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Original Article

Job Strain, Effort-reward Imbalance and Neck, Shoulder and Wrist Symptoms among Chinese Workers

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Abstract: The purpose of this study was to examine the association between psychosocial job stress (by the Job Control-Demand (JCD) model and Effort-Reward imbalance (ERI) model) and musculoskeletal (MS) symptoms among workers in China. Overall, 3,632 male and 1,706 female workers from 13 factories/companies participated in this study. Perceived job stress was evaluated by the Chinese version of the Job Content Questionnaire (JCQ) and ERI Questionnaire. Neck, shoulder and wrist symptoms were assessed by self-report during the past year. Workers reporting high job demands and low job control or high effort and low rewards had moderately increased risk for all MS symptoms. Odds ratios (ORs) were higher in workers reporting both high effort and low rewards. The combination of high physical job demands with low job control showed significant associations with MS symptoms. The effects of psychological demands on symptoms in women, effort and effort-reward imbalance on symptoms among both genders were increased as the number of regions with symptoms increased. These results suggest that high job strain and ERI are associated with neck, shoulder and wrist symptoms in Chinese factory workers independent of individual factors, physical factors, and other psychological variables.

Key words: Psychosocial factors, Job stress, Job strain, Effort-reward imbalance, Work-related musculoskeletal disorders

Introduction

Work-related musculoskeletal disorders (WMSDs, including neck, shoulder and wrist problems) are frequent in the working population with an incidence of 29% in the United States (as reported by Bureau of Labor Statistics in 2008)[1]. In France, pain in the upper limbs accounted for 50% of all reported occupational diseases that caused disability and time lost from work[2]. In Canada, upper limb (neck, shoulder, and arm) WMSDs constituted up to 24% of lost-time workers compensation claims[3]. In China, WMSDs are still not included as occupational disease compensation claims by law, and thus the exact prevalence of WMSDs is not well-known in China. According to two existent studies, Jin *et al.*[4] have reported the overall self-reported annual prevalence of low back pain was 50%, while a study by Chen *et al.*[5] indicated that the prevalence of musculoskeletal pain over the previous 12 months var-

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ied between 7.5% for elbow pain and 32% for low back pain. However, the generalizability of the results is limited because these studies were based on small sample sizes sampled in a single company.

It has been known that WMSDs have a multifactorial etiology; the development of WMSDs may be influenced by biomechanical, psychosocial and individual risk factors[6, 7]. A review of 63 selected studies with regard to WMSD risk factors indicated that heavy physical work, smoking, being overweight, high psychosocial work demands and the existence of co-morbidities were common factors associated with WMSDs[8]. Regarding psychosocial factors, some studies have used theory-based job stress measures[9–25] such as the JCD model[26] and the ERI model[27]. The JCD model predicts that the-adverse health effects occur when job demands are high and decision latitude is low. Social support is a third dimension of this model. Social support exerts both main and buffering effects, i.e., alleviate stress directly or act as a buffer in interaction with stressors[28, 29].

In contrast, the ERI model assumes that adverse health effects occur when there is an imbalance between efforts and occupational rewards. The model also predicts that employees reporting high overcommitment have an elevated risk for experiencing stressful imbalance, which may lead to more health complaints[30–35]. A review of studies on the ERI model has shown that the extrinsic ERI hypothesis has gained considerable support, while the moderating effect of overcommitment on the relation between ERI and employee health has been scarcely examined[36, 37].

