

Psychosocial Factors and Shoulder Symptom Development Among Workers

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Background *Shoulder injuries are a common cause of pain and discomfort. Many work-related factors have been associated with the onset of shoulder symptoms. The psychosocial concepts in the demand–control model have been studied in association with musculoskeletal symptoms but with heterogeneous findings. The purpose of this study was to assess the relationship between the psychosocial concepts of the demand–control model and the incidence of shoulder symptoms in a working population.*

Methods *After following 424 subjects for approximately 1 year, 85 incident cases were identified from self-reported data. Cox proportional hazards modeling was used to assess the associations between shoulder symptoms and demand–control model quadrants.*

Results *Cases were more likely to be female and report other upper extremity symptoms at baseline ($P < 0.05$). From the hazard models, being in either a passive or high strain job quadrant was associated with the incidence of shoulder symptoms. Hazard ratios were 2.17, 95% CI 1.02–4.66 and 2.19, 95% CI 1.08–4.42, respectively.*

Conclusions *Using self-reporting to determine demand–control quadrants was successful in identifying subjects at risk of developing work-related shoulder symptoms. Research is needed to determine if this relationship holds with clinically diagnosed shoulder and other upper extremity musculoskeletal disorders. This may be part of a simple tool for assessing risk of developing these UEMSDs.* Am. J. Ind. Med. 52:57–68, 2009.

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KEY WORDS: *demand–control model; shoulder symptoms; musculoskeletal symptoms; prospective study; Cox proportional hazards model*

INTRODUCTION

Shoulder problems are a common cause of pain and injury. Recent studies of the general adult population in the Netherlands [Bongers, 2001] reported 21% of those surveyed

had shoulder symptoms, in Manchester England it has been reported at 30% [Macfarlane et al., 1998] and in Finland at 34% [Makela et al., 1999]. Neck/shoulder symptoms have been reported at 29% [Grooten et al., 2004] and 32% [Mehlum et al., 2006] in working populations.

In Washington State the average workers' compensation claims (WC) incidence of work-related non-traumatic shoulder disorders is 3.6 per 1,000 fulltime equivalents (FTEs), the average cost per claim is \$14,651 with an average time loss of 247 days. The claims incidence of non-traumatic cases of rotator cuff syndrome (RCS) is 1.7 per 1,000 FTEs with an average cost and time loss of \$29,877 and 323 days respectively [Silverstein and Adams, 2005].

Many physical load factors have been identified as likely contributors to upper extremity musculoskeletal symptoms and disorders. The most frequently identified risk factors have been awkward postures [Frost and Anderson, 1999; Punnett

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et al., 2000; Viikari-Juntura et al., 2000], repetitive movements [Veiersted and Westgaard, 1993; Blanc et al., 1996; Nordstrom et al., 1997; Punnett, 1998] and forceful exertions [Stetson et al., 1993; Fransson-Hall et al., 1996; Roquelaure et al., 1997]. Although the inclusion of psychosocial factors in work-related musculoskeletal disorder (WMSD) studies has been increasing in the past 20 years, results from these studies have varied [van der Windt et al., 2000; Bongers et al., 2002]. Possible reasons for the heterogeneous nature of findings are the lack of prospective studies [NIOSH, 1997; NRC, 2001] and the absence of individual measurement for physical risk factors [NIOSH, 1997].

Other gaps in the literature consist of not including non-work related factors to test for confounding and effect modification as well as a lack of common instruments used to assess psychosocial factors [Bongers, 2001].

The demand–control model originally developed by Karasek [1979] has been used extensively in work related research for various health outcomes. The demand–control model suggests that work-related stress, measured by the mental demands of the job and the level of decision latitude (control) over the job can affect workers' health. Karasek hypothesized that high job demands coupled with low job control (high job strain) will lead to significantly adverse health outcomes. Other studies have further explored the demand–control model by investigating the potential interactive effect of job demands and job control via demand–control quadrants [Hannan et al., 2005; Leroux et al., 2006; van den Heuvel et al., 2005]. Numerous studies have shown positive associations between “job strain” and cardiovascular disease [Schnall and Landsbergis, 1994; Karasek et al., 1998], general quality of life [Lerner et al., 1994] as well as musculoskeletal disorders [Andersen et al., 2002, 2003; Bonde et al., 2003; Hannan et al., 2005; van den Heuvel et al., 2005; Ostergren et al., 2005; Leroyer et al., 2006; Leroux et al., 2005]. The demand–control model is one of the most widely used psychosocial job hazard assessment models, it therefore seems appropriate to further test this model with individual collected prospective data.

The purpose of this study was to assess the relationship between the psychosocial concepts of the demand–control model and the incidence of shoulder symptoms in a working population. We assessed the interactive relationship between the constructs of job demands and job control by using demand–control quadrants.

MATERIALS AND METHODS

Study Design and Subject Selection

Design

A 1-year prospective study was conducted to examine the relationship between the demand–control model and

shoulder symptoms among a cohort of full-time employees in 12 health care and manufacturing sites across western Washington State [Bao et al., 2006a; Silverstein et al., 2006]. Sites were chosen if they employed more than 100 FTE employees, had sufficient variability in physical exposures and agreed to let workers participate during normal work hours with no loss of pay or privileges.

