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SPECIAL ISSUE: Epidemiological Studies of Workplace Musculoskeletal Disorders

A Prospective Study of Musculoskeletal Outcomes Among Manufacturing Workers: II. Effects of Psychosocial Stress and Work Organization Factors

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Objective: The aim of this study was to characterize associations between psychosocial and work organizational risk factors and upper-extremity musculoskeletal symptoms and disorders.

Background: Methodological limitations of previous studies of psychosocial and work organizational risk factors and musculoskeletal outcomes have produced inconsistent associations.

Method: In this prospective epidemiologic study of 386 workers, questionnaires to assess decision latitude ("control") and psychological job demands ("demand") were administered to study participants and were used to classify them into job strain "quadrants." Measures of job stress and job change were collected during each week of follow-up. Incident hand/arm and neck/shoulder symptoms and disorders were ascertained weekly. Associations between exposure measures and musculoskeletal outcomes were estimated with proportional hazard methods.

Results: When compared to the low-demand/high-control job strain referent category, large increases in risk of hand/arm disorders were observed for both high-demand/high-control (hazard ratio [HR] = 4.49, 95% confidence interval [CI] = [1.23, 16.4]) and high-demand/low-control job strain categories (HR = 5.18, 95% CI = [1.39, 19.4]). Similar associations were observed for hand/arm symptoms. A strong association was also observed between the low-demand/low-control job strain category and neck/shoulder disorders (HR = 6.46, 95% CI = [1.46, 28.6]). Statistically significant associations were also observed between weekly stress level and weekly job change and several musculoskeletal outcomes.

Conclusion: Associations between psychosocial risk factors and work organizational factors and musculoskeletal outcomes were large and in the hypothesized direction.

Application: Prevention of occupational musculoskeletal disorders may require attention to psychosocial and work organizational factors in addition to physical factors. Methods to control adverse effects of psychosocial and work organizational risk factors should be explored.

Keywords: psychosocial, work organization, musculoskeletal disorder, prospective study, epidemiology

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INTRODUCTION

In the United States, musculoskeletal disorders (MSDs) accounted for 33% of all workplace injuries and illnesses requiring days away from work in 2011 (U.S. Bureau of Labor Statistics [USBLS], 2012). Workers who sustained musculoskeletal disorders required a median of 11 days to recover before returning to work, compared with 8 days for all other injury and illness (USBLS, 2012). MSD risk has been associated with multiple factors, including personal characteristics (e.g., age, sex, past musculoskeletal conditions), physical factors (e.g., forceful and repetitive motions, awkward posture), psychosocial stress, and workplace organizational factors (National Research Council & Institute of Medicine, 2001).

Although a consensus is emerging that some metrics of forceful exertions, repetitive hand movements, and extremes of posture are associated with upper-extremity MSDs among workers, the literature on psychosocial factors and upper-extremity MSDs is inconsistent. In a comprehensive review, Bongers, Kremer, and ter Laak (2002) discussed several methodological contributors to the heterogeneity of reported associations between psychosocial factors and musculoskeletal disease. Sources of inconsistency include cross-sectional ascertainment of both, stress measures and MSDs, use of nonstandard stress metrics, and incomplete control of potentially confounding factors.

In response to ongoing controversy about the role of workplace factors in the development of MSDs, the U.S. National Institute for Occupational Safety and Health funded a set of studies on associations between work and MSD risk. The current study was funded by this mechanism

and addressed several methodological limitations of previous research by involving a prospective design, assessment of psychosocial and work organizational risk factors with the use of validated metrics, direct quantitative and observational measures of physical exposure, and both self-reported and examination-based assessment of upper-extremity musculoskeletal symptoms and disorders. Although several models of occupational psychosocial stress are available, we used the *demand-control* model originally developed by Karasek and colleagues (Karasek et al., 1988). Furthermore, one metric of work organization previously reported to be a risk factor for upper-extremity MSD, *job change* (Punnett, Gold, Katz, Gore, & Wegman, 2004), was also examined. In this manuscript, we present analyses of the psychosocial and work organizational risk factors. A companion manuscript includes analyses of the physical risk factors.

METHODS

Study Participants

All full-time employees of a household appliance manufacturing facility in Iowa who were at least 18 years of age were eligible to participate. Eligible employees were recruited randomly by assigning computer-generated random numbers to an employee roster and sorting by ascending random number value. Enrollment began in April 2004 and data collection continued until March 2007. The study protocol was approved by the University of Iowa Institutional Review Board. Written consent was obtained from all participants.

