers per year; t-test p<0.001). Using information available on the FRI, cases who participated had higher seniority than non-participants (7.1 vs. 4.3 years, Wilcoxon p=0.04), but did not significantly differ in age, gender, or occupation.

3.3. Study Population Characteristics

Demographics, work histories, and workplace characteristics are summarized stratified by participating cases and controls (Table 3). Overall, study participants ranged in age from 18 to 71 (mean 38) and were predominantly male. Almost all participants were Caucasian. Cases were more likely than controls to be employed in SIC 242 than 249 and more likely to be in workplaces that processed hard wood in 1988 at least some of the time.

Utilizing the combined data from FRI's and interviews, about one-half of all the cases' injuries were overexertions (Table 4); similarly, about 50% of injuries resulted in sprains or strains or joint inflammations. These overall proportions were comparable to the proportions of incidents for which type was recorded on the FRI.

3.4. Consistency of Different Data Sources

Some direct examination of data quality was possible on the basis of items collected from more than one source (DRP, FRI, and/or interview). For example, the 1988 DRP listing as to whether soft or hard wood was processed agreed with 70% of interview responses for the usual job (this item is known to vary over time at many mills and plants, depending on market conditions). Comparing data from FRI's and interviews of cases, the correlation coefficients were 0.99 for age and 0.96 for years employed at the company.

3.5. General Working Conditions

Cases and controls had similar work schedules with an average 8.5 hours per day and 5 days per week, although 73 (18% of all participants) reported working from 10 to 12 hours per day, and 10 participants worked from 65 to 77 hours per week. The prevalence of shift work (28%), production quotas (43%), and incentive wages (40%) were reported by roughly the same proportions of cases and controls. Cases were more likely than controls to be at their usual jobs on the index date of the survey (date of injury for cases and last day worked for controls).

The distribution of job titles was virtually identical between cases and controls. Just over one-half of all participants were machine operators or attendants; about 10% worked in each of the categories of supervisor/foreman, skilled trade, manual material handler, and inspector/grader.

Specific exposures differed among job titles. More exclusively self-paced work was found among skilled trades (87%), foremen (82%), and heavy equipment operators (57%) compared to other jobs (49%, $p<0.001$). The skilled trades and forepersons were also more likely to be able to take very short breaks when they were fatigued (overall chi-square, $p=0.004$). In contrast, inspectors and graders were the most likely to report exclusively machine-paced work (63%) and inability to take breaks (58%).

Male and female workers had very different job titles and working conditions. The proportion of females was markedly lower among heavy equipment operators, skilled trades, and material handlers, and markedly higher among inspector/graders and machine operators (chi-square, $p<0.001$). Women were disproportionately employed in SIC 249 versus 242 (46% versus 7% of interviewees). Female workers on average reported lower lifting demands ($p<0.001$), lower decision latitude ($p<0.001$), and higher social support ($p=0.006$).

Exposure frequencies varied somewhat by Standard Industrial Classification (Table 5). The participants in SIC 242 and 243, where rough logs are sawn into lumber, were almost all male. They were more likely to be in machine-paced jobs, less likely to be able to take a break if fatigued during work, and slightly more exposed to loud noise. Respondents in SIC 249, the manufacture of miscellaneous small and medium wooden items, were almost 50% female. They were more likely to process hard wood, were more exposed to postural stress, and had slightly higher job strain.

3.6. Work Environment Factors Associated with Injury

The overall physical demands of the job were greater for cases than controls by virtually all of the measures available, such as heavy work, awkward positions, and postural stress frequency (Table 6). Cases were also more likely to have machine-paced work and not to be able to take a break if they became fatigued.

Almost one-half (161) of all respondents reported negative skill utilization – that is, that their actual educational levels exceeded the job requirements (by a median value of 4 years). Job psychosocial features were more stressful for cases than controls. The cases reported lower decision latitude (54.8 vs. 58.5; p=0.002), slightly higher psychological job demands (32.4 vs. 31.5; p=0.12), and less social support from both coworkers and supervisors (23.1 vs. 25.0; p<0.001). In addition, the cases reported less job security, with reference to the period before their injuries occurred.

When the injuries of cases were sub-divided into acute incidents and overexertions, some differences were found in the strength of association with work environment factors. The physical effort factor scores – heavy work, awkward positions, and postural stress frequency – were all scored higher among overexertions than acute incidents (2.83 vs. 2.77, 2.56 vs. 2.44, and 2.77 vs. 2.67, respectively). The prevalence of the combined variable of machine-paced work or not being able to take breaks was 80% (53/66) for overexertion cases and 72% (52/72) for acute incident cases, compared with 57% (133/234) for controls.

Spearman pairwise correlations among the work environment factors were highest for the heavy work factor and awkward positions factor (r=0.49), job strain and isostrain (r=0.49), and lockout/tagout and any training (r = 0.50). The absolute value of the remaining correlations ranged from 0.01 to 0.42.

Most participants (at least 84%) reported one or more forms of occupational health and safety (OHS), right-to-know, or ergonomics training in their workplaces. However, cases were less likely to report receiving any OHS training (63% vs. 75%; p=0.03); lockout/tagout programs in the workplace (75% vs. 92%; p<0.001); or safety committees that met regularly (73% vs. 92%; p<0.001). Cases were also less likely to feel that their employers were making a genuine effort to protect their health and safety. When asked what was the response when a potential health or safety hazard was reported to a supervisor, 80% of all participants reported that the supervisor’s response had been to seek to remedy the problem, rather than to threaten job security or reprisals. However, cases were twice as likely as controls to have received a threatening or blaming response (OR =2.1, 95% CI=1.1, 4.2).