Larger companies were chosen to ensure an adequate sample size in each of the departments eligible for study. Departments within these companies were eligible for the study if they employed at least 20 people and had sufficient diversity of physical exposures. This variability in exposure was determined by initial workplace walkthroughs by study ergonomists to classify jobs into one of six exposure categories using a combination of peak hand force and hand activity or repetition. These categories were based primarily upon the American Conference of Governmental Industrial Hygienists (ACGIH), threshold limit value (TLV) with peak hand force classified as either low (0–4) or high (5–10) on a 0–10 hand force scale and repetition rate was classified as either low (0–3), medium (4–6), or high (7–10) [ACGIH, 2003]. Not all departments were eligible for inclusion in this study, due to either small numbers of employees or lack of varied physical exposures.

Subject selection

To be eligible for inclusion in this analysis subjects had to work full-time (≥ 30 hr/week), could not be a temporary worker, could not have a prior traumatic injury to their shoulder and had to be free of shoulder symptoms at baseline.

The case definition for shoulder symptoms was based on self-reported symptoms. The criteria were: subjects at baseline reported being free of any pain, aching, stiffness, burning, numbness or tingling in the shoulder in the past 12 months, no history of acute trauma to the shoulder and; were considered a case during follow-up if they reported shoulder symptoms in the 7 days prior to assessment, of at least moderate intensity (none, mild, moderate, severe or very severe) and; had no traumatic injury to the shoulder during follow-up.

The study design, protocols and instruments were approved by the Washington State Institutional Review Board. Written consent was obtained from all participants at the time of study enrollment. Consent forms were available in different languages and interpreters were used if needed.

Data Collection Instruments and Procedures

Psychosocial factors, detailed personal and health history data, as well as individually assessed physical exposures were collected at baseline. Neck and bilateral upper-extremity (shoulder, elbow/forearm, and hand/wrist)

symptoms were assessed at baseline and again at approximately 4, 8, and 12 months.

Demographics and health history

Self-reported data were collected at baseline on potential confounders and/or effect modifiers during personal history interviews between the subject and research staff. These data included: gender, date of birth for age, race and ethnicity, education, symptoms of neck, elbow/forearm or hand/wrist discomfort, presence of chronic conditions (high blood pressure, diabetes, thyroid problems and arthritis), prior injuries to the neck or upper extremities (slipped disc, tendonitis, fractures), hobbies, number of children at home, as well as information about length of time on the job. Height and weight were measured and body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m²).

Psychosocial assessment

Demand–control quadrants were evaluated using questions from Karasek’s Job Content Questionnaire [Karasek and Theorell, 1990]. Job demands (work fast, work hard, (no) excessive work, not enough time) and job control (learn new things, repetitive work, requires creativity, allows own decision, (little) decision freedom, variety, and lot of say) were used. Continuous scores of job demands and job control were dichotomized at the median of the sample to create high or low demand and high or low control. Demand–control quadrants were created (Fig. 1), according to Karasek, into low strain (low demand, high control), high strain (high demand, low control), active job (high demand, high control), and passive job (low demand, low control). High demand and low control were assessed as separate dichotomous variables, as well as demand–control quadrants.

Physical exposure assessment

In the assessment of baseline physical exposure, durations, frequencies and intensities of forces and postures

were evaluated across job tasks. A detailed description of methods for data collection, processing and analysis is reported elsewhere [Bao et al., 2006a]. Briefly, all subjects were observed by ergonomists on-site and videotaped using two synchronized cameras positioned to video film the worker from two different angles for a minimum of 15 min during a typical work period in order to estimate exposures to forceful exertions, awkward postures and repetitive movements. Forceful exertions were defined as pinch or grip forces or object weights equal to or greater than 8.9 N (corresponding to 2 lbs or 0.9 kg), and power grip forces, object weights or push/pull forces equal to or greater than 44.1 N (corresponding to 10 lbs or 4.5 kg). Cyclic single task jobs were filmed for 15 min. For cyclic jobs with 2–4 tasks, subjects were filmed for 10 min per task (except tasks with very short cycles, which were filmed for 5 min per task). For non-cyclic jobs, subjects were filmed for three random 5-min samples in a typical work shift. During the worksite visits, object weights and push/pull forces were measured using force gauges. Pinch and power grip forces were estimated using a force matching technique [Bao and Silverstein, 2005].

Video data were analyzed to obtain exposure parameters related to forceful exertions and awkward postures [Bao et al., 2006b]. Using the Multimedia Video Task Analysis (MVTA) software [Yen and Radwin, 1995], video data were time studied to obtain percent of time (duty cycle) and frequency in various activities where forceful exertions occurred. According to the time-study results, duty cycle (% of time) and frequency (times/min) were obtained for the different types of forceful exertions (lifting, pushing/pulling, power gripping and pinch gripping) respectively. Overall duty cycle and frequency of exertion were also computed for all forceful exertions irrespective of the types of forceful exertions.

