

Predictors of Upper Extremity Symptoms and Functional Impairment Among Workers Employed for 6 Months in a New Job

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Background We sought to identify personal and work-related predictors of upper extremity symptoms and related functional impairment among 1,108 workers employed for 6 months in a new job.

Methods We collected data at baseline and 6-month follow-up using self-administered questionnaires. Multivariate logistic regression models were created for each outcome variable. Predictors included personal risk factors, physical work exposures and psychosocial factors.

Results Independent predictors for upper extremity symptoms at 6-month follow-up were age, Caucasian race, female gender, baseline history of UE symptoms, and job tasks involving wrist bending or forceful gripping. Independent predictors for functional impairment were baseline history and severity of UE symptoms, wrist bending, and social support.

Conclusions Both personal and work-related factors were independent predictors of upper extremity symptoms and functional impairment in this working population. We found different risk factors for symptoms than for functional impairment related to symptoms. Am. J. Ind. Med. 51:932–940, 2008. © 2008 Wiley-Liss, Inc.

KEY WORDS: musculoskeletal disorders; upper extremity; functional outcomes; work disability; psychosocial risk factors

INTRODUCTION

Musculoskeletal disorders of the upper extremity (UE MSDs) including the shoulder, arm, hand and wrist are among the leading work-related health concerns in the United States [Bernard, 1997; Panel on Musculoskeletal Disorders and the Workplace, 2001] accounting for up to 30% of all injuries and illnesses requiring time away from work [U.S. Department of Labor, 2006]. The etiology can involve personal factors including gender, age, body mass index (BMI), and comorbid diseases [Phalen, 1966; Nathan et al., 1988; Nordstrom et al., 1997; Stevens et al., 1999] or work-related physical exposures, such as forceful and repetitive activities and awkward postures [Kourinka and Forcier, 1995; Bernard, 1997; Nordstrom et al., 1997; Werner et al., 1997; Panel on Musculoskeletal Disorders and the Workplace, 2001]. While recent studies have shown that both

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Contract grant sponsor: Centers for Disease Control and Prevention; Contract grant sponsor: National Institute for Occupational Safety and Health; Contract grant number: R01OH008017-01.

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Accepted 18 June 2008
DOI 10.1002/ajim.20625. Published online in Wiley InterScience
(www.interscience.wiley.com)

personal and work-related physical exposures are independently associated with UE MSDs [Latko et al., 1999; Gell et al., 2005; Werner et al., 2005a], there is continued uncertainty in the literature about the relative contributions of work exposures and personal risk factors [Panel on Musculoskeletal Disorders and the Workplace, 2001].

In addition to personal factors and physical work exposures, research conducted in the last few decades suggests that work-related psychosocial factors including job stress and job demands can also be associated with the development of UE MSDs [Faucett and Rempel, 1994; Leclerc et al., 2001], although evidence for specific associations is inconsistent [Bongers et al., 2002, 2006]. Psychosocial risk factors have also been associated with work disability [Sullivan et al., 2005].

Many of the studies investigating the association of risk factors relative to the development of UE MSDs have utilized cross-sectional designs, whereas a longitudinal design would provide better evidence of disease development over time [Bernard, 1997; Panel on Musculoskeletal Disorders and the Workplace, 2001; Bongers et al., 2002; Werner et al., 2005b]. Past studies have incorporated various combinations of risks in a model predicting typical UE MSDs, but relatively few have included personal, physical work exposures, and work-related psychosocial factors simultaneously [Bernard, 1997; Panel on Musculoskeletal Disorders and the Workplace, 2001; Bongers et al., 2006].

Common outcome measures used in studies of UE MSDs have included the presence of symptoms and clinical signs, as well as lost work time, or return to full work duty status [Pransky et al., 1997, 1999; Amick et al., 2004; Baldwin and Butler, 2006]. Symptoms, though integral to the etiology of disease, do not describe the functional impact on the individual's life. For example, the inability to sustain a full day of work is a common functional limitation that is debilitating for workers and expensive for employers and social insurance programs [Bongers et al., 2002; Amick et al., 2004]. However, workers who return to work may have residual functional disability that is not captured by insurance or administrative data [Evanoff et al., 2002]. Functional impairment resulting from upper extremity symptoms can be used as a measure of severity of disorders as well as the personal cost of the illness. Understanding the factors that contribute to functional impairment outcomes could improve workers' quality of life and lead to a reduction in workers' compensation costs for employers by directly linking worker function to productivity measures [Amick et al., 2004].

In this study, we recruited a cohort of newly hired workers and followed them prospectively to examine the predictors of both upper extremity symptoms and related functional impairment. We examined the contributions of personal factors, physical work exposures, and work-related psychosocial factors simultaneously as potential predictor variables in multivariate models.