The internal consistency of these safety variables appeared quite good. The ratings of employer effort to promoting OHS were positively correlated with ratings of individuals’ supervisor support (Spearman r=0.50, p<0.001) and they were significantly higher for employers who offered OHS training and had established OHS committees or lockout/tagout programs. The ratings were also higher where the response of the supervisor to the report of a potential hazard had been to seek to remedy it.

3.7. Multivariable Analyses

Three separate conditional logistic regression models were constructed for the following outcomes: all injuries versus none; acute injuries vs. none; and overexertions versus none. These results were similar to those from unconditional logistic regression models and in general confirmed the crude associations.

The interaction term for heavy work and awkward positions had a stronger combined effect than either factor separately. The significant risk factors retained in the conditional logistic regression models were this interaction term, the combined variable of machine-paced work or cannot take breaks, any lockout/tagout program, any training, being new on the job, and male gender (Table 7). Job strain was moderately correlated with the heavy work-awkward positions interaction term and machine-paced work/cannot take breaks variable (0.41 and 0.33, respectively) and was not significant in the multivariable models.

Acute incidents were associated with being male, lack of training, and exposure to heavy work-awkward positions. Overexertions were also associated with exposure to heavy work/awkward positions and additionally to machine-paced work/cannot take breaks and being new on the job, but were not linked to gender or training.

Some different exposure-response associations became evident within SIC groups that did not appear in the entire data set (Table 8). In the model for SIC 242/3, injuries were associated with being male, exposure to heavy work/awkward positions, working with hard wood, and lack of training. In the model for SIC 249, exposure to heavy work-awkward positions was not statistically significant; injuries were more strongly linked to machine-paced work/cannot take breaks and absence of a lockout/tagout program.

4. Discussion

This case-control study of risk factors for injuries in wood processing plants identified a number of work environment features that were associated with injury occurrence. Cases were more likely than controls to be employed in machine-paced jobs, to be exposed to dangerous work methods and materials, to experience louder noise levels and faster work pace, to have higher lifting demands and more frequent postural stress, and to experience lower decision latitude and social support at work. The risk factors confirmed in multivariable regression models were high physical workload, machine-paced work or inability to take a break when tired, lack of training, absence of a lockout/tagout program, being new on the job, and being male. Additionally, processing hard wood was significantly associated with injuries within SIC 242/3.

4.1. Consistency of study findings with other literature

These findings are consistent with the *a priori* hypotheses for this study. Hard wood is denser (has higher mass per volume) than soft wood and thus has more potential energy (Cooke & Blumenstock, 1979). Workers processing hard wood are likely to be exposed to higher forces from saw kickbacks and to lift heavier loads. Sawmills were predicted to have higher injury rates because they represent an earlier stage in wood processing, with larger, heavier wood items and many large saw-blades, conveyors, lift trucks, and other vectors of mechanical energy.

Physical workload was also an expected risk factor for both overexertions and acute incidents. The former association is consistent with a large body of literature, across industry groups, on back and upper extremity disorders in relation to forceful manual exertions, rapid work pace, non-neutral body postures, vibration, and low temperatures (National Research Council; Institute of Medicine, 2001). The effect of heavy physical work with acute injury has been examined less often, although associations have been identified among factory workers (Melamed, Yekutieli, Froom, Kristal-Boneh, & Ribak, 1999) and in other sectors (d'Errico et al., 2007; Smith & Mustard, 2004).

Similarly, a variety of organizational factors have been implicated in risk for overexertions but are less well studied for acute injury (Veazie, Landen, Bender, & Amandus, 1994). Examples include machine-paced work in forestry and assembly operations (Bell & MacDonald, 2003; Lilley et al., 2002); piece rate work in forestry, manufacturing, and garment workers (Brisson, Vinet, Vezina, & Gingras, 1989; Kaminski, 2001; Sundstrom-Frisk, 1984); overtime in many industries, including forestry (Caruso, Hitchcock, Dick, Russo, & Schmit, 2004; Dembe, Erickson, Delbos, & Banks, 2005; Folkard & Lombardi, 2006; Lilley et al., 2002); and indicators of psychosocial strain, such as low decision latitude or poor relationships at work, in a wide range of industries (Bongers, de Winter, Kompier, & Hildebrandt, 1993; Bongers, Kremer, & ter Laak, 2002; d'Errico et al., 2007; Swaen, van Amelsvoort, Bultmann, Slangen, & Kant, 2004). Increased risk in manufacturing has been reported with greater labor intensity (i.e., faster work pace and fewer rest breaks; Grunberg, 1983). The simultaneous associations of injury risk in this study with work pace and with inability to rest when tired suggest a mediating effect of physical fatigue, although the actual mechanisms remain to be determined.

Shift work was expected but not found to be a risk factor. The extant literature is inconsistent on whether or not injury risk is higher on later work shifts, and a review of findings across industries from transportation to data-entry operators describes the difficulties of studying shift work due to a change in inherent risks across different shifts for the same job (Folkard & Tucker, 2003). The risks during later shifts may also be at least partially confounded by length of time at work that day (Hanecke, Tiedemann, Nachreiner, & Grzech-Sukalo, 1998).