With regard to the relationship between neck and/or upper extremity symptoms and job stress, past studies have identified that psychosocial work demands[11, 12, 15, 17], job control[11], social support at work[12, 13], and job strain[10, 14, 16, 19] are potential risk factors for neck and/or upper extremity symptoms, although some studies found no particular associations between the two[9, 10, 18, 20, 21]. Because almost all of these studies are reported from western countries, it is unknown whether such relationship can be also observed in Asian countries especially China. In contrast, fewer researches have examined the relationship between neck and/or upper extremity symptoms and ERI model[23, 24]. Rugulies *et al.*[23] found that ERI is associated with neck injuries in San Francisco transit operators in dependently of individual worker characteristics, physical workload, ergonomic problems, baseline pain and job strain. The study by Krause *et al.*[24] suggests ERI predicts regional upper-extremity pain in computer operators working ≥20 h per week. Only one study has analyzed the effects of physical and psychological factors on WMSDs using both job strain and effort-reward imbalance models simultaneously, which found that ERI ratio was a significant predictor for neck and upper extremity and all injuries[25]. Since both models measure different aspects of psychological factors, incorporating two models into a survey makes it possible to identify which model is more sensitive to WMSDs. Previous studies only have examined the relationship between psychosocial factors at work and each symptom, whether using the combination of symptoms should provide a more complete explanatory power than one symptom alone? This hypothesis hasn't been verified. Thus there is a need for comprehensive research on the relationship between WMSDs and psychological factors at work.

The purpose of the present study was (1) to explore the relationship between the prevalence of neck, shoulder and wrist symptoms and combination of symptoms and psychosocial risk factors at workplace; and (2) to compare the effects of the job strain and ERI models on neck, shoulder and wrist symptoms.

Methods

Subjects

A cross-sectional study was conducted in Henan Province in China. The study protocol was approved by the Medical Ethics Committee of the Henan Provincial Institute of Occupational Health. All subjects came from thirteen factories or companies including a diamond production plant (n=274), a diesel engine plant of a tractor factory (n=771), an electrolyte aluminum plant (n=405), a chemical fiber production factory (n=335), a battery plant (n=264), a high voltage electric equipment factory (n=1,772), an environmental protection equipment factory (n=209), an oil equipment factory (n=200), a garment plant (n=176), a mechanical equipment fabrication plant (n=329), a chemical processing plant (n=181), a refractory plant (n=218) and a train transportation company (n=204). Subjects were drawn from the full range of jobs, including managers (n=164), technicians (n=379), assistant workers (n=265) and blue collar workers (n=4,530). Data were collected between November 2008 and June 2009 anonymously. Each subject received the questionnaire in his/her workplace; they were given 45 min to complete the questionnaire and return it to the researcher after shift in his/her workplace. The questionnaire consisted of four parts and covered the following items: Demographics (including gender, age, weight, height, job tenure, job type,

Table 1. Demographics of study participants by gender

Variables	Male		Female		Total	
	n	%	n	%	n	%
	3,632	68.0	1,706	32.0	5,339	100.0
Educational level						
Elementary	30	0.8	15	0.9	45	0.8
Junior high school	720	19.8	378	22.2	1,098	20.6
High school	2,071	57.0	930	54.5	3,001	56.2
College or University	811	22.3	383	22.5	1,194	22.4
Job title						
Blue collar worker	3,164	87.1	1,366	80.1	4,530	84.9
Assistant worker	161	4.4	104	6.1	265	5.0
Technician	218	6.0	161	9.4	379	7.1
Manager	89	2.4	75	4.4	164	3.1
Age						
17–24	806	22.2	279	16.4	1,085	20.3
25–30	790	21.7	238	14.0	1,028	19.3
31–40	1,298	35.7	695	40.7	1,993	37.3
41–61	738	20.3	494	29.0	1,233	23.1
Years of service						
0.08–5	1,766	48.6	744	43.6	2,510	47.0
6–15	839	23.1	376	22.0	1,215	22.8
16–20	687	18.9	392	23.0	1,079	20.2
21–44	340	6.4	194	11.4	534	10.0
Cigarette smoking						
Yes	1,935	53.3	35	2.1	1,970	36.9
No	1,697	46.7	1,671	97.9	3,368	63.1
Alcohol drinking						
Yes	2,062	56.8	80	4.7	2,142	40.1
No	1,570	43.2	1,626	95.3	3,196	59.9
BMI						
Underweight	140	3.9	174	10.2	314	5.9
Normal	2,138	58.9	1,219	71.5	3,357	62.9
Overweight	1,145	31.5	273	16.0	1,418	26.6
Obese	209	5.8	40	2.3	249	4.7

smoking, alcohol consumption, education, work schedule, health and medical background), musculoskeletal symptoms in the neck, shoulder and wrist regions, physical job characteristics and psychosocial factors at work. Reported symptoms were limited to the past 12 months.