MATERIALS AND METHODS

Study Design and Population

This study was conducted within the Predictors of Carpal Tunnel Syndrome (PrediCTS) Study, an ongoing 3-year prospective study of newly hired workers from various industries. The overall PrediCTS study aims are (1) to assess personal and work-related risk factors associated with carpal tunnel syndrome (CTS) and (2) to evaluate the utility of pre-placement, post-offer screening tests including nerve conduction. Eligible study participants, enrolled between July 2004 and October 2006, were newly hired workers at least 18 years of age who were starting a new full-time job (at least 30 hr per week) or had a change to regular benefits status. Subjects were excluded if they (1) had a physical condition that was a contraindication to nerve conduction testing, (2) had a previous diagnosis of CTS or peripheral neuropathy, or (3) were pregnant at baseline, as pregnancy can alter nerve conduction findings. Subject recruitment took place at the time of pre-placement post-offer screening, during apprenticeship training classes, or at company orientations depending upon the hiring procedures of each cooperating employer or apprenticeship program. Subjects were recruited from industries involving both high and low hand-intensive jobs, including manufacturing, construction trades, health-care, and biotechnology. The Washington University School of Medicine Institutional Review Board approved this study and all subjects provided written informed consent prior to participation.

Data Collection and Measures

Initial testing at baseline (time of enrolment) included a brief physical examination of the upper extremities, a bilateral nerve conduction test, and a self-administered questionnaire. Follow-up questionnaires were collected 6 months after baseline. The follow-up questionnaires were mailed to subjects or, when applicable, distributed and collected at apprenticeship training classes or the worksite. To increase the response rate, subjects were mailed a second questionnaire if they did not return a completed questionnaire within 2 weeks after the initial mailing or during the scheduled collection times at the apprenticeship school or worksite. After the second mailing, subjects who failed to return the follow-up questionnaire were called by a study team member and offered the chance to complete the survey by telephone. We pursued subjects with unreturned follow-up questionnaires up to and including 12 months from baseline. Study subjects were compensated for their participation.

Baseline and follow-up questionnaires collected information on personal characteristics, including demographics, medical history, and if applicable, hand and upper extremity

symptoms including a modified Katz hand diagram [Katz et al., 1996], information about medical care for hand/wrist disorders, changes in work productivity and duties, and functional status [Levine et al., 1993]. The questionnaires also addressed work issues including previous work history, physical work exposures of current or most recent job [Nordstrom et al., 1998], and psychosocial measures [Karasek et al., 1998]. Most of the test items used in our questionnaire have been used in previous research of UE MSDs and have been shown to have good to excellent test-retest reliability [Franzblau et al., 1993, 1994, 1997; Katz et al., 1998; Salerno et al., 2001]. Data from the baseline physical examination and nerve conduction studies were not included in the present analyses.

For the current study, we defined four outcomes of interest: (1) prevalent symptoms, (2) prevalent symptoms of at least moderate severity, (3) incident symptoms, and (4) functional impairment related to UE symptoms. Prevalent symptoms were defined as subject reporting upper extremity symptoms of any severity on the 6-month questionnaire, regardless of baseline history. Prevalent symptoms of moderate severity were defined as subjects who reported a symptom severity of 5 or more on a scale of 0 (no discomfort) to 10 (worst discomfort imaginable), based on subjects rating their work discomfort in the previous 30 days for any of the three body regions. Incident symptoms included subjects with no history of UE symptoms in any location at baseline, but who reported new symptoms on the 6-month follow-up questionnaire. Cases of functional impairment included any worker who reported a limitation on the 6-month questionnaire attributed to UE symptoms in any one of the following areas: (1) limited ability to work, (2) decreased productivity, (3) lost time from work, (4) placed on job restrictions, (5) change in job or employer because of symptoms, and the (6) Levine Functional Status Scale. On the Levine Functional Status Scale [Levine et al., 1993], subjects reported difficulty in performing eight regular work duties or activities of daily living from 1 point (no difficulty) to 5 points (cannot perform activity at all). The mean of the eight items was calculated for overall functional status scores at baseline and at 6 months. An effect size was calculated as the mean difference in baseline and follow-up functional status scores divided by the standard deviation of the difference scores. An effect size of 0.8 or greater was considered a positive result; a difference less than 0.8 was negative [Levine et al., 1993].

Independent Predictor Variables

Independent predictor variables were selected a priori based on past literature that showed an association with an outcome of UE MSD. These variables included personal factors, physical work exposures and work related psychosocial factors. Personal factors consisted of age, gender, race and BMI reported selected from items on the baseline

questionnaire. Items used in the analysis from the 6-month questionnaire included the physical work exposures and psychosocial variables. Four self-reported physical work exposures previously described by Nordstrom et al. [1998] were assessed: forceful gripping, wrist bending, lifting and hand-held vibrating tools. Work-related psychosocial factors were three summary scores from Karasek's Job Content Questionnaire (JCQ) [Karasek et al., 1998]. The JCQ variables were categorized into three groups: job decision latitude (job skill discretion and job decision-making authority), social support at work (coworker support and supervisor support), and job insecurity.

Statistical Analysis

Bivariate analyses were conducted using *t* tests and chi-square analysis to identify statistically significant predictor variables for inclusion in a multivariate model. Using cut-points identified as meaningful from previous literature, all selected variables were added to each model. The physical work exposures and psychosocial factors were added to the models as 2-, 3-, and 4-level categorical variables. For physical work exposures, commonly used durations of daily work for 1, 2, and 4 hr were used as the cut-points [Kourinka et al., 1987; Sluiter et al., 2001]. In our statistical models, we evaluated the JCQ scales in tertiles and quartiles and as dichotomous variables (above and below the median value) [Swaen et al., 2004]. Statistical models examined the four separate outcome variables: (1) prevalent UE symptoms, (2) prevalent symptoms of at least moderate severity, (3) incident UE symptoms, and (4) functional impairments related to UE symptoms. For the functional impairment outcome, the UE symptoms were categorized into a three-level symptom severity variable. This variable identified subjects without symptoms, subjects with mild symptoms (less than 5 on a 0–10 symptom severity scale for any UE region) and subjects with severe symptoms at baseline (5 or more on the symptom severity scale of at least one UE region).