Other findings of associations with male gender, employment for one year or less, supervisor support, and management effort to achieve safe working conditions were also consistent with some prior research. Gender, length of experience on the current job, and management style or other organizational features have all been associated with injury risk previously in a wide spectrum of job types (Lindell, 1997; Shannon, Mayr, & Haines, 1997; Shannon et al., 1996; Smith & Mustard, 2004).

Environmental noise has been shown to be at very high levels in sawmills and was predicted to be a risk factor because of interference with the perception of needed information (Koehncke et al., 2003; Moll van Charante & Mulder, 1990). However, in these data, noise was related to overexertions but not acute injuries. It may be that noise contributes to chronic stress and fatigue, but recall bias could also be involved.

4.2. Study limitations and strengths

Interpretation of the statistical associations in terms of etiology, and their generalizability, may be limited somewhat by the potential for non-representative participation of workplaces and of individuals. There were two levels of participation, that of the companies, in providing access to workers for interviews, and that of individual participants who were or were not interviewed.

At the first level, of those companies for which data were available (about two-thirds), the facilities that contributed cases only were more likely to process only hard wood in 1988 than those that contributed both cases and controls. Thus, the association between hard wood and case status may have been partly an artifact of non-representative selection. The limited number of companies that participated also has implications for generalizability. In particular, the participating companies were larger and had higher injury rates than non-participating companies. This was surprising, as the largest companies in this industry had been shown previously to have lower injury rates (Punnett, 1992), and additionally because these companies had a higher prevalence of OHS programs (training, lockout/tagout, etc.) than had been expected.

At the second level, participation by individuals, outright refusals were uncommon but a large proportion of potential participants, especially cases, could not be located. If these workers had moved because they were more severely injured or felt badly treated by their employers after the injury (several comments regarding poor treatment were offered spontaneously as interviews were concluded), and if they had different exposures to working conditions and safety hazards prior to the injury compared with the cases who were interviewed, this would introduce bias in the risk estimates. Specifically, if cases who could not be located had higher exposures this would imply bias toward the null, but obviously neither the occurrence nor direction of bias in this material can be ascertained.

The last issue with respect to subject selection and participation is that cases were identified through the state workers' compensation system. Compensation claims are likely to represent an incomplete sampling of all occupational injuries, possibly a more severe subset of the total number that occur (Alamgir et al., 2006b; Azaroff, Levenstein, & Wegman, 2002). This sampling is probably unlikely to bias the comparisons with working conditions of randomly selected workers unless injuries under certain circumstances (e.g., on jobs with heavier workloads or less supervisory support) are more likely to lead to claims than others. Through experience with the Workers' Compensation Commission, the Maine Bureau of Labor Statistics considers the First Reports to provide a reasonably complete estimate of the injuries occurring among non-self-employed workers. This is because in the state of Maine, an employer who fails to report an injury within 14 days loses the right to contest a worker's claim for benefits.

With respect to information quality, data on employer characteristics were obtained from external databases maintained by state agencies and therefore should be reasonably accurate and objective. Most of the individual-level exposures of interest in this study could only be collected through interviews with workers, raising concern about the potential for misclassification or information bias. In addition, some participants were at work when they were interviewed, and it is possible that this might have influenced their responses. Unfortunately, we did not record this datum for each individual, so we could not examine whether there was any systematic difference by location when interviewed. For a limited number of variables, agreement with other information sources could be evaluated and was found to be high. For some content areas (e.g., employer OHS administrative programs), internal consistency within a group of variables could be assessed and was found to be fairly good.

5. Impact on Industry

Assuming that the findings of this study are valid, they provide evidence for the preventable nature of many work-related injuries occurring in sawmills and other wood processing plants in Maine or elsewhere. We have taken the first step in prevention, which is to identify the most important risk factors of injury in order to prioritize the points of intervention. High physical work load, including lifting demands and postural stress, can be addressed by numerous engineering and administrative controls, ranging from material handling devices, to installation of jigs and fixtures for tools and materials, to job rotation. The National Institute for Occupational Safety and Health has developed a formula to be used for redesigning lifting tasks, based on biomechanical, physiological, and psychophysical inputs (Waters, Putz-Anderson, Garg, & Fine, 1993). Dangerous work methods and materials can be avoided by good industrial safety practices, and noise levels can similarly be reduced by proper engineering, selection, and installation of equipment. Mechanization of hazardous manual tasks has been shown to successfully reduce injuries in the logging industry, although some new injuries occurred through machine maintenance; this illustrates that a hazard assessment should be conducted for considered interventions to understand which new hazards may be introduced (Laflamme & Cloutier, 1988).

Inability to stop work for a few minutes when tired and associated work organization features (e.g., high work pace, machine-pacing, production quotas, and the nature and quality of supervision) are under the direct control of the employer. Decision latitude and social support are similarly consequences of the engineering and administrative organization of the workplace. Karasek and Theorell (1990) and LaMontagne, Keegel, and Vallance (2007) have described administrative job redesign processes to reduce psychosocial strain in the work environment.

The higher risk for workers with one year or less on the current job suggests either a healthy worker effect in the study population or an effect of less experience with actual job conditions, or both; to the extent that the latter is true, employer attention to training and other programs specifically targeting the newer worker may have a beneficial effect. There is also evidence here for the effectiveness of a lockout/tagout program, which is required by OSHA regulations but (according to participants' responses) had not been instituted in all of these workplaces.