Of the 6711 potentially eligible workers, 5909 (88.1%) agreed to participate. Because 9.6% of the respondents did not provide information about their WMSDs, or they had more than three missing values for psychosocial factors, they were excluded from the analyses, leaving a study population of 5338 subjects. Thus the overall weighted response rate was 79.6%. Table 1 summarizes the characteristics of the participants in the study.

Measurement Methods

Job stress

Psychological demands, physical demands, job control, and the social support dimensions of the job strain model were used in this study[38, 39]. The reliability and validity of the Chinese version of the Job Content Questionnaire have been established[34, 40]. Psychological demands and physical demands were measured with nine items and five items respectively, whereas job control was assessed by ten items and social support was assessed by eleven items. Physical demands items included questions related to the extent of physical effort, lifting heavy loads, rapid physical activity, awkward body position and awkward arm position. An item example is "My job requires lots of physical effort". Answers for each question were "Strongly disagree (1)", "Disagree (2)", "Agree (3)" and "Strongly agree (4)". Cronbach's α coefficient for the psychological demands, physical demands, job control, supervisor social support and coworker social support scales in this sample were 0.60, 0.77, 0.70, 0.62 and 0.65, respectively.

The ERI questionnaire was also used in this study[41]. The reliability and validity of Chinese version of this questionnaire have also been established[34, 40]. It consists of the following three scales: extrinsic efforts (6 items), occupational rewards (11 items), and overcommitment (6 items). Extrinsic efforts were evaluated by measuring the psychosocial workload; occupational rewards focus on the worker's financial status (i.e. salary), self-esteem, and career opportunity (e.g. promotion prospects and job security). Overcommitment as a personal (intrinsic) component was defined as a set of attitudes, behaviors, and emotions reflecting excessive striving along with a strong desire for approval and esteem. Cronbach's α for the effort, rewards, and overcommitment scales in this study were 0.78, 0.58, and 0.64, respectively.

Definition of outcomes

Outcomes were assessed by a questionnaire adapted from the Dutch symptoms questionnaire for the analysis of musculoskeletal symptoms[42]. Symptoms were computed by creating three independent categories corresponding to the number of symptoms. Symptoms included pain and discomfort. "Discomfort" was explained to subjects as being any unpleasant subjective sensation including pain, numbness, soreness, and/or any limitation of physical activity. Answers were yes/no. Subjects who responded affirmatively to one of the following questions were considered to have musculoskeletal symptoms in the neck, shoulders, wrists:

1. "Have you had pain and discomfort in your neck lasting more than 24 h in the past 12 months?"
2. "Have you had pain and discomfort in your shoulders (right or left or both) lasting more than 24 h in the past 12 months?"
3. "Have you had pain and discomfort in your wrists lasting more than 24 h in the past 12 months?"

Potential Confounding Variables

Job Satisfaction

Job satisfaction was measured using the Chinese version of the Occupational Stress Indicator (12 items)[43, 44], including questions related to the job itself, achievement, organizational design and structure, organizational processes and personal relationships. Questions were summed to give a 'total job satisfaction' score with a Cronbach's α of 0.93 in this study.

Depressive symptoms

Depressive symptoms were measured with the Chinese version of the Center for Epidemiological Studies Depression (CES-D) Scale[45]. The CES-D consists of 20 items, and all items were answered on a scale ranging from 0 (Rarely or never) to 3 (Everyday). This scale has been used extensively in China since the 1980's[46]. The Cronbach's α of the CES-D was 0.85 in this study.

Negative affectivity

Negative affectivity was measured by 5 items adopted from the Chinese version of the Occupational Stress Indicator[43] with a Cronbach's α of 0.80 in this study. An item example is "During the past few weeks did you ever feel upset because someone criticized you?"