Subjects with missing data were excluded from the logistic regression analyses. All statistical analyses were performed using SPSS version 14.0 [SPSS, 2005].

RESULTS

The PrediCTS study enrolled 1,108 newly hired workers. Of the 1,108 workers enrolled in the study at baseline, 962 workers returned the 6-month follow-up questionnaire for a follow-up rate of 87%. Follow-up questionnaires were completed on average 7.06 months after baseline (range: 3.67–12.93 months). Six additional follow-up questionnaires were returned, but were completed by subjects after 12 months from baseline and were therefore excluded from data analysis. Forty-eight percent ($n = 462$) of follow-up questionnaires were returned by mail, 34.4% ($n = 331$) were

collected at apprenticeship training classes or the worksite, and 17.6% (n = 169) were conducted by telephone. The demographics, physical work exposures, and psychosocial variables for the study population are shown in Table I. The mean age for all subjects at baseline was 30.5 years, with an average BMI of 28.5 (kg/m²). Sixty-five percent were male, 64% were Caucasian, and 31% reported UE symptoms at baseline.

Frequencies of the four outcomes of interest are shown in Table I. Differences in baseline personal characteristics

TABLE I. Characteristics of the Study Population (N = 962)

Variable	Mean	SD
Personal risk factors ^a		
Age (years)	30.5	10.3
Body mass index (kg/m ²)	28.5	6.5
Variable	n	%
Personal risk factors ^a		
Caucasian race	611	64
Male gender	624	65
Baseline UE symptoms	300	31
Variable	n	%
Physical work exposures ^b		
Wrist bending (≥4 hr/day)	395	41
Forceful gripping (≥4 hr/day)	265	28
Lifting >2 lbs (≥4 hr/day)	418	44
Vibrating tools (≥4 hr/day)	197	21
Variable	Mean	SD
Psychosocial variables ^{b,c}		
Social support, range (8–32)	24.6	3.9
Job decision latitude, range (24–96)	65.8	11.8
Job insecurity, range (3–12)	4.9	1.5
Variable	n	%
Outcome variables		
Prevalence symptoms ^d	419	43.6
Prevalence symptoms of moderate severity ^e	267	27.8
Incident symptoms ^f	212	32.4
Functional impairment	190	19.8
Limited ability to work	121	12.6
Decreased productivity	83	8.6
Lost time from work	33	3.4
Job restrictions	16	1.7
Changes in employment	16	1.7
Functional Status Scale (Levine)	82	8.5

^aData from baseline questionnaires.

^bData from 6-month follow-up questionnaires.

^cRange of possible scores for each scale.

^dSubjects with UE symptoms at 6 months from baseline, regardless of baseline history.

^eSubjects with prevalent UE symptoms at 6 months with symptom severity ≥5/10 on a 0–10 symptom severity scale.

^fSubjects with no history of UE symptoms at baseline, but who reported new symptoms at 6 months; N = 655 (number of subjects reporting no symptoms at baseline).

(including age, gender, BMI, race, and baseline symptoms) were compared between subjects who completed the 6-month follow-up and those who were lost to follow-up. There were no significant differences found between groups except for a higher proportion of non-Caucasians among those without follow-up data compared to those who completed follow-up (43–52% vs. 34–40% respectively for the various outcomes).

Outcome 1: Prevalence Symptoms

Table II lists the predictors of prevalent UE symptoms among workers employed for 6 months in a new job. Thirty-two percent (32%) of workers with baseline symptoms had no symptoms at the 6-month follow-up (not shown). Caucasian race, female gender, and job tasks involving 4 hr or more of wrist bending per day increased the odds of reported UE symptoms. Workers who reported UE symptoms at baseline were much more likely to continue to report symptoms at 6-month follow-up. Older age and forceful grip were also significant risk factors. None of the psychosocial variables were significant predictors of prevalent UE symptoms at 6 months using modeling with 2-, 3-, or 4-level cutpoints. We modeled physical exposures using cutpoints of 1 or 2 hr and found similar results, to those found with the 4 hr cut-point.

Outcome 2: Prevalence Symptoms of Moderate Severity

Subjects with pain of at least moderate severity (pain scale ratings of ≥5/10) were compared to all other subjects. These other subjects included those who had less severe symptoms as well as subjects without any symptoms. Of those workers who reported a symptom of 5 or greater on the severity scale for at least one body part at baseline, 34% did not have any severe symptoms on the 6-month questionnaire, and 23% reported no symptoms of the upper extremity. Results of this model are shown in Table II. When this requirement of moderate severity of symptoms was added as the outcome containing the same predictors as the first model, all predictors remained significant with the exception of forceful gripping.