Acknowledgments

The authors gratefully acknowledge the following individuals for interviewing, workplace observations, data entry, and data management: B. Brown, M. Christmas, T. Cutter, D. Linehan, W. Rodwell, M. Stanley, D. Thompson, and H. Wellman. Shylendra Kumar carried out the majority of the data management, cleaning, and preliminary statistical analysis. The United Paperworkers' International Union and the United Brotherhood of Carpenters and Joiners assisted with subject recruitment. The study Advisory Committee and other health and safety professionals shared invaluable information regarding the wood product industry and general OHS practices in the state of Maine: Mr. William Peabody, Maine Department of Labor; Dr. Greg Bogdan and Ms. Rhonda Webber, Maine Bureau of Health; Ms. Diana White and Mr. George Lambertson, Maine Labor Group on Health; Dr. William Moore and Mr. Ivan Most, University of Southern Maine; and particularly Mr. Peter Lammert of the Maine Forest Service, Department of Conservation. Special thanks are expressed to Mr. James McGowan, Director, Maine Bureau of Labor Standards, for providing uninterrupted access to First Reports of Injury for the duration of the study. Comments by an anonymous reviewer helped to improve the final version of the manuscript.

This study was supported by Grant Number R01-OH02741 from the National Institute for Occupational Safety and Health. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH.

Biographies

Christina Holcroft, Sc.D., has a doctorate in biostatistics from the Harvard School of Public Health and experience and training in occupational epidemiology from the Work Environment Department at University of Massachusetts Lowell, where she was research faculty when the analyses and manuscript for this research were finalized. She currently works at the Centre for Clinical Epidemiology and Community Studies at the Jewish General Hospital in Montreal, Canada as a biostatistics consultant and research collaborator. Her research interests are in occupational health and safety and intervention studies.

Laura Punnett, Sc.D., earned her doctoral degree in epidemiology and occupational health and safety from the Harvard School of Public Health and obtained post-doctoral training in occupational ergonomics at The University of Michigan. She is Professor of Epidemiology and Occupational Ergonomics in the Department of Work Environment, University of Massachusetts Lowell, as well as Senior Associate at the UML Center for Women and Work and Co-Director of the Center for the Promotion of Health in the New England Workplace. Her primary research expertise is in the relationship of work-related musculoskeletal disorders and other health outcomes to physical workload and psychosocial stress at work. More recently she has become interested in the broader range of health effects that manifest a gradient by gender and socioeconomic status, and how much of those effects can be explained by working conditions.

Abbreviations

DRP	Maine Department of Conservation Directory of Roundwood Processors and Exporters
FRI	First Reports of Injury
JCQ	Job Content Questionnaire
MBLS	Maine Department of Labor, Bureau of Labor Standards
NAICS	North American Industry Classification System

OHS occupational health and safety

OSHA Occupational Safety and Health Administration

SIC Standard Industrial Classification

References

Alamgir H, Koehoorn M, Ostry A, Tompa E, Demers PA. An evaluation of hospital discharge records as a tool for serious work related injury surveillance. Occupational and Environmental Medicine. 2006a; 63(4):290–296. [PubMed: 16556751]

Alamgir H, Koehoorn M, Ostry A, Tompa E, Demers PA. How many work-related injuries requiring hospitalization in British Columbia are claimed for workers' compensation? American Journal of Industrial Medicine. 2006b; 49(6):443–451. [PubMed: 16586407]

Alamgir H, Tompa E, Koehoorn M, Ostry A, Demers PA. Costs and compensation of work-related injuries in British Columbia sawmills. Occupational and Environmental Medicine. 2007a; 64(3): 196–201. [PubMed: 17053018]

Alamgir H, Tompa E, Koehoorn M, Ostry A, Demers PA. The hospital costs of treating work-related sawmill injuries in British Columbia. Injury. 2007b; 38(5):631–639. [PubMed: 17303140]

Azaroff LS, Levenstein C, Wegman DH. Occupational injury and illness surveillance: conceptual filters explain underreporting. American Journal of Public Health. 2002; 92(9):1421–1429. [PubMed: 12197968]

Bell JL, MacDonald LA. Hand lacerations and job design characteristics in line-paced assembly. Journal of Occupational Environmental Medicine. 2003; 45(8):848–856. [PubMed: 12915786]

Bode CO, Giwa SO, Oke DA. Factory floor injury in a Lagos sawmill. West African Journal of Medicine. 2001; 20(4):256–260.

Bongers PM, de Winter CR, Kompier MA, Hildebrandt VH. Psychosocial factors at work and musculoskeletal disease. Scandinavian Journal of Work, Environment and Health. 1993; 19(5):297–312.

Bongers PM, Kremer AM, ter Laak J. Are psychosocial factors, risk factors for symptoms and signs of the shoulder, elbow, or hand/wrist?: A review of the epidemiological literature. American Journal of Industrial Medicine. 2002; 41(5):315–342. [PubMed: 12071487]

Borg, G. Psycho physical studies of effort and exertion. In: Borg, G., Ottoson, D., editors. The Perception of Exertion in Physical Work. London: MacMillan Press Ltd; 1986.

Brisson C, Vinet A, Vezina M, Gingras S. Effect of duration of employment in piecework on severe disability among female garment workers. Scandinavian Journal of Work, Environment and Health. 1989; 15(5):329–334.