Distributions of work postures of the upper extremity were obtained using a time-sampled posture analysis method [Bao et al., 2007]. From the video, postures were estimated by paired analysts for numerous randomly selected frames. Seventy-five frames were analyzed for single task jobs, 40 frames per task for two-task jobs, 45 frames per task for three-task jobs and 20 frames per task for four-task jobs. Percent of time in defined posture sectors were computed and used in the analysis.

Analyses of repetitive shoulder movements were conducted using the recorded videos. The MVTA software [Yen and Radwin, 1995] was again used to perform the time-studies. Frequencies of shoulder movements were then calculated from the time-study results [Bao et al., 2006a].

Statistical analysis

Descriptive statistical analyses were conducted for all potential covariates of interest both to determine variability

		Job Demands	
		Low	High
Job Control	High	Low strain	Active job
	Low	Passive job	High Strain

FIGURE 1. Demand–control model quadrants.

and the need to categorize continuous variables. Chi-square and ANOVA were conducted to determine the distribution of all potential covariates across demand–control quadrants. Post hoc analyses of categorical variables were performed using Chi-square tests between pairs of the demand–control quadrants. Significance levels (P -values) were multiplied by 6 to adjust for the multiple comparisons (Bonferonni). Cox regression analysis was used to model the relationship between incident shoulder symptoms and demand–control quadrants. Kaplan–Meier survival curves and log-rank test of equality were computed for all categorical covariates to determine whether or not to include the covariates in the full model. All covariates that were statistically significant at $P \leq 0.2$ in unadjusted analysis with incident shoulder symptoms were then entered into an age and gender adjusted Cox proportional hazards model one at a time. The simultaneous effect of the covariates on the regression coefficients for time to shoulder symptoms and demand–control quadrants was assessed. Any covariate that changed the hazard ratio for a demand–control quadrant by 10% or more was kept in the model. The proportional hazards assumption was tested by examining both adjusted and unadjusted log-log plots of covariates and by calculating the Schoenfeld residuals for all covariates and testing their relationship to the ranked time to onset of the shoulder symptoms outcome variable. Interactions were assessed by creating product terms of all potential two-way interactions with demand–control model quadrants. Squared multiple correlations (SMC) were examined to test for multicollinearity in the multivariate model. The effects of high job demand and low job control on the incidence of should symptom cases were also assessed using Cox proportional hazards model. All analyses were completed with SPSS version 15.0 (SPSS for Windows, Rel. 15.0.0. 2006. Chicago: SPSS, Inc., Chicago, IL).

RESULTS

Of the 733 subjects available for this analysis, 424 subjects (57.8% response rate) met the inclusion criteria. Subjects were excluded from analysis for a number of reasons; 90 (12.3%) had missing data, and 101 (13.8%) were lost to study before the first follow-up. An additional 118 subjects (16.1%) were excluded as 77 (10.5%) had shoulder symptoms at baseline and 41 (5.6%) had a prior injury to their shoulder. Excluded subjects with demand–control model data did not differ from the study sample by demand–control quadrants ($P = 0.88$). Personal characteristics of the study sample are presented by demand–control quadrant in Table I. There were no statistically significant differences in gender, age, height, BMI, education, smoking status, chronic diseases, pain medication usage, having a second job, high repetition or high force hobbies across demand–control quadrants, or symptoms in the neck, elbow/forearm or hand/

wrist at baseline ($P > 0.05$). Post hoc tests indicate significant differences in the distribution of race between low strain and high strain jobs ($P = 0.018$) and between high strain and passive jobs ($P = 0.012$). Asian/Pacific Islanders had an observed count that was 1.5 times more than expected in the low strain quadrant compared to the high strain quadrant and 1.8 times the expected count in passive jobs when high strain and passive jobs were compared.

Physical exposure characteristics by demand–control quadrants are presented in Table II. There were significant differences in the distributions of the lifting exposures (lifting weights, lifting percent of time and lifting frequency), the frequency and duty cycles of forceful exertions as well as the percent of time neck was rotated $\geq 45^\circ$ and frequency of shoulder movements ($P < 0.05$). Post hoc tests indicated there were higher than expected counts in low strain jobs with no lifting exposures (no lifting weights, no percent of time or frequency of lifting) compared to either high strain or passive jobs. There were also significant differences in the distribution of the frequency of forceful exertions between low strain and high strain jobs ($P = 0.012$). There was a higher than expected count for frequencies of forceful exertions ≥ 5 times per minute in high strain and passive jobs compared to low strain jobs.

Incidence of Shoulder Symptom Cases

Due to the small number of non-dominant side shoulder cases ($n = 27$), analysis presented here are for dominant side shoulder cases. Eight-five subjects (20%) became shoulder symptom cases by one year. The incidence rate of shoulder symptoms was 23.5 per 1,000 person-months in this study, ranging from 14.8 (low strain) to 29.6 (passive jobs) per person-months (Table III).