Outcome 3: Incident Symptoms

The model for incident UE symptoms among workers employed for 6 months in a new job is shown in Table II. Significant risk factors for incident UE symptoms included Caucasian race, female gender, and work tasks involving wrist bending and forceful gripping. None of the psychosocial variables were statistically significant in this model for incident symptoms at 6-month follow-up.

TABLE II. Logistic Regression Analyses for Three Outcomes, Prevalence Symptoms, Prevalence Symptoms With Moderate Severity, and Incident Symptoms Using the Same Independent Predictors

Independent variables	Prevalence symptoms (N = 815)		Prevalence symptoms with moderate severity (N = 811) ^a		Incident symptoms (N = 560) ^b	
	OR	95% CI	OR	95% CI	OR	95% CI
Personal risk factors						
Age (per 10 years)	1.15	1.00–1.30	1.17	1.00–1.34	1.17	1.00–1.35
Race (Caucasian:other)	1.98	1.37–2.87	2.22	1.46–3.38	1.78	1.15–2.74
Gender (female:male)	1.93	1.34–2.79	1.96	1.31–2.94	1.76	1.14–2.71
Body mass index (per unit BMI)	1.00	0.98–1.03	1.01	0.99–1.04	1.00	0.97–1.03
Baseline UE symptoms (presence:absence)	4.49	3.20–6.30	3.76	2.66–5.32	—	—
Physical work exposures ^c						
Wrist bending	1.89	1.34–2.67	2.07	1.44–3.00	1.71	1.13–2.60
Forceful gripping	1.51	1.00–2.28	1.12	0.71–1.71	2.00	1.22–3.27
Lifting >2 lbs	0.83	0.58–1.21	1.11	0.74–1.65	0.71	0.45–1.12
Vibrating tools	1.10	0.70–1.70	1.42	0.90–2.26	0.93	0.54–1.58
Psychosocial variables						
Social support						
Low	1.0	—	1.0	—	1.0	—
Medium	0.81	0.55–1.20	0.83	0.55–1.27	0.75	0.47–1.20
High	0.82	0.53–1.28	0.76	0.47–1.22	0.78	0.46–1.34
Job decision latitude						
Low	1.0	—	1.0	—	1.0	—
Medium	0.93	0.63–1.37	0.75	0.50–1.15	0.85	0.54–1.35
High	1.09	0.71–1.68	0.74	0.46–1.17	1.03	0.62–1.72
Job insecurity						
Low	1.0	—	1.0	—	1.0	—
Medium	1.43	0.98–2.08	1.07	0.71–1.62	1.48	0.94–2.33
High	1.38	0.91–2.10	1.24	0.79–1.94	1.20	0.70–2.03

Regression models used to estimate ORs included all variables listed in the tables.

^aAs a result of missing data points, 811 of 962 (84%) subjects were included in the analysis.

^bAs a result of missing data points, 560 out of 658 (85%) subjects who were symptom free at baseline were included in the analysis.

^cAll variables within this group refer to ≥ 4 hr compared to < 4 hr as the reference group.

Outcome 4: Functional Impairment

The fourth logistic regression model predicted the outcome of functional impairment related to UE symptoms. The outcome was a composite variable of five items related to the ability to work without limitations. The sixth component of the composite outcome comes from a change in the Levine Functional Status Score of 0.8 from baseline to 6 months follow-up. Frequencies for each measure of functional impairment included in the composite outcome are listed in Table I.

Twenty percent of subjects reported that their symptoms were severe enough at 6-month follow-up to report a positive response to any one of the measures indicating a functional impairment. Limited ability to work (13%), decreased work productivity (9%), and limitation on the Functional Status

Scale (9%) were the most commonly reported functional impairments.

Table III shows the results of the logistic model for functional impairment due to UE symptoms at 6 months. The presence of baseline UE symptoms in the model was predictive of functional impairment at 6 months, with severe symptoms at baseline being a stronger predictor of functional impairment than mild symptoms. Age, race, and gender also showed effects, though these effects were not statistically significant for race and gender. Physical work exposures (wrist bending) and work-related psychosocial factors (social support) were also significant predictors of functional impairment. Social support from coworkers and supervisors was protective against functional impairment; workers reporting the highest levels of support were less than half as likely to report a functional impairment related to their UE

TABLE III. Outcome 4: Logistic Regression Analysis Modeling Personal, Work Exposure, and Psychosocial Predictors of Functional Impairment Due to Upper Extremity Symptoms Among Workers Employed for 6 Months in a New Job (N = 801)*

Independent variable	OR	95% CI
Personal risk factors		
Age (per 10 years increment)	1.20	1.00–1.40
Caucasian race	1.51	0.96–2.39
Female gender	1.53	0.97–2.41
Body mass index	1.01	0.98–1.04
Mild baseline UE symptoms ^a	1.79	1.08–2.97
Severe baseline UE symptoms ^b	4.73	3.00–7.45
Physical work exposures ^c		
Wrist bending	1.76	1.17–2.66
Forceful gripping	1.31	0.82–2.11
Lifting >2 lbs	1.21	0.78–1.88
Vibrating tools	0.94	0.56–1.57
Psychosocial variables		
Social support	0.37	0.21–0.63
Job decision latitude	1.26	0.75–2.10
Job insecurity	1.26	0.77–2.07

*As a result of missing data points, 801 of 962 (83%) subjects were included in the analysis.