Collection of Exposure and Covariate Information

Demographics and work and health history. Questionnaires administered at the time of entry into the study were used to obtain information about demographic characteristics (age, race, sex, height, weight, hand dominance, education, household income), personal health (tobacco use, diabetes, alcoholism, hypothyroidism, rheumatoid arthritis and other collagen vascular diseases, pregnancy, hormone replacement therapy), upper-extremity symptoms during the previous 3 years and during the previous week, and prior disorder or trauma of the upper extremities. Information about past work both within the facility and elsewhere, current employment outside of the facility (i.e., second jobs), nonoccupational hand-intensive activities, and aerobic activity was also collected.

Psychosocial risk factors. At the time of entry into the study, subscales of the Job Content Questionnaire (JCQ; Karasek et al., 1988) were administered to all participants. Responses were then used to calculate scores of the Psychological Job Demands, Decision Latitude, Supervisor Support, and Coworker Support scales. In addition, the full Positive and Negative Affectivity Scale was also administered (Watson, Clark, & Tellegen, 1988).

Exposure information collected during follow-up. During each week of follow-up, study participants completed a preprinted log documenting daily work practices and work organization. Work practices and work organization factors recorded on the log included hours worked each day at each work task, any changes to usual tasks or workstations, weekly hours worked at a second job, weekly hours of nonoccupational hand-intensive activity, weekly hours of aerobic activity, and a single item metric of weekly job stress level reported on a 0-to 10-cm visual analog scale (VAS).

Physical risk factors. Detail of methods used to estimate exposure to physical risk factors is provided in a companion paper (Gerr et al., 2014). A brief description is provided here. For each participant, a 10-min sample of the intensity of forceful exertions, repetition, and postures assumed by the upper extremity and neck was obtained during performance of his or her assigned task(s). For study participants with multiple tasks, each task was sampled separately so that representative measures of exposures typical for that participant were obtained.

The intensities of distal upper-extremity and neck/shoulder forceful exertions were estimated with surface electromyography. Repetition was assessed with the Hand Activity Level (HAL) method (Latko et al., 1997). Two trained investigators blinded to participant health status rated repetition on the HAL scale for each task performed by each participant by viewing three

representative work cycles. Multimedia Video Task Analysis™ (MVTA, Ergonomics Analysis and Design Research Consortium, Madison, WI) was used to assess postures of the neck, shoulder, and wrist (Dartt et al., 2009; Bao, Spielholz, Howard, & Silverstein, 2006; Meyer & Radwin, 2007; Yen & Radwin, 2000).

The time spent performing each task during each work day (reported on the logs) was combined with the physical risk factor exposure measures to construct weekly time-weighted-average exposure estimates. Repeat measures of the physical risk factors were obtained when participants reported major task changes.

Assessment of Musculoskeletal Outcomes

Musculoskeletal symptoms of the hand, wrist, elbow, shoulder, and neck were assessed at entry into the study and each week during the follow-up period with standard preprinted questions about symptom location, quality, severity, and duration administered with the preprinted log of work practices and work organization. A participant was classified as having incident symptoms when he or she reported new-onset pain, numbness, tingling, or burning (a) of 30 min or more total duration over the course of the previous week, (b) of intensity 5 or higher on a 0-to-10 VAS or resulting in use of analgesic medication, and (c) not resulting from acute trauma. Study participants reporting incident symptoms that met the study case definition were also asked to participate in a standard clinical examination of the upper extremities. Details of the upper-extremity examination protocol and upper-extremity disorder case definitions are provided in a companion manuscript (Gerr et al., 2014). If the clinical examination was positive, then the participant was also classified as an incident disorder case. Participants meeting symptom or disorder case definitions at study entry (i.e., prevalent cases) were not eligible for inclusion in the prospective (i.e., incidence) analyses for that specific outcome. Because week was the unit of time analysis, this exclusion criterion eliminated only those participants meeting the study case definitions during the week prior to study entry. Thus, individuals with intermittent (but not constant) symptoms and disorders were among those followed over time.

Data Analysis and Statistical Methods

All neck and shoulder disorders were pooled into a single dichotomized *neck/shoulder disorders* outcome variable and all hand, wrist, and elbow disorders were pooled into a single dichotomized *hand/arm disorders* outcome variable. Analyses were performed separately for each of four musculoskeletal outcomes: (a) hand/arm symptoms, (b) hand/arm disorders, (c) neck/shoulder symptoms, and (d) neck/shoulder disorders.

Psychosocial and work organization variable parameterization. To analyze JCQ responses, we first categorized results for each participant into one of four "job strain quadrants." Job strain quadrants were constructed by first dichotomizing the Psychological Job Demand and Decision Latitude scale scores at the median values of the full-sample score distributions. Job strain quadrants were then constructed from the four possible combinations of the two dichotomized scales, that is, *low demand/high control* (the referent category for all job strain quadrant analyses), *low demand/low control, high demand/high control*, and *high demand/low control*. Values for the other three psychosocial risk factors, that is, coworker support, supervisor support, and negative affectivity, were analyzed as continuous measures. Weekly job change, a time-varying dichotomous variable, was coded as positive for participants who reported on the weekly task log (a) a "change in your usual tasks or workstations" or (b) a "change in tools used at your workstation" that, in the opinion of the study ergonomist, resulted in a meaningful change in exposure to physical risk factors. Weekly job stress was analyzed as a continuous variable with values ranging from 0 to 10.