Effects of the Demand–Control Model on Incidence of Shoulder Symptom Cases

Demand–control quadrants

Unadjusted and multivariate results for the association between demand–control quadrants and the incidence of shoulder symptoms are presented in Table IV. Crude hazard ratios for demand–control quadrants show no statistically significant associations with shoulder symptoms. When adjusted for age and gender, those in passive jobs and high strain jobs had a statistically significantly increased risk of shoulder symptoms compared to those in low strain jobs. These associations remain in the full multivariate model. As observed in the survival curves (Fig. 2), subjects reporting passive jobs had almost identical survival patterns as those who reported being in high strain jobs.

TABLE I. Personal Characteristics by Demand–Control Quadrants (N = 424)

	Low strain (n = 82) (%)	High strain (n = 145) (%)	Active job (n = 129) (%)	Passive job (n = 68) (%)	P-value*
Gender (female)	47.6	50.3	48.1	41.2	0.67
Age					0.48
18–34 years old	25.6	37.9	38.8	35.3	
35–54 years old	65.0	53.1	55	54.4	
55+ years old	9.8	9.0	6.2	10.3	
Height in inches mean ± SD	66.6 ± 4.4	67.3 ± 3.9	67.4 ± 4.0	66.6 ± 4.2	0.38
BMI (kg/m ²)					0.26
14–24.9	40.2	42.7	40.9	44.1	
25–29.9	40.2	32.9	27.6	38.2	
≥30	19.5	24.5	31.5	17.6	
Race					0.004
Asian/Pacific Islander	24.4	10.3	17.8	29.4	
Other	26.8	19.3	17.1	17.6	
Caucasian	48.8	70.3	65.1	52.9	
<i>Post hoc pairwise comparisons^b</i>	<i>a</i>	<i>ab</i>	<i>c</i>	<i>b</i>	
Neck, elbow or hand/wrist symptoms at baseline	17.1	28.3	24.0	22.1	0.29
At least a high school education	85.4	84.8	82.9	82.4	0.93
Current smoker	18.3	30.3	26.4	33.8	0.14
Currently have children at home?	53.7	52.8	55.1	62.7	0.59
Self-reported chronic diseases (arthritis, diabetes, thyroid problems or high blood pressure)	19.5	20.0	17.8	17.6	0.96
Self-reported previous diagnosis of neck, elbow/forearm or hand/wrist	19.5	26.9	21.7	20.6	0.54
Currently taking medication for pain	37.8	46.2	35.7	33.8	0.21
Currently work a second job	8.5	7.6	9.3	2.9	0.43
Years in current job					0.12
Less than a year	23.2	37.9	27.9	25.0	
1–3 years	24.4	26.9	30.2	26.5	
More than 3 years	52.4	35.2	41.9	48.5	
High repetition hobbies ^a	26.8	23.4	29.5	17.6	0.30
High force hobbies ^a	30.5	35.2	38.0	20.6	0.08

*P-value = Chi-square test or ANOVA.

^aHigh repetition hobbies: gardening, home improvement, knitting/sewing, playing an instrument, video games and woodworking. High force hobbies: gardening, golf, home improvement, knitting/sewing, volleyball, weightlifting and woodworking.

^bPost hoc pairwise Chi-square tests. A common letter between pairs of demand–control quadrants indicates a significant difference ($P < 0.05$) in the distribution between them.

Effects of Separate Demand–Control Factors on the Incidence of Shoulder Symptom Cases

Unadjusted and multivariate results for the association between job demands and the incidence of shoulder symptoms were not statistically significant (Table V). Unadjusted and multivariate results for the association between job control and the incidence of shoulder symptoms were statistically significant (Table V). Multivariate survival curves for the incidence of shoulder symptoms by high and low job control are presented in Figure 3.

Additional Covariates–Personal and Physical Load Factors

Among the categorical covariates tested using Kaplan–Meier survival curves, gender, age, self-reported race, neck, elbow/forearm or hand/wrist symptoms at baseline, years on the current job and participating in high force hobbies were all statistically significantly related to shoulder symptoms at $P < 0.05$ although years on the current job and high force hobbies did not retain significance in the multivariate models. Lifting weights, percent of time spent lifting, lifting frequency, awkward trunk posture and awkward upper arm

TABLE II. Physical Exposures by Demand–Control Quadrants (N = 424)