^aSubjects scored symptoms between a 0 and 4 on a 0–10 symptom severity scale.

^bSubjects scored symptoms ≥ 5 on a 0–10 symptom severity scale.

^cAll variables within this group refer to ≥ 4 hr compared to < 4 hr as the reference group.

symptoms versus those workers who reported the lowest levels of support.

DISCUSSION

The results of this study suggest that the risk factors for UE symptoms may be different than the risk factors for functional impairment due to UE symptoms. Personal risk factors including female gender, and Caucasian race were predictive of both prevalent and incident symptoms among workers employed for 6 months in a new job with increasing age predictive in all models. Some physical work exposures were significant in both symptom and functional impairment models. Interestingly, job-related psychosocial variables were not associated with self-reported UE symptoms, but higher social support from coworkers and supervisors was associated with a lower risk of work-related functional impairment.

One of the unique features about this study was the comparison of the same predictor variables with several different outcome measures. Using a longitudinal design, we were able to compare results using prevalent as well as incident cases. We were also able to compare the results of symptom outcomes with a functional behavior outcome

that is less commonly used in studies of risk factors of musculoskeletal disease.

Our results are similar to some past studies. The frequencies of prevalent symptoms (44%) are consistent with previous studies, which have shown that prevalence of upper extremity symptoms in workers may exceed 50% at any point in time [Franzblau et al., 1993]. Walker-Bone et al. [2004] reported 44.8% prevalence of UE symptoms in a general practice patient population.

Personal risk factors including female gender, age, and BMI have consistently been associated with musculoskeletal symptoms in working populations [Silverstein et al., 1986; Werner et al., 2005b,c; Melchior et al., 2006]. Murray [2003] has described how patterns of employment may be disproportionate by gender, education, and race leading to disproportionate injury rates. In our study, members of the construction trades were predominantly Caucasian. As these were the subjects with the highest physical exposures, this likely explains our finding of Caucasian race as a risk factor.

Studies that document the association between psychosocial factors and upper extremity symptoms were recently reviewed by Bongers et al. [2006]. Some of these studies showed a modest relationship between high job demands, low job decision latitude and poor social support with neck and upper limb symptoms whereas others found no association [Nahit et al., 2003; Cole et al., 2005; Bongers et al., 2006]. All three of our predictive models for symptoms did not result in any significant associations for these psychosocial factors, even though our symptom outcome reflected symptoms present at the hand/wrist, elbow or neck/shoulder. Our predictive model for functional impairment showed that high social support was associated with less impairment indicating that social support from one's coworkers and supervisors at work could be protective. Such a finding suggests that among workers with upper extremity symptoms, those with higher social support are less likely to have interference with regular work or daily tasks.

Work exposure risk factors have been quantified in a variety of ways in studies of predictive symptom models. Most studies have used self-reported or observational methods to quantify exposures. A few studies have utilized direct measurement with detailed video analysis to quantify work exposure and compared the findings to symptom report [Bao et al., 2006]. The results have shown associations with some work factors, although the specific factors vary among studies. Most often, an element of hand force and repetition was predictive of symptoms followed by posture [Latko et al., 1999; Gell et al., 2005; Bao et al., 2006; Silverstein et al., 2006]. In some cases, the work exposure is expressed as an intensity or degree of the specific risk. In other cases, the exposure was expressed by total duration of time performed during a typical workday [Silverstein et al., 1986; Nordstrom et al., 1997; Nahit et al., 2003]. These differences make comparisons of models more challenging. Our results

showed a moderate effect for duration of posture in all models (i.e., wrist bending) with hand force (i.e., forceful gripping) predictive in only some of the models. There were fewer workers classified as cases whose job activities involved an element of hand force compared to other studies, which may account for the inconsistent findings across all models. Repetition in the Nordstrom questionnaire is only assessed with one question about assembly line work. Very few of the workers in this study performed assembly line work, therefore this variable was not included in the analysis.

Studies investigating the relationship between work-related exposures and health outcomes most frequently use symptoms of the upper extremity as the outcome [Silverstein et al., 1987; Macfarlane et al., 2000; Leclerc et al., 2001; Feveile et al., 2002; Nahit et al., 2003; Werner et al., 2005a,b,c]. Many studies concerning UE symptoms have been cross-sectional in nature, which can only identify risk factors rather than more conclusively demonstrating causal relationships [Leclerc et al., 2001; Bongers et al., 2002; Werner et al., 2005a,b,c]. Several authors have discussed the transient nature of symptoms in the early stages of musculoskeletal disorders [Silverstein et al., 1986]. Our results showed that 32% of workers with baseline symptoms did not report upper extremity symptoms 6 months later. Of those workers who reported a severe symptom of at least one UE region at baseline (rating $\geq 5/10$ symptom severity scale), 23% had no symptoms of the upper extremity at 6 months. Cross sectional designs are less likely to capture all cases of disease with as much accuracy as longitudinal studies. In a longitudinal study, Werner et al. [2005c] found that workers with baseline symptoms were 3.14 times more likely to have symptoms after 5-year of follow-up. Our study results were consistent with Werner's, showing a fourfold increase in reported symptoms at 6 months in subjects who had baseline symptoms. Therefore, presence of symptoms at one point in time may predict future symptoms.