Unadjusted rates and relative risks. Incidence rates were calculated for each of the four outcomes. Unadjusted relative risks (i.e., hazard ratios [HRs]) of the associations between psychosocial and work organizational risk factors and time from enrollment to the first occurrence of each of the four outcomes were estimated separately with Cox regression models (Cox & Oakes, 1984; Kalbfleisch & Prentice, 2002).

Consistent with standard analytical practice, participants who left the study without manifesting the outcome were censored at the time they were lost to follow-up. Separate regression models were constructed for each of the four primary musculoskeletal outcomes. When appropriate, time-varying independent variables were used to model changes in a participant's risk due to changes in her or his exposure during the study (Cox & Oakes, 1984).

Multivariable analyses. Adjusted relative risks were also estimated with the use of survival analysis. Because of the large number of variables, an initial screening to eliminate variables unlikely to be confounders was performed. First, the association between each covariate listed in Table 1 (i.e., personal characteristics, health and comorbid conditions, occupational characteristics, and physical exposure measures) and time to the first occurrence of each of the four outcomes was estimated separately. Those variables associated with each outcome with probability of <0.2 were retained as potential confounders and included in the initial, multivariable model for that outcome. Thus, for each of the four outcomes, the initial multivariable models included the a priori selected psychosocial or work organizational risk factor variables of interest and all potentially confounding variables remaining after initial screening.

The a priori psychosocial measures were job strain quadrant, coworker support, supervisor support, and negative affectivity, which were entered simultaneously into multivariable models. The a priori time-varying work organization variables, weekly job stress and weekly job change, were analyzed individually in separate models. Ultimately, three models (one model for the psychosocial factors as a group and separate models for weekly job stress and weekly job change) were constructed for each of the four musculoskeletal outcomes.

After models with the a priori psychosocial or work-organizational variables and the potentially confounding variables remaining after initial screening were constructed, the potentially confounding variables were removed sequentially and the change in the HR for the association of each of the psychosocial and work-organizational measures with each musculoskeletal outcome was examined separately. While performing this modified backward elimination procedure, we removed the least statistically significant potential confounder first, with the next least statistically significant potential confounder removed next, and so on. If the HR for any of the a priori psychosocial or work organizational measures changed by more than 15% when a covariate was removed, then that covariate was retained in the model. All covariates were subject to removal. The final model for each of the four outcomes included the a priori selected psychosocial or work organizational measures and only those covariates that confounded their relationships with the outcome.

To explore modification of the effect of psychosocial and work organizational factors by sex, we repeated all analyses after stratification by sex. To assist in interpretation in the stratified analyses, we used all job strain category cut points that were used in the analysis of the full cohort.

All analyses were performed with SAS Version 9.2 (SAS Institute, Cary, NC).

RESULTS

Study Participants

Contact was made with 749 workers, of whom 386 agreed to participate and signed an informed consent (51.5%). A description of the study facility, details of participant eligibility criteria, and flowcharts that depict recruitment, participation, and dropout of study participants are provided in a companion paper (Gerr et al., 2014). Among the 318 study participants who contributed person time to the analysis of incident neck/shoulder disorders, the mean age was 43 years, and just more than half were female (Table 1). The average body mass index was 27.5 kg/m^2. Slightly fewer than one third of the participants had education beyond high school, and about one third were smokers. Slightly more than one quarter worked on second shift (3 p.m. to 11 p.m.). Participants had worked at the study facility an average of 16 years at the time of enrollment. Participants contributed a total of 12,119 person-weeks of observation to the study.

TABLE 1: Descriptive Statistics of Demographic, Personal Health, Occupational, and Psychosocial Characteristics (*N* = 318)