Bureau of Labor Statistics [BLS]. Maine incidence rates of nonfatal occupational injuries and illnesses by industry and case types, 2004: US Department of Labor, Survey of Occupational Injuries and Illnesses. 2006. Available at http://www.maine.gov/labor/labor_-stats/publications/injuries/2004rates.pdf

Burridge JD, Marshall SW, Laing RM. Work-related hand and lower-arm injuries in New Zealand, 1979 to 1988. Australian and New Zealand Journal of Public Health. 1997; 21(5):451–454. [PubMed: 9343887]

Caruso CC, Bushnell T, Eggerth D, Heitmann A, Kojola B, Newman K, et al. Long working hours, safety, and health: toward a National Research Agenda. American Journal of Industrial Medicine. 2006; 49(11):930–942. [PubMed: 16948157]

Caruso, CC., Hitchcock, EM., Dick, RB., Russo, JM., Schmit, JM. Overtime and extended work shifts: recent findings on illnesses, injuries, and health behaviors. Atlanta: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; 2004. DHHS(NIOSH) Publication No. 2004-143

Checkoway, H., Pearce, NE., Kriebel, D. Research Methods in Occupational Epidemiology. 2nd. New York: Oxford University Press; 2004.

Cooke WN, Blumenstock MW. The determinants of occupational injury severity: The case of Maine sawmills. Journal of Safety Research. 1979; 11:115–120.

Dembe AE, Erickson JB, Delbos RG, Banks SM. The impact of overtime and long work hours on occupational injuries and illnesses: new evidence from the United States. Occupational and Environmental Medicine. 2005; 62(9):588–597. [PubMed: 16109814]

d'Errico A, Punnett L, Cifuentes M, Boyer J, Tessler J, Gore R, et al. Hospital injury rates in relation to socioeconomic status and working conditions. Occupational and Environmental Medicine. 2007; 64:325–333. [PubMed: 17182643]

Folkard S, Lombardi DA. Modeling the impact of the components of long work hours on injuries and qaccidents. American Journal of Industrial Medicine. 2006; 49(11):953–963. [PubMed: 16570251]

Folkard S, Tucker P. Shift work, safety and productivity. Occupational Medicine (London). 2003; 53(2):95–101.

Grunberg L. The effects of the social relations of production on productivity and workers' safety: an ignored set of relationships. International Journal of Health Services. 1983; 13(4):621–634. [PubMed: 6642813]

Hanecke K, Tiedemann S, Nachreiner F, Grzech-Sukalo H. Accident risk as a function of hour at work and time of day as determined from accident data and exposure models for the German working population. Scandinavian Journal of Work, Environment and Health. 1998; 24(Suppl 3):43–48.

Jones T, Kumar S. Comparison of ergonomic risk assessments in a repetitive high-risk sawmill occupation: Saw-filer. International Journal of Industrial Ergonomics. 2007; 37:744–753.

Kaminski M. Unintended consequences: organizational practices and their impact on workplace safety and productivity. Journal of Occupational Health Psychology. 2001; 6(2):127–138. [PubMed: 11326725]

Karasek RA, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. The Job Content Questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. Journal of Occupational Health Psychology. 1998; 3(4):322–355. [PubMed: 9805280]

Karasek, RA., Theorell, T. Healthy work: stress, productivity, and the reconstruction of working life. New York, NY: Basic Books, Inc; 1990.

Koehncke N, Taylor M, Taylor C, Harman L, Hessel PA, Beaulne P, et al. An investigation of noise levels in Alberta sawmills. American Journal of Industrial Medicine. 2003; 43(2):156–164. [PubMed: 12541270]

Laflamme L, Cloutier E. Mechanization and risk of occupational accidents in the logging industry. Journal of Occupational Accidents. 1988; 10:191–198.

LaMontagne AD, Keegel T, Vallance D. Protecting and promoting mental health in the workplace: developing a systems approach to job stress. Health Promotion Journal of Australia. 2007; 18(3): 221–228. [PubMed: 18201165]

Landsbergis PA, Schnall PL, Warren K, Pickering TG, Schwartz JE. Association between ambulatory blood pressure and alternative formulations of job strain. Scandinavian Journal of Work, Environment and Health. 1994; 20(5):349–363.

Lilley R, Feyer AM, Kirk P, Gander P. A survey of forest workers in New Zealand. Do hours of work, rest, and recovery play a role in accidents and injury? Journal of Safety Research. 2002; 33(1):53–71. [PubMed: 11979637]

Lindell MK. Occupational safety and health inspection scores predict rates of workers' lost-time injuries. Accidents Analysis and Prevention. 1997; 29(5):563–571.

Maine Department of Labor. Census of Maine Manufacturers, 1986. Augusta ME: BLS #615, Research and Statistics Division, Bureau of Labor Standards, Maine Department of Labor; 1989a.

Maine Department of Labor. Occupational Injuries and Illnesses in Maine, 1987. Augusta ME: BLS #614, Research and Statistics Division, Bureau of Labor Standards, Maine Department of Labor; 1989b.

Maine Department of Labor. Industry pro file for subsector (3-digit) wood product manufacturing. 2006. Available at http://www.maine.gov/labor/labor_stats/ (labor market analysis)

McPeek, J., et al. Analysis of Occupational Injuries and Illnesses for Wisconsin Industry, Saw Mills and Planing Mills. Madison, WI: State of Wisconsin Department of Industry, Labor and Human Relations; 1976. SIC 2420

Melamed S, Yekutieli D, Froom P, Kristal-Boneh E, Ribak J. Adverse work and environmental conditions predict occupational injuries. The Israeli Cardiovascular Occupational Risk Factors Determination in Israel (CORDIS) Study. American Journal of Epidemiology. 1999; 150(1):18–26. [PubMed: 10400549]

Moll van Charante AW, Mulder PG. Perceptual acuity and the risk of industrial accidents. American Journal of Epidemiology. 1990; 131(4):652–663. [PubMed: 2316497]

National Research Council; Institute of Medicine. Musculoskeletal disorders and the workplace: Low back and upper extremities. Washington, DC: National Academy Press; 2001.