Individual factors

Individual factors included 1) sex; 2) age (in four categories: 17 to 24 yr, 25 to 30 yr, 31 to 40 yr, and 41 to 61 yr); 3) length of service years (in four categories: 0.08 to 5 yr, 6 to 15 yr, 16 to 20 yr, and 21 to 44 yr); 4) education level (elementary school, junior high school, high school and college or university); 5) job title (blue collar worker, assistant worker, technician, or manager); 6) cigarette smoking (yes, no); 7) alcohol drinking (yes, no); 8) and body mass index (BMI) (underweight: BMI <18.5 kg/m^2, normal:BMI ≥ 18.5 and <24 kg/m^2, overweight: BMI ≥ 24 kg/m^2 and <28 kg/m^2 and obese: BMI ≥ 28 kg/m^2) as recommended by the Ministry of Health of The People's Republic of China in 2003[47].

Physical job characteristics

Physical job characteristics were assessed by a questionnaire adapted from the Dutch musculoskeletal questionnaire[42]. Physical job characteristics included awkward postures and repetitive work of the neck, upper extremities and trunk, heavy lifting, and using vibrating tools and so on. Awkward postures questions included "have to work in a bent/twisted trunk posture for long periods", "have to bent neck forward/backward or twist neck in work", "have to bent/twist wrist", "and have to hold hands above shoulder level" and so on. An example of questions about

Table 2. Prevalence of symptoms by gender

Variables		Male		Female		Total	
		n	%	n	%	n	%
Neck symptoms	yes	1,611	44.4	985	57.7	2,596	48.6
	no	2,021	55.6	721	42.3	2,742	51.4
Shoulder symptoms	yes	1,236	34.0	837	49.1	2,073	38.8
	no	2,396	66.0	869	50.1	3,265	61.2
Wrist symptoms	yes	1,169	32.2	620	36.3	1,789	33.5
	no	2,463	67.8	1,086	63.7	3,549	66.5
One region symptoms		860	25.6	353	20.7	1,213	22.7
Two regions symptoms		735	21.9	437	25.6	1,172	22.0
Three regions symptoms		562	16.7	405	23.7	967	18.1
No symptoms		1,475	43.8	511	30.0	1,986	37.2
Total		3,362		1,706		5,338	

awkward postures is "Do you in your work often have to bent your neck forward or hold your neck in a forward posture for long periods?" Repetitive work questionnaires included "have to make the same movements with arms, hands and fingers many times per minutes", "have to make the same movements (bending and twisting with trunk many times per minute". Heavy lifting questions included "have to lift/push/pull/carry very heavy loads (more than 20 kg) in work". Sedentary work referred to having to sit for long periods in work. Each item was classified into two categories: yes/no.

Statistical analysis

The questionnaires were coded and verified by two researchers. The descriptive analysis of the data included the prevalence of musculoskeletal symptoms. All the psychological factor scale scores were calculated for all subjects who had no more than three missing item values per scale, missing item values were replaced by the mean of the other responses in this scale for the same subject. Internal consistency was analyzed with Cronbach's α coefficients. The continuous measures of the psychological factors were dichotomized, indicating low and high values of exposure. Both job strain and the effort-reward imbalance were computed by creating four independent categories: (1) low demands (effort) and high control (or rewards), (2) high demands (effort) and high control (or rewards), (3) low demands (effort) and low control (or rewards) and (4) high demands (effort) and low control (or rewards).

Correlation between psychosocial factors was calculated by Pearson's product-moment correlation coefficients. Logistic regression analyses were performed to estimate the associations between job strain or effort-reward imbalance and worker's musculoskeletal symptoms. Independent variables included potential confounding factors and psychosocial factors, dependent included neck, shoulder and wrist symptoms. Furthermore, symptoms were computed by creating three independent categories: (1) one region with symptoms; (2) two regions with symptoms and (3) three regions with symptoms, to examine the combined effects. Univariate and multivariate analyses were carried out. The significance level at which variables were entered and removed from the model was set at 5%. The factors that were significantly associated with neck, shoulder and wrist symptoms in the univariate analysis were included only in the multivariate stepwise procedure. Only the final model configuration is presented. The same procedure was also carried out in order to test effects of continuous measures of main dimensions of job strain and ERI model. Adjusted odds ratios (aORs) and 95% confidence intervals (95% CIs) were estimated for each musculoskeletal region. In a subsequent analysis, psychological demands, physical demands, job control, effort, and rewards were simultaneously controlled for each other. All analyses were adjusted for job satisfaction, depressive symptoms and negative affectivity. Because differences between women and men have been reported in the neck, shoulder and wrist symptoms, analyses were stratified by sex. An alpha of 5% was used for all statistical analyses. All analyses were conducted using SPSS 13.0.