Percent subjects	Low strain (n = 82) (%)	High strain (n = 145) (%)	Active job (n = 129) (%)	Passive job (n = 68) (%)	P-value*
Force measurements					
Power grip					0.15
No power grip	72.0	75.9	79.1	63.2	
<20 lbs	9.8	9.7	9.3	8.8	
>20 lbs	18.3	14.5	11.6	27.9	
Lifting weights					0.003
No lifting	54.9	31.0	50.4	33.8	
<10 lbs	31.7	51.7	33.3	50.0	
≥10 lbs	13.4	17.2	16.3	16.2	
<i>Post hoc pairwise comparisons^a</i>	<i>ab</i>	<i>ac</i>	<i>c</i>	<i>b</i>	
Lifting percent of time					0.004
None	54.9	31.0	50.4	33.8	
<5% time	15.9	20.7	17.1	23.5	
≥5% time	29.3	48.3	32.6	42.6	
<i>Post hoc pairwise comparisons</i>	<i>ab</i>	<i>ac</i>	<i>c</i>	<i>b</i>	
Lifting frequency					0.004
None	54.9	31.0	50.4	33.8	
<5 times/min	34.1	49.0	35.7	51.5	
≥5 times/min	11.0	20.0	14.0	14.7	
<i>Post hoc pairwise comparisons</i>	<i>ab</i>	<i>ac</i>	<i>c</i>	<i>b</i>	
Frequency of forceful exertions					<0.001
No forceful exertions	40.2	17.2	39.5	16.2	
<5 times/min	39.0	50.3	39.5	54.4	
≥5 times/min	20.7	32.4	20.9	29.4	
<i>Post hoc pairwise comparisons</i>	<i>ab</i>	<i>ac</i>	<i>cd</i>	<i>bd</i>	
Duty cycle of forceful exertions					<0.001
<1 times/min	41.5	20.0	42.6	20.6	
≥1 <10 times/min	23.2	23.4	18.6	33.8	
≥10 times/min	35.4	56.6	38.8	45.6	
<i>Post hoc pairwise comparisons</i>	<i>ab</i>	<i>ac</i>	<i>cd</i>	<i>bd</i>	
Postures					
Neck extension >5° or neck flexion ≥20°					0.11
<50% time	25.6	37.9	39.5	27.9	
≥50 <65% time	26.8	32.4	27.1	33.8	
≥65% time	47.6	29.7	33.3	38.2	
Neck rotation ≥45°					0.01
<5% time	52.4	29.2	45.3	42.6	
≥5 <10% time	24.4	29.9	29.7	27.9	
≥10% time	23.2	41.0	25.0	29.4	
<i>Post hoc pairwise comparisons</i>	<i>a</i>	<i>ab</i>	<i>b</i>	<i>c</i>	
Trunk flexion ≥20°					0.07
<5% time	43.9	24.8	33.3	38.2	
≥5 <15% time	29.3	47.6	37.2	36.8	
≥15% time	26.8	27.6	29.5	25.0	
Trunk lateral flexion ≥10°					0.14
<10% time	41.5	22.9	32.6	27.9	
≥10 <25% time	34.1	43.1	35.7	36.8	
≥25% time	24.4	34.0	31.8	35.3	

(Continued)

TABLE II. (Continued)

Percent subjects	Low strain (n = 82) (%)	High strain (n = 145) (%)	Active job (n = 129) (%)	Passive job (n = 68) (%)	P-value*
Trunk rotation between 10 and 45° and trunk lateral flexion ≥30°					0.17
<25% time	39.0	22.2	33.3	29.4	
≥25 < 45% time	29.3	44.4	37.2	39.7	
≥45% time	31.7	33.3	29.5	30.9	
Frequency of shoulder movements					<0.0001
<10 times/min	35.4	11.7	38.0	19.1	
≥10 < 20 times/min	45.1	45.5	42.6	42.6	
≥20 times/min	19.5	42.8	19.4	38.2	
Post hoc pairwise comparisons	<i>ab</i>	<i>ac</i>	<i>cd</i>	<i>bd</i>	
Upper arm extension >5° or flexion ≥45°					0.87
<20% time	36.6	32.4	37.2	29.4	
≥20 < 35% time	37.8	42.8	36.4	39.7	
≥35% time	25.6	24.8	26.4	30.9	
Upper arm outward rotation >5° or upper arm inward rotation ≥45°					0.26
<15% time	56.1	42.1	51.2	44.1	
≥15 < 20% time	17.1	17.2	13.2	22.1	
≥20% time	26.8	40.7	35.7	33.8	
Upper arm abduction ≥30°					0.21
<10% time	54.9	42.8	51.9	42.6	
≥10 < 20% time	20.7	33.8	25.6	38.2	
≥20% time	24.4	23.4	22.5	19.1	
Uses vibrating tools	7.3	8.3	7.8	10.3	0.92

*P-value = Chi-square test.

^aPost hoc pairwise Chi-square tests. A common letter between pairs of demand–control quadrants indicates a significant difference ($P < 0.05$) in the distribution between them.

posture had $P \leq 0.2$, although only awkward upper arm posture retained statistical significance in the multivariate models. The lifting variables were all highly correlated ($P < 0.001$); therefore, they were not entered into the model together. The effect of both the demand–control quadrants and awkward arm postures seemed to increase in each instance when one of the lifting variables (measured weights, frequency or percent of time lifting) were entered into the model, although none of the lifting variables were statistically significant. We could not find an interaction effect with awkward arm posture and any of the lifting

variables. It may be that we had inadequate numbers to see such an interaction, or that awkward upper arm postures independently explained most of the effect that lifting had in the model.

Self-reporting being Asian/Pacific Islander and reporting neck, elbow/forearm or hand/wrist symptoms at baseline appeared to be strongly associated with incident shoulder symptoms in the multivariate model (Table IV). Awkward upper arm posture (extension $>5^\circ$ or flexion $\geq 45^\circ$) at between 20% and 35% of time was also associated with incident shoulder symptoms.