O'Gara, K. California Sawmills and Planing Mills Industry: Analysis of Work Injuries and Illnesses. San Francisco, CA: Division of Labor Statistics and Research, Department of Industrial Relations; 1978.

Ostry A, Marion S, Green LW, Demers P, Teschke K, Hershler R. Downsizing and industrial restructuring in related to changes in psychosocial conditions of work in British Columbia sawmills. Scandinavian Journal of Work, Environment and Health. 2000; 26(3):273–278.

Punnett L. Epidemiologic study of sawmill injuries in Maine. Final Report to the Centers for Disease Control (Grant #R29/CCR 103677). 1992

Punnett L, van der Beek AJ. A comparison of approaches to modeling the relationship between ergonomic exposures and upper extremity disorders. American Journal of Industrial Medicine. 2000; 37(6):645–655. [PubMed: 10797508]

SAS. SAS Statistical Software: Release 8.2. Cary, NC: Author; 2001.

Shannon HS, Mayr J, Haines T. Overview of the relationship between organizational and workplace factors and injury rates. Safety Science. 1997; 26(3):201–217.

Shannon HS, Walters V, Lewchuck W, Richardson J, Moran LA, Haines T. Workplace organizational correlates of lost-time accident rates in manufacturing. American Journal of Industrial Medicine. 1996; 29(3):258–268. [PubMed: 8833778]

Smith PM, Mustard CA. Examining the associations between physical work demands and work injury rates between men and women in Ontario, 1990-2000. Occupational and Environmental Medicine. 2004; 61(9):750–756. [PubMed: 15317915]

Sundstrom-Frisk C. Behavioural control through piece-rate wages. Journal of Occupational Accidents. 1984; 6:49–59.

Swaen GM, van Amelsvoort LP, Bultmann U, Slangen JJ, Kant IJ. Psychosocial work characteristics as risk factors for being injured in an occupational accident. Journal of Occupational and Environmental Medicine. 2004; 46(6):521–527. [PubMed: 15213513]

U.S. Census Bureau. 1987 SIC to 2002 NAICS, manufacturing, part (SICs 24–29). 2006. Available at http://www.census.gov/epcd/naics02/

Veazie MA, Landen DD, Bender TR, Amandus HE. Epidemiologic research on the etiology of injuries at work. Annual Review of Public Health. 1994; 15:203–221.

Waters TR, Putz-Anderson V, Garg A, Fine LJ. Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics. 1993; 36(7):749–776. [PubMed: 8339717]

Table 1

Information collected in the standardized interview of wood processing employees. Constituents of physical effort and safety hazard factors are listed with the actual score range and Cronbach alpha coefficient.

Demographics
Job title and work history
Types of wood products processed
Shift length and schedule
Production quotas
Wage basis (hourly vs. piece rate)
Machine pacing
Psychosocial work environment
Health and safety program elements, e.g., worker training or labor-management committees
Injury characteristics (for cases)
Heavy Work Factor (Range 1.375 – 4; α=0.74)
Lots of physical effort (JCQ q21) [a]
Move or lift very heavy loads on my job (JCQ q24) [a]
Rapid and continuous physical activity (JCQ q25) [a]
Reach up to shoulder height or above [b]
Bend forward at the waist or stoop down [b]
Bend, lean or twist to one side [b]
Pace of work [c]
Physical intensity of work [c]
Awkward Positions Factor (Range 1 – 4; α=0.86)
Work for long periods with body in physically awkward positions (JCQ q30) [a]
Work for long periods with head or arms in physically awkward positions (JCQ q31) [a]
Postural Stress Frequency Factor (Range 1 – 4; α=0.59)
Reach forward of your body with your whole arm [b]
Twist the arm or forearm [b]
Bend the wrist [b]
Pinch with the fingers [b]
Safety Hazards Factor (Range=0 – 2, α=0.72)
Dangerous placement of objects (JCQ q41) [d]
Poor housekeeping or maintenance (JCQ q42) [d]
Dangerous tools, machinery, or equipment (JCQ q44) [d]
Exposure to fire hazard, burns, or shocks (JCQ q45) [d]
Dangerous work methods (JCQ q47) [d]
Perceived Safety Climate Factor (Range=0.67 – 4, α=0.71)
Health & safety training has helped avoid injury or disease [e]
Employer is willing to spend money on a safely engineered workplace [e]
Safety director is genuinely concerned and has taken constructive measures for prevention [e]
Noise Level (Range 1 – 4)
How loud do you have to talk to the person standing next to you (JCQ q46) [f]

[a]Strongly disagree / Disagree / Agree / Strongly agree; Job Content Questionnaire

[b]Rarely / Sometimes / Often / Constantly

[c]1 is "very, very light" and 7 is "very, very hard"; rescaled 1-4

[d]Not exposed / Slight problem / Sizeable or great problem; Job Content Questionnaire

[e]No program / Strongly disagree / Disagree / Agree / Strongly agree; scaled 0-4

[f]Whisper / Normal voice / Loud voice / Shout; Job Content Questionnaire

Table 2

Comparisons of participating and non-participating wood processing employers (data from multiple sources (see Methods section)).