Variable	*M* (*SD*)	*n* (%)
Personal characteristics		
Age (years)	43.1 (10.0)	—
Female sex	—	165 (51.9)
Height males (cm)	178.7 (9.1)	—
Height females (cm)	165.2 (6.5)	—
Body mass index (kg/m^2)	27.5 (5.4)	—
Education beyond high school	—	95 (29.9)
Right-handed	—	280 (88.1)
Non-White ethnicity	—	26 (8.2)
Annual household income ≥ $50,000	—	130 (40.9)
Health and comorbid conditions		
Hormone medication (% of women)	—	35 (21.2)
Currently pregnant (% of women)	—	1 (0.6)
Currently smoke	—	104 (32.7)
Hand outcome comorbidity	—	45 (14.2)
Past history of hand/arm pain	—	64 (21.1)
History of cervical disc disease	—	10 (3.1)
Past history of neck/shoulder pain	—	26 (8.2)
Occupational characteristics		
Hours per week primary assembly job	31.9 (10.0)	—
Hours per week at second job	1.1 (4.4)	—
Hours per week upper-extremity-intense activities	3.7 (6.4)	—
Hours per week nonwork aerobic activity	0.2 (0.4)	—
Years at study work site	15.8 (11.1)	—
Second shift	—	84 (26.4)
Physical exposure measures		
Hand Activity Level	4.7 (1.3)	
Percentage time wrist flexion	2.8 (2.9)	
Percentage time wrist extension	9.1 (7.1)	
Percentage time shoulder elevation 60° to 90°	10.8 (8.0)	
Percentage time shoulder elevation >90°	2.4 (4.0)	
Percentage time neck flexion	14.6 (15.2)	
Percentage time neck extension	4.9 (7.0)	
Forearm extensor muscle (% RVE)	47.2 (27.3)	
Forearm flexor muscle (% RVE)	90.0 (74.5)	
Trapezius muscle (% RVE)	46.1 (44.2)	
Psychosocial factors and work organization		
Decision latitude (“control”)	56.2 (9.8)	—
Psychological job demand (“demand”)	23.1 (3.3)	—
Job strain: Low demand/high control		71 (22.3)
Job strain: High demand/high control		81 (25.5)
Job strain: Low demand/low control		78 (24.5)
Job strain: High demand/low control		88 (27.7)
Coworker support	17.7 (2.4)	—
Supervisor support	14.3 (2.9)	—
Negative affectivity	16.5 (5.2)	—
Weekly stress value (from task log VAS)	3.3 (2.1)	—
Job change		48 (15.1)

Note. RVE = relative voluntary exertion, VAS = visual analog scale.

Psychosocial and Work Organization Characteristics

Means and standard deviations of the Decision Latitude scale, Psychological Job Demand scale, Coworker Support scale, and Supervisor Support scales of the JCQ are provided in Table 1. In addition, mean negative affectivity and mean positive affectivity scores of the Positive and Negative Affect Schedule, weekly job stress, and number of participants who reported experiencing at least one change in job during the follow-up period are provided in Table 1. The median value of decision latitude score was 56 and the median value of the psychological job demand score was 22.

Incidence of Musculoskeletal Outcomes

A brief description of the incident musculoskeletal outcomes is provided next. More detailed results of musculoskeletal outcomes (and their associations with physical exposures) are presented in a companion paper (Gerr et al., 2014).

Hand/arm outcomes. During follow-up, the incidence of hand/arm symptoms was 58/100 person years (PY) and of hand/arm disorders was 19/100 PY. Among hand/arm disorders, the highest incidence rate was observed for carpal tunnel syndrome (8.8/100 PY). Common tendon disorders included lateral epicondylitis (6.2/100 PY) and DeQuervain's tendonitis (tendonitis of the first dorsal compartment, 3.1/100 PY).

Neck/shoulder outcomes. The incidence of neck/shoulder symptoms was 54/100 PY and of neck/shoulder disorders was 14/100 PY. Among neck/shoulder disorders, the highest incidence rate was observed for somatic neck pain syndrome (10.7/100 PY). Incident rotator cuff tendonitis and bicipital tendonitis were also common.

Associations Between Psychosocial and Work Organization Risk Factors and Musculoskeletal Outcomes

Unadjusted associations with hand/arm outcomes. Elevated HRs were observed for the three nonreferent job strain quadrant categories for both hand/arm symptoms and hand/arm disorders when compared with the referent job strain quadrant category (Table 2). Consistent with expectation, the largest unadjusted associations were observed for the high-demand/low-control job strain category when compared with the low-demand/high-control category for both hand/arm symptoms (HR = 3.39, 95% CI = [1.85, 6.22]) and hand/arm disorders (HR = 5.48, 95% CI = [1.85, 16.3]). No statistically significant unadjusted associations were observed between coworker support, supervisor support, negative affectivity, or positive affectivity and either hand/arm symptoms or hand/arm disorders.

Self-reported job stress, collected weekly on a 0- to 10-cm VAS, was strongly associated with both hand/arm symptoms (HR = 1.39, 95% CI = [1.29, 1.50]) and hand/arm disorders (HR = 1.30, 95% CI = [1.17, 1.46]). Note that the HR represents the risk increase per unit increase of weekly job stress (on a 0- to 10-cm VAS). Finally, self-reported job change, also collected weekly, was strongly associated with both hand/arm symptoms (HR = 4.05, 95% CI = [2.63, 6.24]) and hand/arm disorders (HR = 3.29, 95% CI = [1.63, 3.63]).