TABLE III. Incidence of Shoulder Symptoms by Demand–Control Quadrants (N = 424)

	Low strain (n = 82)	High strain (n = 145)	Active job (n = 129)	Passive job (n = 68)
Cases	11	33	23	18
Person months	745	1,159	1,108	608
Incidence rate per 1,000 person months	14.8	28.5	20.8	29.6

TABLE IV. Hazard Ratios for Shoulder Symptom Cases, Crude and Multivariate Models by Demand–Control Quadrants (N = 424)

	Unadjusted		Age and gender adjusted		Multivariate model	
	HR	95% CI	HR	95% CI	HR	95% CI
Gender (female)			1.80	(1.14–2.83)	1.76	(1.09–2.82)
Age category						
18–34 years old			1.00		1.00	
35–54 years old			1.56	(0.91–2.66)	1.47	(0.85–2.52)
55+ years old			2.58	(1.24–5.37)	2.56	(1.23–5.33)
Race						
Caucasian					1.00	
Asian/Pacific Islander					1.80	(1.05–3.08)
Other					0.97	(0.53–1.80)
Neck, elbow or hand/wrist symptoms at baseline					1.66	(1.05–2.61)
Awkward upper arm posture (extension >5° or flexion ≥45°)						
<20% time					1.00	
≥20% and <35% time					1.84	(1.08–3.13)
≥35% time					1.15	(0.61–2.17)
Demand–control quadrants						
Low strain	1.00		1.00		1.00	
High strain	1.92	(0.97–3.80)	1.98	(1.00–3.92)	2.19	(1.08–4.42)
Active job	1.39	(0.68–2.85)	1.50	(0.73–3.09)	1.72	(0.83–3.59)
Passive job	1.92	(0.91–4.08)	2.10	(0.99–4.46)	2.17	(1.02–4.66)

HR, hazard ratio; 95% CI, 95th percent confidence interval.

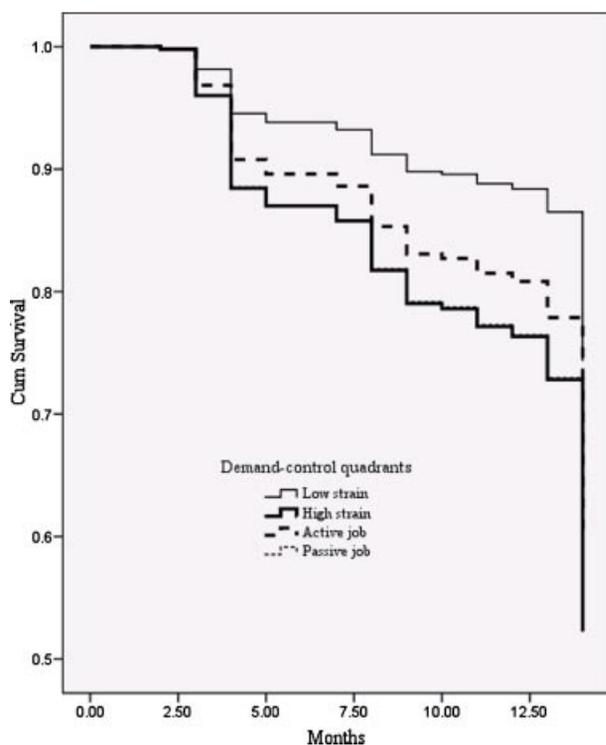


FIGURE 2. Multivariate survival curves for the incidence of shoulder symptoms by demand–control quadrants.

There were no statistically significant results from the analysis of two-way interactions between the demand–control quadrants and age, gender, self-reported race, neck, shoulder or hand/wrist baseline symptoms or awkward upper arm posture.

Potential Misclassification

This study did not incorporate job change data, in order to assess the potential for misclassification of demand–control quadrants or physical exposure categorization, subjects with and without job changes were compared. During the 1-year follow-up period, 58 subjects (13.7%) had a total of 72 job changes where physical exposure data were re-collected.

Of the 58 participants who reported changing jobs, 53 subjects (91.3%) repeated the psychosocial questionnaire 1 year after baseline. The high strain quadrant increased by nine subjects, active job decreased by six subjects, low strain decreased by two subjects and passive job decreased by one subject. This increase in the high strain job quadrant suggests that by not including job change data into our models we may have underestimated the effect of high strain jobs in predicting shoulder symptoms.

TABLE V. Hazard Ratios for Shoulder Symptoms Cases, Crude and Multivariate Models by Job Demand and Job Control (N = 424)

	Unadjusted		Age and gender adjusted		Multivariate model ^a	
	HR	95% CI	HR	95% CI	HR	95% CI
Low demand	1.00		1.00		1.00	
High demand	1.16	(0.74–1.82)	1.19	(0.76–1.86)	0.77	(0.48–1.23)
High control	1.00		1.00		1.00	
Low control	1.56	(1.01–2.41)	1.56	(1.01–2.41)	1.56	(1.004–2.41)

HR, hazard ratio; 95% CI, 95th percent confidence interval.