Workplace characteristic	Participating Companies*			Non-participating Companies*
	Cases & controls (N=20)	Cases only (N=31)	Cases or controls (N=51)	(N=202)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Workforce size, 1990	195 (342)	80 (61)	112 (188) [a]	32 (51)
Annual sales ($ million), 1990	6.9 (4.5)	4.9 (4.7)	5.6 (4.6) [a]	2.9 (5.1)
Board feet processed (1,000's), 1988	7.2 (3.0)	6.1 (2.2)	6.5 (2.5) [a]	4.7 (2.4)
Injury rate, 1990 **	261 (231)	226 (189)	236 (199) [a]	85 (166)
	Number (%)	Number (%)	Number (%)	Number (%)
SIC + (1990): 242	5 (63%)	17 (61%)	22 (61%) [b]	76 (43%)
243-245	0 (0%)	2 (7%)	2 (6%)	53 (30%)
249	3 (38%)	9 (32%)	12 (33%)	49 (28%)
Wood (1988): Hard	4 (33%)	11 (46%)	15 (42%) [c]	34 (26%)
Soft	6 (50%)	7 (29%)	13 (36%)	55 (42%)
Both hard & soft	2 (17%)	6 (25%)	8 (22%)	42 (32%)

*Because of missing data, the number of observations in each column varies for each comparison variable.

**Per 1,000 workers per year.

[a] $p<0.001$ from Wilcoxon non-parametric test compared to non-participants.

[b] $p<0.001$ from chi-square test compared to non-participants.

[c] $p<0.05$ from chi-square test compared to non-participants.

+In comparison with NAICS codes, wood product manufacturing (NAICS code 321, previously SIC code 24) includes sawmills and wood preservation (NAICS code 3211), veneer, plywood, and engineered wood product manufacturing (3212), and other wood product manufacturing (3219).

Table 3

Demographics, work histories and workplace characteristics of cases and controls (data from multiple sources (see Methods section)).

Demographics and work history	**Controls (n=251+)**	**Cases (n=157+)**	
	Number (%)	**Number (%)**	**P-value***
Gender: Male	128 (83%)	185 (74%)	0.04
	Mean (SD)	Mean (SD)	P-value **
Age	37.6 (13.6)	38.2 (10.4)	0.20
Years in wood industry	10.7 (10.9)	12.0 (9.0)	0.20
Years with current employer	10.3 (9.4)	9.6 (8.2)	0.46
Years in current job	5.5 (7.4)	5.7 (6.3)	0.79
Workplace characteristics			
Workforce size (1990)	150 (119)	171 (128)	0.13
Sales, $ million (1990)	12.0 (5.9)	9.4 (2.1)	0.001
Injury rate (1990) ++	279 (132)	269 (187)	0.54
	Number (%)	Number (%)	P-value *
SIC (1990): 242	72 (55%)	51 (36%)	
243	4 (3%)	0 (0%)	
249	54 (42%)	91 (64%)	<0.001
Wood (1988): Hard	64 (47%)	94 (45%)	
Soft	45 (33%)	98 (47%)	
Both hard & soft	27 (20%)	18 (9%)	0.003

+Because of missing data, the number of subjects varies for each characteristic compared, from 61 to 155 cases and 76 to 251 controls.

++Per 1,000 workers per year.

*From chi-square test statistic.

**From Student’s T-test statistic.

Table 4

Type of incident and nature of injury for 139 interviewed injury cases (data from First Reports of Injury and interviews).

Type of incident	Number (%)	Nature of injury	Number (%)
Struck against or by	27 (19%)	Amputation, laceration	12 (9%)
Fall	22 (16%)	Contusion	11 (8%)
Caught in or abraded	10 (7%)	Dislocation; fracture	18 (13%)
Overexertion	72 (52%)	Hernia, rupture	7 (5%)
Bodily reaction; miscellaneous	8 (6%)	Sprain/strain, joint inflammation	75 (54%)
		Scratch, abrasion	4 (3%)
		Burn; multiple; miscellaneous	12 (9%)

Table 5

Working conditions, physical exposures and organizational features in the usual jobs of wood processing workers (interview data) by Standard Industrial Classification. Factor score variables are described in Table 1.

Variable (range)	SIC 242/243 (n=241[a])	SIC 249 (n=151[a])	P-value*
	Mean (SD)	Mean (SD)	
Heavy work factor (1.4 – 4)	2.61 (0.6)	2.64 (0.5)	0.56
Awkward positions factor (1 – 4)	2.27 (0.6)	2.34 (0.8)	0.30
Interaction between heavy work & awkward positions factors (1.1 – 3.9)	2.02 (0.5)	2.07 (0.6)	0.37
Postural stress frequency factor (1 – 4)	2.53 (0.7)	2.73 (0.8)	0.01
Job strain (0.3 – 1.8)	0.52 (0.2)	0.56 (0.2)	0.045
Safety hazards factor (0 – 2)	0.27 (0.4)	0.24 (0.4)	0.46
Perceived safety climate factor (0.7 – 4)	2.92 (0.6)	2.98 (0.7)	0.23
Noise (1 – 4)	2.97 (0.8)	2.81 (0.7)	0.045
	Number (%)	Number (%)	P-value**
Wood type: Hard	40 (20%)	78 (61%)	
Soft	122 (61%)	12 (9%)	
Both hard & soft	38 (19%)	39 (30%)	<0.001
Machine-paced work[b]	131 (57%)	67 (45%)	0.02
Cannot take break if tired[c]	115 (54%)	40 (31%)	<0.001
Machine-paced work *or* cannot take breaks	154 (69%)	78 (57%)	0.02
Isostrain: High demand / Low control / Low social support	41 (18%)	21 (15%)	0.42
Lockout / tagout program[d]	192 (87%)	115 (86%)	0.78
Any training[e]	203 (91%)	132 (95%)	0.17
New on job (<=1 year seniority)	90 (38%)	33 (22%)	0.001
Gender: male	214 (90%)	83 (55%)	<0.001

*From Wilcoxon non-parametric test.