Hand/arm multivariable models. Final multivariable models of associations between hand/arm outcomes and psychosocial and work organizational risk factors are presented in Table 3 for both the full cohort and for each sex stratum, separately. For the full cohort, elevated HRs were observed for all nonreferent job strain quadrant categories and both hand/arm symptoms and hand/arm disorders when compared with the referent job strain quadrant category. Effects were strongest for hand/arm disorders. When compared with the low-demand/high-control job strain referent category, large and statistically significant increases in risk of hand/arm disorders were observed for both high-demand/high-control (HR = 4.49, 95% CI = [1.23, 16.4]) and high-demand/low-control job strain categories (HR = 5.18, 95% CI = [1.39, 19.4]). Because of small cell sizes, estimation precision was poor and CIs were large for these outcomes. Strong and statistically significant effects of weekly stress level and weekly job change on both hand/arm symptoms and hand/arm disorders persisted after adjustment for

TABLE 2: Unadjusted Associations Between Psychosocial and Work Organizational Risk Factors and Hand/Arm and Neck/Shoulder Outcomes

	Hand/Arm Symptoms		Hand/Arm Disorders		Neck/Shoulder Symptoms		Neck/Shoulder Disorders	
Variable	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Psychosocial risk factors								
Job strain: Low demand/high control	1.00	—	1.00	—	1.00	—	1.00	—
Job strain: High demand/high control	2.48	[1.31, 4.68]	4.49	[1.49, 13.5]	1.87	[1.02, 3.42]	2.02	[0.61, 6.72]
Job strain: Low demand/low control	2.10	[1.08, 4.07]	1.89	[0.53, 6.71]	1.61	[0.85, 3.05]	3.00	[0.94, 9.60]
Job strain: High demand/low control	3.39	[1.85, 6.22]	5.48	[1.85, 16.3]	1.81	[0.98, 3.33]	2.77	[0.88, 8.72]
Coworker support	1.01	[0.92, 1.11]	0.95	[0.83, 1.07]	0.94	[0.86, 1.02]	0.94	[0.82, 1.09]
Supervisor support	0.95	[0.88, 1.02]	0.98	[0.88, 1.10]	0.99	[0.92, 1.07]	0.99	[0.88, 1.11]
Negative affectivity	1.02	[0.99, 1.05]	1.02	[0.99, 1.07]	1.03	[1.00, 1.07]	1.03	[0.97, 1.10]
Weekly stress level	1.39	[1.29, 1.50]	1.30	[1.17, 1.46]	1.36	[1.26, 1.48]	1.31	[1.15, 1.50]
Weekly job change	4.05	[2.63, 6.24]	3.29	[1.63, 6.63]	3.36	[2.12, 5.30]	1.95	[0.84, 4.53]

Note. HR = hazard ratio; CI = confidence interval.

confounding factors. Negative affectivity was not associated with any hand/arm outcome in the multivariable models.

Sex-stratified analyses of hand/arm symptoms showed generally stronger effects of psychosocial and work organizational factors among men than among women. For example, among participants in the high-demand/low-control job strain category, the HR for men was 4.69 (95% CI = [1.30, 16.9]), whereas the HR for women was 1.74 (95% CI = [0.70, 4.30]).

Unadjusted associations with neck/shoulder outcomes. Unadjusted associations of moderate size and varying statistical significance were observed between the three job strain quadrants and neck/shoulder symptoms when compared with the referent job strain quadrant (Table 2). No HR exceeded a value of 2. Unadjusted associations between the three job strain quadrants, when compared with the referent job strain quadrant, and neck/shoulder disorders were larger than those observed for neck/shoulder symptoms. Contrary to expectation, the strength of the unadjusted associations between job strain category and both neck/shoulder outcomes were similar across the three job strain categories (high demand/high control, low demand/low control, and high demand/low control) when compared with the referent category (low demand/high control). No statistically significant unadjusted associations were observed between coworker support, supervisor support, or positive affectivity and either neck/shoulder symptoms or neck/shoulder disorders.

Self-reported weekly job stress was strongly associated with both neck/shoulder symptoms (HR = 1.36, 95% CI = [1.26, 1.48]) and neck/shoulder disorders (HR = 1.31, 95% CI = [1.15,

TABLE 3: Final Multivariate Models of Associations Between Psychosocial and Work Organizational Risk Factors and Hand/Arm Outcomes