^aAdjusted for age, gender, race, neck, elbow or hand/wrist symptoms at baseline and awkward upper arm posture.

Comparing those who reported a job change and those who did not, we found no statistically significant difference in shoulder symptom case status between those who reported job changes versus those who did not change jobs during our study period ($P > 0.05$). Although this cannot completely rule out the possibility of misclassification in physical exposures, which may have affected our ability to see confounding or effect modification, it does not appear to have affected shoulder symptom case status.

DISCUSSION

The main findings of this analysis were that subjects who reported working in passive jobs (low demand, low control) or high strain jobs (high demand, low control) were more likely to develop shoulder symptoms than those in low strain

jobs (low demand, high control); and that subjects in low control jobs were more likely to develop shoulder symptoms than subjects in high control jobs. These associations were statistically significant after controlling for age, gender and other potential confounders, including physical load factors.

While comparisons to most previous studies are somewhat problematic due to differences in study designs (most were cross sectional) and data collected (most physical exposures used self-report and group level data), some comparisons can be made. Many found high demand and/or low control to be associated with shoulder problems [Andersen et al., 2002, 2003; Bonde et al., 2003; Ostergren et al., 2005; Leroyer et al., 2006]. For those studies where demand–control quadrants were assessed, they found high strain jobs (high demand and low control) had the highest risk ratios, when compared with low strain jobs (low demand and high control) [Hannan et al., 2005; Leroux et al., 2005; van den Heuvel et al., 2005]. Our results are similar, where high strain jobs had statistically significantly higher hazard ratios when compared with low strain jobs.

Our results indicate that job control might have a larger impact on shoulder symptoms than job demands. Both passive and high strain jobs indicate low control, and from our analyses of job demands and job control as separate factors, job control was statistically significantly associated with incident shoulder symptoms, whereas job demand was not. It is likely that job control was driving the statistical significance of both passive and high strain jobs, as they had very similar hazard ratios and overlapping confidence intervals.

Increasing control over the way one performs a job may lead to less awkward postures and muscle tension due to psychosocial stress. This suggests allowing workers to participate in job design may decrease muscle load and psychosocial strain.

Assessing demand–control quadrants is a relatively simple way to evaluate the risk of developing shoulder symptoms in a working population. Musculoskeletal symptoms have been shown to be significant predictors of subsequent musculoskeletal disorders [Silverstein et al., 2006; Descatha et al., 2008]. Including a short self-report

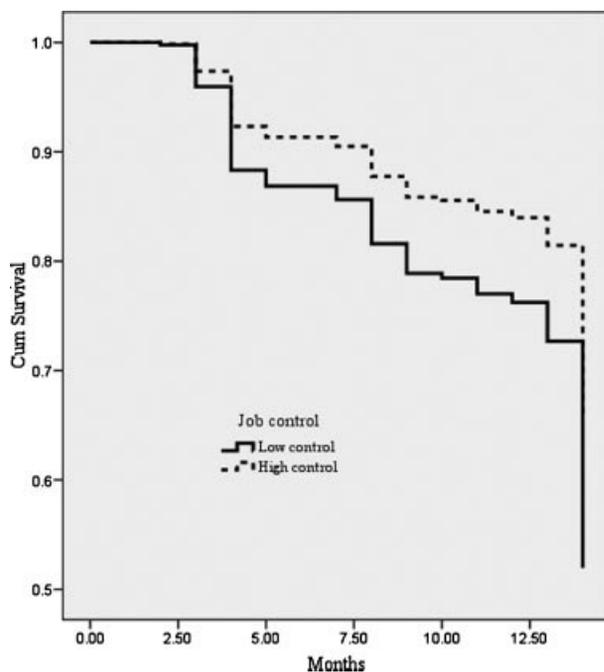


FIGURE 3. Multivariate survival curves for the incidence of shoulder symptoms by job control.

questionnaire regarding MSD symptoms and psychosocial factors can be part of an effective job hazard assessment tool.

An important strength of this study was the prospective design, which allowed us to detect temporal relationships between the demand–control model and the incidence of shoulder symptoms. This analysis is consistent with other studies in that subjects who reported being in the high strain job quadrant appeared to be at an increased risk of developing shoulder symptoms.

An additional strength was that the physical exposure data were individually collected which allowed us to better evaluate the contribution of physical exposures for each subject. Our population also varied by occupational group, self-reported race and age, allowing us to test the relationship between shoulder symptoms and demand–control quadrants in a diverse population.

Our study was limited by the relatively small sample size ($N = 424$), particularly when subjects were categorized by demand–control quadrants. This may have reduced the chances of identifying any effect modification.

Another potential limitation is that job change data are not included in our analyses, although post hoc comparisons of those who did and did not change jobs show no serious misclassification of physical exposure categories, we may have underestimated the effect of being in the high strain job quadrant.