**From chi-square test statistic.

[a]The number of subjects varies for each comparison because of missing data.

[b]Yes on interview to: "Do you have to keep up with a machine or fixed speed production line?"

[c]Response of "Cannot take breaks" to "If you get tired and would like to slow down your work pace, what happens?"

[d]Yes on interview to: "Do you know of any lockout/tagout program in your plant?"

[e]Yes on interview to either "Do you know of any right-to-know training? …safety or ergonomics training?"

Table 6

Working conditions, physical exposures and organizational features (interview data) in usual jobs of 157 cases and 251 controls[a]. Factor score variables are described in Table 1.

Variable (range)	**Cases**	**Controls**	**P-value***
	Mean (SD)	**Mean (SD)**	
Heavy work factor (1.4 – 4)	2.81 (0.6)	2.51 (0.5)	<0.001
Awkward positions factor (1 – 4)	2.50 (0.7)	2.16 (0.6)	<0.001
Interaction between heavy work & awkward positions factors (1.1 – 3.9)	2.24 (0.6)	1.91 (0.5)	<0.001
Postural stress frequency factor (1 – 4)	2.72 (0.7)	2.52 (0.8)	0.02
Job strain (0.3 – 1.8)	0.58 (0.2)	0.51 (0.1)	0.001
Safety hazards factor (0 – 2)	0.34 (0.5)	0.21 (0.3)	0.01
Perceived safety climate factor (0.7 – 4)	2.65 (0.7)	3.13 (0.5)	<0.001
Noise (1 – 4)	3.08 (0.8)	2.80 (0.7)	<0.001
	Number (%)	Number (%)	P-value **
Wood type: Hard	60 (50%)	60 (27%)	
Soft	47 (39%)	90 (41%)	
Both hard & soft	13 (11%)	71 (32%)	<0.001
Machine-paced work	90 (63%)	109 (44%)	<0.001
Cannot take break if tired	74 (56%)	86 (38%)	0.001
Machine-paced work *or* cannot take breaks	105 (76%)	133 (57%)	<0.001
Isostrain: High demand / Low control / Low social support	35 (25%)	29 (12%)	<0.001
Lockout / tagout program	95 (75%)	223 (92%)	<0.001
Any training	113 (84%)	236 (97%)	<0.001
New on job (<=1 year)	62 (40%)	64 (26%)	0.003
Gender: male	128 (83%)	185 (74%)	0.04

[a]The number of subjects varies for each comparison because of missing data.

*From Wilcoxon non-parametric test.

**From chi-square test statistic.

Table 7

Multivariable analyses of all injuries, acute incidents and overexertions using conditional logistic regression with strata SIC 242/243 and SIC 249. '—' represents a factor not retained in the model and 'xxx' represents a factor that was not considered for the particular outcome.

Risk Factor	All injuries (n=303)	Acute incidents (n=257)	Overexertions (n=253)
	OR (95% CI)*	OR (95% CI)*	OR (95% CI)*
Interaction between heavy work & awkward positions factors (1.1 – 3.9)	2.3 (1.3, 4)	2.5 (1.3, 5)	2.9 (1.5, 5)
Machine-paced work or cannot take breaks	2.0 (1.1, 4)	—	3.6 (1.5, 8)
Lockout / tagout program	0.5 (0.2, 1.2)	—	xxx
Any training	0.3 (0.1, 0.9)	0.2 (0.1, 0.6)	—
New on job (<=1 year)	—	—	2.2 (1.1, 4.5)
Gender: female	0.3 (0.1, 0.6)	0.05 (0.01, 0.4)	—
Model chi-square (d.o.f.) **	55.50 (5)	41.04 (3)	35.27 (3)
P-value	<0.0001	<0.0001	<0.0001

* Exponentiated coefficient with test-based confidence interval.

** From Log-Likelihood ratio test of intercept plus covariates versus intercept alone.

Table 8

Multivariable logistic regression analyses of all injuries stratified by SIC. '—' represents a factor not retained in the model.

Risk Factor	SIC 242/243 (n=168) OR (95% CI)*	SIC 249 (n=101) OR (95% CI)*
Interaction between heavy work & awkward positions factors (1.1 – 3.9)	4.3 (2.0, 9)	—
Machine-paced work or cannot take breaks	—	9 (2.5, 32)
Lockout / tagout program	—	0.05 (0.01, 0.3)
Any training	0.3 (0.1, 0.9)	—
New on job (<=1 year)	—	—
Gender: female	0.1 (0.02, 0.6)	0.3 (0.1, 0.9)
Hard wood only (vs. soft or both)	3.5 (1.5, 8)	—
Model chi-square (d.o.f.) **	40.63 (4)	37.43 (3)
P-value	<0.0001	<0.0001

* Exponentiated coefficient with test-based confidence interval.

** From Log-Likelihood ratio test of intercept plus covariates versus intercept alone.