	Hand/Arm Symptoms						Hand/Arm Disorders	
	Female		Male		Full Cohort		Full Cohort	
Variable	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Psychosocial risk factors[a]								
Job strain: Low demand/high control	1.00	—	1.00	—	1.00	—	1.00	—
Job strain: High demand/high control	2.06	[0.81, 5.29]	2.85	[0.86, 9.44]	2.17	[1.08, 4.39]	4.49	[1.23, 16.4]
Job strain: Low demand/low control	1.85	[0.71, 4.85]	4.27	[1.19, 15.3]	2.37	[1.15, 4.87]	2.53	[0.62, 10.3]
Job strain: High demand/low control	1.74	[0.70, 4.30]	4.69	[1.30, 16.9]	2.39	[1.17, 4.88]	5.18	[1.39, 19.4]
Coworker support	1.00	[0.88, 1.13]	1.14	[0.98, 1.34]	1.08	[0.99, 1.18]	1.00	[0.87, 1.14]
Supervisor support	0.94	[0.85, 1.04]	1.17	[0.97, 1.41]	1.02	[0.94, 1.12]	1.05	[0.92, 1.20]
Negative affectivity	0.95	[0.89, 1.00]	0.99	[0.92, 1.06]	0.98	[0.94, 1.02]	0.95	[0.89, 1.02]
Weekly stress level[b]	1.35	[1.21, 1.50]	1.29	[1.14, 1.46]	1.33	[1.23, 1.44]	1.31	[1.17, 1.46]
Weekly job change[c]	1.75	[0.95, 3.22]	3.66	[1.74, 7.69]	2.39	[1.50, 3.82]	2.90	[1.43, 5.88]

Note. HR = hazard ratio; CI = confidence interval.
[a]Full-cohort and sex-stratified associations between psychosocial risk factors and hand/arm symptoms controlled for all psychosocial risk factors listed for the model as well as height, hand-intensive activities (hours per week), weekly stress level, weekly job change, comorbid conditions, second job (hours per week), and history of hand symptoms. Associations between psychosocial risk factors and hand/arm disorders controlled for all psychosocial risk factors listed in table as well as history of hand symptoms, body mass index, comorbid conditions, weekly stress level, weekly job change, second job (hours per week), and Hand Activity Level.
[b]Full-cohort and sex-stratified associations between weekly stress level and hand/arm symptoms controlled for weekly job change. Associations between weekly stress level and hand/arm disorders were not confounded by any of the examined covariates.
[c]Full-cohort and sex-stratified associations between weekly job change and hand/arm symptoms controlled for weekly job stress and history of hand symptoms. Associations between weekly job change and hand/arm disorders controlled for job strain and body mass index.

1.50]). Note that the HR represents the risk increase per unit increase of weekly job stress (on a 0- to 10-cm VAS). Self-reported weekly job change was associated with both neck/shoulder symptoms (HR = 3.36, 95% CI = [2.12, 5.30]) and neck/shoulder disorders (HR = 1.95, 95% CI = [0.84, 4.53]).

Neck/shoulder multivariable models. Final multivariable models of associations between hand/arm and neck/shoulder outcomes and

psychosocial and work organizational risk factors are presented in Table 4 for both the full cohort and for each sex stratum, separately. In analyses of the full cohort, adjusted HRs of associations between job strain quadrant category and neck/shoulder symptoms were all greater than unity (although not statistically significant) when compared with the referent category but smaller than the comparable unadjusted associations. Conversely, adjusted associations between job strain quadrant category and neck/shoulder disorders were larger than the comparable unadjusted associations. Again, perhaps due to small cell sizes, only the association between the low-demand/low-control job strain quadrant category and neck/shoulder disorders was statistically significant (HR = 6.46, 95% CI = [1.46, 28.6]). Strong and statistically significant associations between weekly stress level and neck/shoulder symptoms (HR = 1.32, 95% CI = [1.22, 1.44]) and neck/shoulder disorders (HR = 1.27, 95% CI = [1.11, 1.46]) persisted after controlling for confounding. A statistically significant association between weekly job change and neck/shoulder symptoms (HR = 2.27, 95% CI = [1.40, 3.68]) also remained after controlling for confounding. Negative affectivity was not associated with any neck/shoulder outcome in the multivariable models.

In contrast to the sex-stratified analyses of hand/arm symptoms, the sex-stratified analyses of neck/shoulder symptoms showed stronger effects of job strain among women than among men. Specifically, among women, all job strain categories had HRs greater than 2, whereas among the men, all job strain categories had hazard ratios below unity (albeit with very wide CIs). Effects of coworker support, supervisor support, negative affectivity, weekly stress level, and weekly job change were similar among the men and women.

DISCUSSION

Associations between psychosocial risk factors and hand/arm symptoms and hand/arm disorders were large and in the hypothesized direction. For example, a statistically significant five-fold increase in risk of hand/arm disorders was observed among participants in the high-demand/low-control group in comparison with the referent low-demand/high-control group. Associations between psychosocial risk factors and neck/shoulder symptoms and neck/shoulder disorders were also elevated but less consistently than for hand/arm symptoms and hand/arm disorders.

A number of previous investigators have observed associations between musculoskeletal outcomes and measures of occupational psychosocial stress, although considerable inconsistency is found in the published literature (Bongers et al., 2002). Many studies were cross-sectional and therefore susceptible to bias from cause-effect reversal. Specifically, in cross-sectional studies, it may be possible for the experience of musculoskeletal symptoms to affect reporting of occupational psychosocial stress. Because information about occupational psychosocial stress was collected prior to incident musculoskeletal outcomes, such reversal was unlikely in the current study.