Results

Table 2 indicates the prevalence of symptoms by gender. The prevalence of symptoms in the neck, shoulder and wrist regions in females was higher than those in males

Table 3. Correlation matrix for the main dimensions of job strain and ERI model

		1	2	3	4	5	6	7	8	9	
1	Job control		0.78^{b}	–0.09^{b}	0.29^{b}	–0.26^{b}	–0.42^{b}	0.29^{b}	–0.49^{b}	0.43^{b}	9
2	Psychological job demand	–0.14^{b}		–0.14^{b}	0.28^{b}	–0.33^{b}	–0.45^{b}	0.25^{b}	–0.53^{b}	0.38^{b}	8
3	Physical job demand	–0.12^{b}	0.51^{b}		–0.10^{b}	0.24^{b}	0.16^{b}	0.04^{a}	0.18^{b}	0.04^{a}	7
4	Social support	0.34^{b}	–0.19^{b}	–0.09^{b}		–0.15^{b}	–0.41^{b}	0.29^{b}	–0.39^{b}	0.25^{b}	6
5	Supervisor support	0.40^{b}	–0.27^{b}	–0.18^{b}	0.81^{b}		0.46^{b}	–0.12^{b}	0.39^{b}	–0.18^{b}	5
6	Coworker support	0.17^{b}	–0.05^{a}	–0.04	0.82^{b}	0.33^{b}		–0.27^{b}	0.61^{b}	–0.34^{b}	4
7	Effort	–0.08^{b}	0.61^{b}	0.56^{b}	–0.13^{b}	–0.20^{b}	0.01		–0.29^{b}	0.54^{b}	3
8	Reward	0.42^{b}	–0.35^{b}	–0.28^{b}	0.56^{b}	0.57^{b}	0.34^{b}	–0.32^{b}		–0.34^{b}	2
9	Overcommitment	–0.06^{a}	0.46^{b}	0.44^{b}	–0.11^{b}	–0.16^{b}	–0.02	0.58^{b}	–0.29^{b}		1
		9	8	7	6	5	4	3	2	1	

a: $p<0.05$; b: $p<0.01$. The superscript was used for male and a subscript for female.

($p<0.01$).

Table 3 presents a correlation matrix of the main dimensions of job strain and ERI model. A high correlation was found between demands and effort. The negative correlations between overcommitment, effort, and demands on the one hand and rewards on the other confirmed the theoretical assumptions underlying these measures, as did the positive associations between effort, demands, and overcommitment.

Psychological demands and effort were risk factors for neck symptoms, overcommitment was risk factor for neck symptoms in women; psychological demands and effort were risk factors for shoulder symptoms, rewards was risk factor for shoulder symptoms in men and overcommitment was risk factor for shoulder symptoms in women; low job control was risk factor for wrist symptoms in women, effort was risk factor for wrist symptoms in men. More specifically, when the dimensions of the two models were simultaneously controlled, it appeared that effort was the strongest risk factor for neck, shoulder and wrist symptoms except for shoulder and wrist symptoms in women. Continuous job strain and ERI variables also had similar effects (Table 4).

When symptoms were computed by creating three independent categories corresponding to the number of symptoms reported the influence of effort on symptoms increased as the number of symptoms increases in both genders (Table 5).