Functional impairment outcomes are not often measured in MSD research or tracked clinically after injured workers return to work, but could have significant cost implications for employers as indirect costs associated with MSDs are high. Some proxy measures used in past studies to describe altered behaviors due to symptoms include loss work days, number of sick days, light duty work assignment, job change, use of over the counter medications or other self-initiated treatments [Pransky et al., 1997, 1999]. Silverstein et al. [1987] investigated job change, job transfer due to symptoms and temporary job change among workers reporting MSD symptoms. Results showed workers with symptoms are 2.7 times more likely to change jobs although there was no statistical association with type or degree of work exposures. Functional limitations in normal activities have also been used as indicators for behavior changes due to the presence of hand and wrist symptoms. Two studies showed that working-age adults reported functional limitations for 5–13% of all

normal activities caused by wrist or hand pain [Palmer, 2003; Walker-Bone et al., 2004]. These results were similar to the findings in our study with functional limitations reported for 8.5% of normal activities among working adults. The factors that cause the transition from acute symptoms to chronic disabling arm pain and functional behavior changes, however, are not well understood [Palmer, 2003; Gatchel, 2004].

The results of our functional impairment model are consistent with models of the disablement process. Disablement models suggest that there are numerous risk factors that can lead to a medical impairment at the body structure/body function level such as report of symptoms or physical limitation. However, not all individuals with symptoms or a physical limitation experience a functional or activity-based impairment in their work duties or activities of daily living due to their condition [Verbugge and Jette, 1994]. Our results show that reporting of symptoms at baseline increased the likelihood of developing a functional limitation 6 months later, and that more severe symptoms increased the probability of functional limitation. Higher self-reported physical demands of work were also associated with functional limitation. This may occur in part because symptomatic workers in physically demanding occupations have greater work-related exacerbation of symptoms, or experience more decline in work ability due to symptoms than do workers in less physically demanding jobs.

The study results also suggest that functional status is an important outcome for treatment of work-related musculoskeletal disorders that needs to be assessed beyond simply whether or not a worker returns to work. Most importantly, despite different insurance systems that encourage health professionals to only look at either work or personal factors in isolation, personal and work-related risk factors are interdependent on one another and need to be considered in both prevention and treatment of upper extremity musculoskeletal disorders. Use of paper and pencil assessments which capture self-reported musculoskeletal symptoms, such as the questionnaire used in this study, can produce meaningful information about the risk factors workers face on the job, and could lead to more focused injury prevention efforts.

There were potential limitations in this study. The study population was predominately male and Caucasian. These variables were controlled for in each of the models. Another limitation was the lack of a measure of repetitive work exposure for inclusion in the models. Many of our workers performed repetitive tasks within their jobs but few of our workers performed the same task all day long. We had few workers whose jobs would be considered mono-task. In addition, all data collected for this study were self-reported and not independently verified by medical records, worker's compensation records, or employers. Workers who were symptomatic could have reported higher physical work exposures than workers who were asymptomatic, resulting in larger odds ratios for the associations between work

exposures and symptoms or functional impairment. In a sub-study of our worker population, comparison of self-reported to observer-verified physical exposures did not find that the presence or absence of symptoms affected over- or under-reporting of exposures by workers relative to observed exposures [Dale et al., 2007]. Though other studies have found that self-reported exposures are often higher than observed exposures, we found no evidence that differential reporting of exposures between symptomatic and asymptomatic workers occurred. Finally, our analyses used multiple logistic regression models to examine the role of workplace physical exposures as independent risk factors for UE symptoms and functional impairment after adjustment for personal and psychosocial factors. Because of collinearity between personal, psychosocial, and physical risk factors, these models may have underestimated the associations between workplace physical factors and UE symptoms and functional impairment.

CONCLUSIONS

The risk factors for upper extremity symptoms in a working population may be different than the risk factors for functional impairment due to symptoms. Functional status is an important outcome that needs to be included in future epidemiological and public health studies beyond traditional return-to-work outcomes or presence or absence of symptoms. Both personal factors and physical work exposure are important predictors of self-reported symptoms. Work-related psychosocial factors, including support from coworkers and supervisors, were a predictor of functional impairment. Both personal and workplace factors must be considered in efforts to reduce symptoms and disability related to upper extremity musculoskeletal disorders in working populations.

ACKNOWLEDGMENTS

The authors wish to thank Dr. Carolyn Baum for her thoughtful review of this manuscript. We also wish to acknowledge Jaime Strickland, Carla Farrell, Jeff Krato, Alicia Johnson, Rebecca Abraham, and Nina Six for their diligent efforts in subject recruitment and follow-up.