Other potential confounders of the association between occupational psychosocial stress and musculoskeletal outcomes in past studies include the individual personality trait known as negative affectivity (Andersen et al., 2002) as well as occupational exposure to physical risk factors (Choi et al., 2011; MacDonald, Karasek, Punnett, & Scharf, 2001). Persons with greater negative affectivity might be expected to report higher levels of all adverse experiences, including both stress and musculoskeletal discomfort. If uncontrolled, this tendency alone could create the appearance of an association between psychosocial stress and musculoskeletal outcomes. In the current study, a standard measure of negative affectivity (Watson et al., 1988) was obtained, and associations between psychosocial measures and musculoskeletal outcomes were adjusted for it. Interestingly, negative affectivity appears to have little potential to confound the observed associations due to its weak association with the musculoskeletal outcomes. We also found that measures of exposure to physical factors did not confound associations between psychosocial factors and musculoskeletal outcomes. Specifically, we examined associations between a priori physical risk factors and the musculoskeletal outcomes and found no association of sufficient

TABLE 4: Final Multivariate Models of Associations Between Psychosocial and Work Organizational Risk Factors and Neck/Shoulder Outcomes

	Neck/Shoulder Symptoms						Neck/Shoulder Disorders	
	Female		Male		Full Cohort		Full Cohort	
Variable	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Psychosocial risk factors[a]								
Job strain: Low demand/ high control	1.00	—	1.00	—	1.00	—	1.00	—
Job strain: High demand/ high control	2.85	[1.08, 7.51]	0.82	[0.28, 2.37]	1.67	[0.85, 3.26]	3.24	[0.75, 14.0]
Job strain: Low demand/ low control	2.18	[0.82, 5.77]	0.88	[0.26, 2.93]	1.41	[0.71, 2.82]	6.46	[1.46, 28.6]
Job strain: High demand/ low control	2.01	[0.75, 5.39]	0.35	[0.09, 1.32]	1.17	[0.58, 2.35]	3.10	[0.74, 12.9]
Coworker support	0.94	[0.83, 1.06]	1.07	[0.86, 1.32]	0.97	[0.88, 1.07]	1.03	[0.89, 1.20]
Supervisor support	1.03	[0.93, 1.13]	1.05	[0.87, 1.28]	1.04	[0.95, 1.13]	1.04	[0.91, 1.19]
Negative affectivity	1.00	[0.95, 1.05]	1.01	[0.93, 1.09]	1.00	[0.96, 1.05]	1.00	[0.93, 1.07]
Weekly stress level[b]	1.32	[1.22, 1.44]	1.25	[1.09, 1.44]	1.32	[1.22, 1.44]	1.27	[1.11, 1.46]
Weekly job change[c]	2.30	[1.43, 3.71]	2.27	[0.90, 5.74]	2.16	[1.34, 3.50]	1.17	[0.48, 2.83]

Note. HR = hazard ratio; CI = confidence interval.
[a]Full-cohort associations between the psychosocial risk factors and neck/shoulder symptoms were controlled for the psychosocial risk factors listed in the table as well as sex, education, history of disc disease, height, history of neck pain, weekly job change, and weekly job stress. Sex-stratified associations were controlled for the same covariates except for sex. Associations between psychosocial risk factors and neck/shoulder disorders controlled for all psychosocial risk factors listed in table as well as sex, neck posture, history of neck pain, history of disc disease, shift, and weekly job stress.
[b]Full-cohort and sex-stratified associations between weekly stress level and neck/shoulder symptoms controlled for weekly job change. Associations between weekly stress level and neck/shoulder disorders controlled for sex.
[c]Full-cohort associations between weekly job change and neck/shoulder symptoms controlled for weekly job stress and sex. Sex-stratified associations controlled for weekly job stress only. Associations between weekly job change and neck/shoulder disorders controlled for sex, shift, hours worked per week, neck posture, and weekly job stress.

strength to cause confounding. In addition, although not presented, we also examined a composite metric of exposure, the strain index (Moore & Garg, 1995), as a potential confounder of associations between the work organizational and psychosocial risk factors and the musculoskeletal outcomes and again found no evidence of such confounding.