Table 6 shows results of the logistic regression analyses of the three body region symptoms by job strain and effort-reward imbalance. Job strain was associated with elevated risk for symptoms in three body regions; the risks for females were higher than those for males. To be more specific, for the psychological demands, the risk for symptoms in three body regions for female workers who had both high demands and low control was about 1.50 times as high as that for female workers with low demands and high control (*OR* varied from 1.55 to 1.63). Similar results were found for physical demands. The same pattern of results was found with regard to the four-categorical effort-reward imbalance indicator. This indicator was associated with elevated risks for neck, shoulder, and wrist symptoms. More specifically, the risk for neck symptoms for female workers was about two times as high (OR=1.83).

When symptoms were computed by creating three independent categories, the effects of psychological demands in job strain model in women and effort-reward imbalance on symptoms among both genders were also increased as the number of regions with symptoms increased (Table 7).

Discussion

Neck, shoulder and wrist symptoms prevalence

The results showed that neck, shoulder and wrist symptoms were common among the subjects studied. More than one in three subjects had experienced some form of symptoms during the past 12 months (33.5–48.6%). Neck symptoms were the most prevalent problem among the participants. The results also showed that symptoms among subjects occurred at a high rate in comparison with Chinese offshore oil installation workers (the prevalence of neck, shoulder and wrist symptoms was 25%, 20% and 13.5% respectively)[5]. One interpretation would be that the jobs and activities in these subjects were much as demanding as those in offshore oil installation workers. Furthermore, the subjects in our study might be exposed to high levels of risk factors, particularly physical risks.

Relationship between psychosocial factors and musculo-

Table 4. Adjusted odd ratios (ORs) with 95% confidence intervals (95%CI) for neck, shoulder and wrist symptoms by gender