REFERENCES

- Amick BC III, Habeck RV, Ossmann J, Fossel AH, Keller R, Katz JN. 2004. Predictors of successful work role functioning after carpal tunnel release surgery. *J Occup Environ Med* 46:490–500.
- Baldwin ML, Butler RJ. 2006. Upper extremity disorders in the workplace: Costs and outcomes beyond the first return to work. *J Occup Rehabil* 16:303–323.
- Bao S, Spielholz P, Howard N, Silverstein B. 2006. Quantifying repetitive hand activity for epidemiological research on musculoskeletal disorders—Part I: Individual exposure assessment. *Ergonomics* 49:361–380.
- Bernard B. 1997. Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders for the neck, upper extremity, and low back. Cincinnati, OH: Department of Health and Human Services, National Institute for Occupational Safety and Health.
- Bongers PM, Kremer AM, ter Laak J. 2002. Are psychosocial factors, risk factors for symptoms and signs of the shoulder, elbow, or hand/wrist? A review of the epidemiological literature. *Am J Ind Med* 41:315–342.
- Bongers PM, Ijmker S, van den Heuvel S, Blatter BM. 2006. Epidemiology of work related neck and upper limb problems: Psychosocial and personal risk factors (part I) and effective interventions from a bio behavioural perspective (part II). *J Occup Rehabil* 16:279–302.
- Cole DC, Ibrahim S, Shannon HS. 2005. Predictors of work-related repetitive strain injuries in a population cohort. *Am J Public Health* 95:1233–1237.
- Dale AM, Johnson A, Strickland J, Taylor B, Symanzik J, Evanoff BA. 2007. Validity of self-reported physical work activities and predictors of over- and under-reporting. Boston, MA: PREMUS.
- Evanoff B, Abedin S, Grayson D, Dale AM, Wolf L, Bohr P. 2002. Is disability underreported following work injury? *J Occup Rehabil* 12:139–150.
- Faucett J, Rempel D. 1994. VDT-related musculoskeletal symptoms: Interactions between work posture and psychosocial work factors. *Am J Ind Med* 26:597–612.
- Feveile H, Jensen C, Burr H. 2002. Risk factors for neck-shoulder and wrist-hand symptoms in a 5-year follow-up study of 3,990 employees in Denmark. *Int Arch Occup Environ Health* 75:243–251.
- Franzblau A, Werner R, Valle J, Johnston E. 1993. Workplace surveillance for carpal tunnel syndrome: A comparison of methods. *J Occup Rehabil* 3:1–14.
- Franzblau A, Werner RA, Albers JW, Grant CL, Olinski D, Johnston E. 1994. Workplace surveillance for carpal tunnel syndrome using hand diagrams. *J Occup Rehabil* 4:185–198.
- Franzblau A, Salerno DF, Armstrong TJ, Werner RA. 1997. Test-retest reliability of an upper-extremity discomfort questionnaire in an industrial population. *Scand J Work Environ Health* 23:299–307.
- Gatchel RJ. 2004. Psychosocial factors that can influence the self-assessment of function. *J Occup Rehabil* 14:197–206.
- Gell N, Werner RA, Franzblau A, Ulin SS, Armstrong TJ. 2005. A longitudinal study of industrial and clerical workers: Incidence of carpal tunnel syndrome and assessment of risk factors. *J Occup Rehabil* 15:47–55.
- 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.
- Katz JN, Punnett L, Simmons BP, Fossel AH, Mooney N, Keller RB. 1996. Workers' compensation recipients with carpal tunnel syndrome: The validity of self-reported health measures. *Am J Public Health* 86:52–56.
- Katz JN, Lew RA, Bessette L, Punnett L, Fossel AH, Mooney N, Keller RB. 1998. Prevalence and predictors of long-term work disability due to carpal tunnel syndrome. *Am J Ind Med* 33:543–550.
- Kourinka I, Forcier L. 1995. Work related musculoskeletal disorders: A reference book for prevention. London: Taylor and Francis.

- Kourinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sorensen F, Andersson G, Jorgensen K. 1987. Standardised Nordic questionnaire for the analysis of musculoskeletal symptoms. *Appl Ergon* 18:233–237.
- Latko WA, Armstrong TJ, Franzblau A, Ulin SS, Werner RA, Albers JW. 1999. Cross-sectional study of the relationship between repetitive work and the prevalence of upper limb musculoskeletal disorders. *Am J Ind Med* 36:248–259.
- Leclerc A, Landre MF, Chastang JF, Niedhammer I, Roquelaure Y. 2001. Upper-limb disorders in repetitive work. *Scand J Work Environ Health* 27:268–278.
- Levine DW, Simmons BP, Koris MJ, Daltroy LH, Hohl GG, Fossel AH, Katz JN. 1993. A self-administered questionnaire for the assessment of severity of symptoms and functional status in carpal tunnel syndrome. *J Bone Joint Surg Am* 75:1585–1592.
- Macfarlane GJ, Hunt IM, Silman AJ. 2000. Role of mechanical and psychosocial factors in the onset of forearm pain: Prospective population based study. *Br Med J* 321:676–679.
- Melchior M, Roquelaure Y, Evanoff B, Chastang JF, Ha C, Imbernon E, Goldberg M, Leclerc A. 2006. Why are manual workers at high risk of upper limb disorders? The role of physical work factors in a random sample of workers in France (the Pays de la Loire study). *Occup Environ Med* 63:754–761.
- Murray LR. 2003. Sick and tired of being sick and tired: Scientific evidence, methods, and research implications for racial and ethnic disparities in occupational health. *Am J Public Health* 93:221–226.
- Nahit ES, Taylor S, Hunt IM, Silman AJ, Macfarlane GJ. 2003. Predicting the onset of forearm pain: A prospective study across 12 occupational groups. *Arthritis Rheum* 49:519–525.
- Nathan PA, Meadows KD, Doyle LS. 1988. Occupation as a risk factor for impaired sensory conduction of the median nerve at the carpal tunnel. *J Hand Surg [Br]* 13:167–170.
- Nordstrom DL, Vierkant RA, DeStefano F, Layde PM. 1997. Risk factors for carpal tunnel syndrome in a general population. *Occup Environ Med* 54:734–740.
- Nordstrom DL, Vierkant RA, Layde PM, Smith MJ. 1998. Comparison of self-reported and expert-observed physical activities at work in a general population. *Am J Ind Med* 34:29–35.
- Palmer KT. 2003. Regional musculoskeletal conditions: Pain in the forearm, wrist and hand. *Best Pract Res Clin Rheumatol* 17:113–135.
- Panel on Musculoskeletal Disorders and the Workplace CoBaSSaE, National Research Council. editor. 2001. Executive Summary: Musculoskeletal Disorders and the Workplace: Low Back and Upper Extremities. Washington, DC: National Academy of Sciences, National Research Council.
- Phalen GS. 1966. The carpal-tunnel syndrome Seventeen years' experience in diagnosis and treatment of six hundred fifty-four hands. *J Bone Joint Surg Am* 48:211–228.
- Pransky G, Feuerstein M, Himmelstein J, Katz JN, Vickers-Lahti M. 1997. Measuring functional outcomes in work-related upper extremity disorders. Development and validation of the Upper Extremity Function Scale. *J Occup Environ Med* 39:1195–1202.
- Pransky G, Benjamin K, Himmelstein J, Mundt K, Morgan W, Feuerstein M, Koyamatsu K, Hill-Fotouhi C. 1999. Work-related upper-extremity disorders: Prospective evaluation of clinical and functional outcomes. *J Occup Environ Med* 41:884–892.
- Salerno DF, Franzblau A, Armstrong TJ, Werner RA, Becker MP. 2001. Test-retest reliability of the Upper Extremity Questionnaire among keyboard operators. *Am J Ind Med* 40:655–666.
- Silverstein BA, Fine LJ, Armstrong TJ. 1986. Hand wrist cumulative trauma disorders in industry. *Br J Ind Med* 43:779–784.
- Silverstein B, Fine L, Stetson D. 1987. Hand-wrist disorders among investment casting plant workers. *J Hand Surg [Am]* 12:838–844.
- Silverstein B, Fan J, Bao S, Howard N, Spielholz P, Smith C, Bonauto D, Viikari-Juntura E. 2006. How well does the Strain Index predict carpal tunnel syndrome. In: Pikaar RN, Koningsveld EAP, Settels PJM, editors. IEA 2006 Congress: Meeting Diversity in Ergonomics Maastricht. The Netherlands: Elsevier Ltd., p 1–4.
- Sluiter JK, Rest KM, Frings-Dresen MH. 2001. Criteria document for evaluating the work-relatedness of upper-extremity musculoskeletal disorders. *Scand J Work Environ Health* 27 (Suppl 1):1–102.
- SPSS I. 2005. Version 14.0 of the statistical package for the social sciences. Statistical Software. 14.0 edition. Chicago: SPSS, Inc.
- Stevens JC, Smith BE, Weaver AL, Bosch EP, Deen HG Jr, Wilkens JA. 1999. Symptoms of 100 patients with electromyographically verified carpal tunnel syndrome. *Muscle Nerve* 22:1448–1456.
- Sullivan MJ, Feuerstein M, Gatchel R, Linton SJ, Pransky G. 2005. Integrating psychosocial and behavioral interventions to achieve optimal rehabilitation outcomes. *J Occup Rehabil* 15:475–489.
- Swaen GM, van Amelsvoort LP, Bultmann U, Slangen JJ, Kant IJ. 2004. Psychosocial work characteristics as risk factors for being injured in an occupational accident. *J Occup Environ Med* 46:521–527.
- U.S. Department of Labor. 2006. Bureau of Labor Statistics. Nonfatal occupational injuries and illnesses requiring days away from work, 2005. USDL report number: 06-1982. Available at <http://www.bls.gov/iif/home.htm>.
- Verbugge L, Jette AM. 1994. The disablement process. *Social Science Medicine* 38:1–14.
- Walker-Bone K, Palmer KT, Reading I, Coggon D, Cooper C. 2004. Prevalence and impact of musculoskeletal disorders of the upper limb in the general population. *Arthritis Rheum* 51:642–651.
- Werner RA, Franzblau A, Albers JW, Buchele H, Armstrong TJ. 1997. Use of screening nerve conduction studies for predicting future carpal tunnel syndrome. *Occup Environ Med* 54:96–100.
- Werner RA, Franzblau A, Gell N, Hartigan AG, Ebersole M, Armstrong TJ. 2005a. Incidence of carpal tunnel syndrome among automobile assembly workers and assessment of risk factors. *J Occup Environ Med* 47:1044–1050.
- Werner RA, Franzblau A, Gell N, Ulin SS, Armstrong TJ. 2005b. A longitudinal study of industrial and clerical workers: Predictors of upper extremity tendonitis. *J Occup Rehabil* 15:37–46.
- Werner RA, Franzblau A, Gell N, Ulin SS, Armstrong TJ. 2005c. Predictors of upper extremity discomfort: A longitudinal study of industrial and clerical workers. *J Occup Rehabil* 15:27–35.