During the past decade, two prospective studies of risk factors for MSD have included measures of occupational psychosocial stress. Van den Heuvel, van der Beek, Blatter, Hoogendoorn, and Bongers (2005) examined associations between psychosocial stress ascertained with the JCQ and musculoskeletal outcomes among 787 participants who were followed prospectively for 3 years. Significant increases in adjusted risk ratios were observed for neck/shoulder symptoms, and nonsignificant increases were observed for distal upper-extremity symptoms among persons reporting greater psychosocial stress. The authors did not explore modification of the effect of stress by gender. Smith, Silverstein, Fan, Bao, and Johnson (2008) examined associations observed prospectively between neck and upper-extremity outcomes and JCQ-based psychosocial measures among 424 health care and manufacturing workers. After controlling for physical and other risk factors, the authors found that participants employed in "passive" (i.e., low demand/low control) and "high-strain" jobs (i.e., high demand/low control) had a doubling of risk of shoulder symptoms when compared with participants employed in "low-strain" jobs (i.e., low demand/high control). Contrary to the current study, the authors did not observe a significant modification of the effect of stress by gender when an interaction term was included in multivariable models.

In a cross-sectional study of 733 workers from 12 work sites, Silverstein et al. (2008) examined associations between physical and psychosocial risk factors and rotator cuff syndrome. Positive but non–statistically significant effects of job strain quadrant were observed. No modification of effect by gender was reported. Andersen et al. (2002) reported results of a cross-sectional study of 3,123 workers from 19 facilities in Denmark. Psychosocial stress was ascertained with the JCQ. Personality traits were also ascertained. High demand and low control were each associated with increased risk of neck/shoulder pain with pressure tenderness in adjusted models. The authors did not explore modification of the effect of stress by gender. Overall, consistent main effects of occupational psychosocial strain, as measured with the JCQ, were observed among the existing literature and the current study. However, it appears that the significant Gender × Strain interaction reported in the current study has not been observed previously.

In addition to a single assessment of occupational psychosocial stress obtained at entry into the study, we also assessed job stress with a single VAS administered during each week of follow-up. This time-varying measure of occupational stress was statistically significantly associated with all four musculoskeletal outcomes. The risk increase varied from 29% to 39% per unit of increase in weekly job stress, a metric collected on a 0-to-10 VAS. To put this finding into perspective, participants reporting weekly job stress one standard deviation above the mean weekly job stress value (i.e., 5.4 units) had 2.6 times the risk of hand/arm disorders when compared with participants who reported weekly job stress one standard deviation below the mean weekly job stress value (i.e., 1.2 units). Elevations of risk were similar for the other three musculoskeletal outcomes.

Job change was statistically significantly associated with hand/arm symptoms and hand/arm disorders. The risk of hand/arm disorders was more than three times greater among participants reporting a job change than among participants who did not report a job change. A statistically significant increase in neck/shoulder symptoms, but not neck/shoulder disorders, was also observed among participants reporting a job change. In the current facility, job change was frequently made on the basis of manufacturing need (i.e., model changes, discontinuations, etc.). We have no reason to believe that job change was the result of musculoskeletal outcomes, a phenomenon that could explain the observed association. We are aware of only one other study in which job change was examined as a risk factor for musculoskeletal outcomes. Punnett et al. (2004) reported that a "change in job assignment or job content appeared to confer an increased risk for development of new disorders" among automobile manufacturing workers and suggested that the observation "deserves further investigation" (p. 672).

Several limitations may impact interpretation of the results of the current study. First, as noted in the companion article, the study sample is pre-

dominantly one of very-long-term employees. Thus, it is possible that employees most susceptible to work-related musculoskeletal outcomes had left employment prior to initiation of the study. Such a process might attenuate observed associations. Second, although the temporal sequence of the JCQ and the musculoskeletal outcomes is clear (i.e., the JCQ was administered at the time of study entry when, by definition, those in the prospective cohort analysis were free of symptoms and disorders that met study case definitions), the weekly job stress variable was collected weekly. Because the experience of symptoms might affect weekly stress reporting, we also analyzed associations between weekly job stress and musculoskeletal outcomes in multivariable analyses with a 1-week lag time. Although some attenuation of the association strength was observed, the weekly stress level HRs remained greater than unity for all four outcomes (and ranged from 1.10 to 1.15 per unit change in weekly stress level).

Other limitations include a modest participation rate and the loss of some participants during follow-up (i.e., dropout). In the companion article, we compared those who dropped out with those who remained in the study and found few meaningful differences. Regardless, replication of this study in other settings will provide additional evidence of generalizability.

CONCLUSIONS

In summary, in this prospective study of occupational MSDs, both psychosocial stress, as assessed with the JCQ and a weekly stress metric, and job change were associated with substantial increases in MSD risk. The increases persisted after control for important personal characteristics and occupational exposure to physical factors. These results suggest that efforts to prevent occupational MSDs should include evidence-based methods of mitigating exposure to occupational psychosocial stress and other high-risk organizational factors.

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KEY POINTS

- Occupational psychosocial stress was an important risk factor for incident hand/arm symptoms and disorders and incident neck/shoulder symptoms and disorders.
- A single-item weekly job stress metric was a strong risk factor for these musculoskeletal outcomes.
- Job change, a common management method in large manufacturing organizations, was strongly associated with incident musculoskeletal outcomes.

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