Variable	Neck symptoms		Shoulder symptoms		Wrist symptoms	
	Men	Women	Men	Women	Men	Women
Job strain model						
Psychological demands	1.31 (1.11–1.53) a	1.60 (1.24–2.07) a	1.32 (1.12–1.55)b	1.36 (1.07–1.73)a	1.14 (0.97–1.35)	1.16 (0.90–1.48)
Physical demands	1.02 (0.86–1.21)	1.25 (0.95–1.64)	1.15 (0.96–1.37)	1.17 (0.91–1.50)	0.92 (0.77–1.10)	1.02 (0.79–1.32)
Job control	0.98 (0.84–1.14)	0.93 (0.73–1.18)	1.15 (0.98–1.35)	1.20 (0.95–1.51)	1.10 (0.94–1.30)	1.37 (1.07–1.75)a
Supervisor social support	1.04 (0.87–1.23)	1.03 (0.79–1.32)	1.04 (0.88–1.23)	0.88 (0.69–1.13)	1.06 (0.88–1.27)	0.91 (0.71–1.18)
Coworker social support	1.12 (0.94–1.34)	1.21 (0.93–1.58)	1.00 (0.84–1.20)	1.11 (0.86–1.43)	0.77 (0.65–0.92)	1.11 (0.85–1.45)
Continuous measures						
Job strain (psychological demands)	1.50 (1.09–2.07)a	3.18 (1.84–5.52)b	1.73 (1.25–2.39)b	1.72 (1.05–2.82)a	1.40 (1.02–1.91)a	2.20 (1.31–3.69)b
Job strain (physical demands)	1.33 (1.01–1.74)a	1.87 (1.21–2.87)b	1.67 (1.27–2.19)b	1.38 (0.92–2.07)	1.37 (1.05–1.80)a	1.56 (1.02–2.40)a
Effort-reward imbalance model						
Effort	1.45 (1.24–1.71)b	1.59 (1.24–2.04) b	1.34 (1.13–1.58)b	1.27 (1.01–1.61)a	1.25 (1.05–1.47)a	1.23 (0.96–1.58)
Reward	1.08 (0.91–1.29)	1.03 (0.81–1.33)	1.20 (1.00–1.44)a	1.02 (0.80–1.30)	1.10 (0.92–1.32)	1.13 (0.87–1.46)
Overcommitment	1.08 (0.92–1.26)	1.47 (1.16–1.87) b	1.07 (0.91–1.26)	1.33 (1.06–1.67)a	1.02 (0.87–1.20)	1.23 (0.97–1.56)
Continuous measures						
ERI	1.85 (1.44–2.39)b	3.86 (2.30–6.48)b	1.66 (1.30–2.12)b	1.82 (1.17–2.81)b	1.29 (1.02–1.23)a	1.56 (1.00–2.42)a
Job strain and ERI model scales analyzed simultaneously						
Job psychological demands	1.17 (0.99–1.39)	1.36 (1.04–1.78)a	1.15 (0.97–1.37)	1.22 (0.95–1.58)	1.06 (0.89–1.27)	1.03 (0.79–1.34)
Physical demands	0.94 (0.79–1.12)	1.11 (0.84–1.47)	1.05 (0.87–1.26)	1.07 (0.83–1.39)	0.87 (0.72–1.04)	0.93 (0.71–1.22)
Job control	1.00 (0.86–1.18)	0.97 (0.76–1.23)	1.10 (0.94–1.30)	1.23 (0.97–1.55)	1.10 (0.94–1.30)	1.39 (1.08–1.77)a
Supervisor social support	1.02 (0.86–1.22)	1.03 (0.79–1.33)	0.90 (0.75–1.09)	0.88 (0.69–1.13)	1.03 (0.85–1.24)	0.89 (0.69–1.17)
Coworker social support	1.13 (0.95–1.35)	1.21 (0.93–1.58)	0.97 (0.81–1.17)	1.11 (0.86–1.44)	0.76 (0.64–0.92)b	1.10 (0.84–1.44)
Effort	1.42 (1.19–1.68)b	1.43 (1.10–1.88)b	1.27 (1.07–1.52)b	1.21 (0.94–1.56)	1.25 (1.04–1.50)a	1.28 (0.98–1.67)
Reward	1.04 (0.86–1.18)	0.98 (0.75–1.27)	1.20 (0.99–1.45)	0.98 (0.76–1.27)	1.14 (0.94–1.38)	1.09 (0.83–1.43)
Overcommitment	1.07 (0.91–1.25)	1.39 (1.09–1.77)b	1.06 (0.90–1.25)	1.29 (1.02–1.62)a	1.03 (0.88–1.22)	1.24 (0.97–1.57)
Continuous measures						
Job strain (psychological demands)	1.17 (0.71–1.95)	2.52 (1.09–5.82)a	1.09 (0.65–1.81)	1.46 (0.70–3.05)	1.07 (0.64–1.78)	2.13 (0.99–4.54)
Job strain (physical demands)	0.92 (0.60–1.40)	0.69 (0.36–1.35)	1.32 (0.86–2.04)	0.91 (0.50–1.65)	1.22 (0.78–1.89)	0.92 (0.50–1.72)
ERI	1.82 (1.37–2.42)b	3.13 (1.76–5.56)b	1.46 (1.11–1.92)b	1.64 (1.00–2.67)a	1.17 (0.90–1.53)	1.22 (0.76–1.98)

Neck symptoms: Adjusted for age, length of experience, educational level, BMI, physical job characteristics, job satisfaction, depressive symptoms, and negative affectivity in both genders, and for job title, smoking and drinking in males. Shoulder symptoms: Adjusted for age, length of experience, BMI, physical job characteristics, job satisfaction, depressive symptoms, and negative affectivity in both genders, for job title and smoking in males, and for educational level in females. Wrist symptoms: Adjusted for length of experience, job title, physical job characteristics, job satisfaction, depressive symptoms, and negative affectivity in both genders, as well as for age and educational level in males, and for BMI in females. a: $p<0.05$; b: $p<0.01$.

skeletal symptoms

Overall, findings in this study support both main hypothesis of the job strain model and ERI model. Both models had independent effects on musculoskeletal symptoms studied. The findings demonstrate associations between job strain or effort-reward imbalance and workers' musculoskeletal symptoms.