Another limitation may have been the case definition. We relied solely on self-reported symptoms of the shoulder and did not require a physical examination nor for subjects to be free of neck, elbow/forearm or hand/wrist symptoms. A total of 101 subjects (23.8%) reported at least one symptomatic region (neck, elbow/forearm or hand/wrist) at baseline and these subjects were more likely to become a shoulder symptom case than those who were symptom free at baseline ($P = 0.001$). These co-morbid symptoms may have affected subjects' baseline demand–control quadrant designation and may have diluted the association between demand–control quadrants and shoulder symptoms. It is possible that symptoms may have affected how workers viewed their job characteristics, or workers with these pre-existing symptoms may have opted out of higher strain jobs in an effort to alleviate symptoms. Further prospective studies using both demand–control quadrants and separate factors of job demands and job control in a symptom free working population are needed to explore this possibility.

We were also unable to use national means as cut points in our data as we did not use the full set of questions from the JCQ. This may affect our ability to generalize the findings to the larger population. In a recent study, however, Karasek et al. [2007] found questions similar to those in the JCQ to be highly correlated to the original JCQ, with comparable high job strain designations being moderately correlated. The demand–control model appears to be quite robust as significant associations have been found with various health

outcomes when using the full set of validated questions from the JCQ [Landsbergis et al., 1994] various subsets of JCQ questions [Lerner et al., 1994; Hellerstedt and Jeffery, 1997; Gimeno et al., 2004b] and different but conceptually similar questions [Nahit et al., 2003; Gimeno et al., 2004a; Sanne et al., 2005].

Although subjects were similarly distributed by gender at baseline (48% female), females were more likely to develop shoulder symptoms in this analysis than men ($P = 0.001$). Similar results of females having higher proportions of musculoskeletal symptoms have been reported [Andersen et al., 2002; Strazdins and Bammer, 2004]. Females were also more likely to have symptoms of the neck, elbow/forearm or hand/wrist at baseline but were less likely to spend more time in awkward upper arm postures than males ($P < 0.001$). The reasons why females appear to be at greater risk in this analysis are not known, but may be due to factors not studied in this analysis, such as gender divisions in domestic work [Strazdins and Bammer, 2004].

Self-reported Asian/Pacific Islanders were more likely to develop shoulder symptoms in this analysis than non-Asian/Pacific Islanders. The significance of this finding is not clear, but may be related to stature and other physical factors not directly measured in this study. Height was statistically significantly inversely related to shoulder symptom cases in univariate analysis ($P = 0.001$). Asian/Pacific Islanders were shorter than non-Asian/Pacific Islanders (mean height 64.0 inches vs. 67.8 inches) ($P < 0.001$). Asian/Pacific Islanders were also more likely than non-Asian/Pacific Islanders to have a higher percent of time in awkward upper arm postures (>5 extension or ≥ 45 flexion) ($P = 0.007$).

Arm elevation, especially when accompanied with hand loads, has been found in lab studies to increase the intramuscular pressure (IMP) in the infra- and supraspinatus rotator cuff muscles [Palmerud et al., 2000]. IMP is used to measure muscle force output, muscle fatigue and local muscle blood flow, indicators of risk for shoulder tendonitis. The increased time in awkward arm elevations may help explain why Asian/Pacific Islanders were more likely to report shoulder symptoms. There may also be some relationship with length of arms, trunk height and the configurations of workstations/equipment. A recent study of hand, forearm and upper-arm length found that Vietnamese subjects had the smallest dimensions of all racial/ethnic groups studied and that forearm and upper arm length for minority populations were less than the 50th percentile of the overall United States population [Gnaneswaran and Bishu 2006].

Co-morbid symptoms at baseline and their effect on subsequent shoulder symptom development is an important finding in this study. Upper extremity musculoskeletal disorders of different body regions presumably have different etiologies but the results from this analysis suggest that symptoms in one area may affect resulting symptoms in another and in fact may overwhelm the ability to detect

relationships between symptoms and physical or psychosocial risk factors. The reasons for this potentially important effect of co-morbid symptoms are not known. They may be due to prior physical or psychosocial changes meant to alleviate symptoms in one body region that end up stressing a different region, or may be due to differing tolerances of various body regions to the same set of risk factors. Whatever the cause, the issue of co-morbid symptoms deserves further study and may have important implications for research designed to study the etiology of only one specific musculoskeletal disorder.

In summary, this study found a significant association between high strain jobs and passive jobs and the incidence of shoulder symptoms in a working population. Additionally, we found job control to be a stronger predictor than job demands for the development of shoulder symptoms. These results are important additions to the literature as the data were from a prospective study, where the job designation preceded the incidence of shoulder symptoms. We were also able to include individually collected physical exposure data into our models to test the effect of psychosocial factors in a more complete model of potential workplace hazards. Personal health information, demographic data and detailed physical exposures are all important potential contributors to the development of musculoskeletal symptoms. By examining the contributions of these factors in a model with demand–control quadrants we were able to show that self-reported psychosocial hazard assessment is a good predictor for future shoulder symptom development. Symptoms have been shown to be a good predictor of subsequent musculoskeletal disorders; the identification of potential risk factors is an important step in preventing these costly injuries.

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