Job strain

Statistical analysis revealed that psychological demands were significantly associated with musculoskeletal symptoms in different body regions. This finding is to contrast with the results of some previous studies in which no association was found between perceived psychological demands and reported symptoms[10, 14, 21, 23]. Kerr et al.[48] pointed out that when physical demands were included in a model of musculoskeletal symptoms, the significance of psychological demands would disappear. In our study, the remaining psychological factors in the regression models may indicate the strong influence of these factors on symptom occurrence and imply that the employees studied may be exposed to high levels of psychological demands. It is to be noted that many studies have indicated a significant role of psychosocial factors in the development of neck, shoulder and wrist musculoskeletal symptoms, which is in accord with our findings[6, 7]. In our study, we found only the effect of social support from coworkers on the existence of neck symptoms and job control on wrist symp-

Table 5. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) of neck, shoulder and wrist symptoms by job strain and effort-reward imbalance

	Male			Female		
	One symptom	Two symptoms	Three symptoms	One symptom	Two symptoms	Three symptoms
Job strain (job strain model)						
Psychological demands	1.09 (0.90–1.34)	1.49 (1.20–1.86)[b]	1.36 (1.04–1.76)[a]	1.04 (0.72–1.50)	1.81 (1.26–2.58)[b]	1.61 (1.08–2.40)[a]
Physical demands	1.08 (0.87–1.33)	0.89 (0.70–1.14)	1.10 (0.83–1.47)	1.05 (0.72–1.53)	1.19 (0.81–1.76)	1.15 (0.76–1.72)
Job control	0.96 (0.79–1.16)	1.08 (0.87–1.34)	1.04 (0.80–1.35)	1.47 (1.06–2.03)a	1.07 (0.76–1.50)	1.51 (1.04–2.20)[a]
Supervisor social support	1.03 (0.84–1.27)	1.01 (0.80–1.27)	1.11 (0.82–1.49)	1.40 (1.00–1.96)a	1.09 (0.77–1.54)	0.90 (0.61–1.34)
Coworker social support	1.13 (0.91–1.41)	0.97 (0.77–1.23)	0.89 (0.66–1.19)	1.07 (0.75–1.52)	1.41 (0.97–2.05)	1.24 (0.83–1.86)
Effort-reward imbalance (ERI model)						
Effort	1.26 (1.04–1.54)[a]	1.56 (1.25–1.94)[b]	1.80 (1.37–2.37)[b]	1.01 (0.71–1.45)	1.51 (1.05–2.16)a	1.60 (1.11–2.31)[a]
Reward	0.92 (0.75–1.14)	1.10 (0.87–1.40)	1.40 (1.04–1.89)[a]	1.33 (0.95–1.84)	1.08 (0.76–1.54)	1.00 (0.68–1.46)
Overcommitment	1.07 (0.88–1.30)	1.13 (0.91–1.40)	0.95 (0.72–1.24)	1.26 (0.91–1.74)	1.28 (0.91–1.79)	1.77 (1.24–2.55)[b]
Job strain and ERI model scales analyzed simultaneously						
Psychological demands	1.02 (0.83–1.26)	1.29 (1.02–1.63)a	1.15 (0.87–1.52)	0.97 (0.66–1.42)	1.62 (1.11–2.37)a	1.28 (0.84–1.96)
Physical demands	1.04 (0.84–1.29)	0.81 (0.63–1.04)	0.96 (0.72–1.29)	0.98 (0.66–1.46)	1.11 (0.74–1.65)	0.98 (0.64–1.50)
Job control	0.99 (0.81–1.20)	1.11 (0.89–1.39)	1.04 (0.79–1.35)	1.45 (1.05–2.01)[a]	1.13 (0.80–1.60)	1.59 (1.09–2.33)[a]
Supervisor social support	1.05 (0.85–1.30)	0.99 (0.78–1.26)	1.01 (0.74–1.37)	1.37 (0.97–1.93)	1.09 (0.76–1.56)	0.93 (0.62–1.40)
Coworker social support	1.16 (0.93–1.44)	0.97 (0.77–1.24)	0.84 (0.62–1.14)	1.04 (0.73–1.48)	1.42 (0.97–2.07)	1.21 (0.80–1.82)
Effort	1.26 (1.06–1.55)[a]	1.52 (1.20–1.92)[b]	1.73 (1.29–2.33)[b]	1.05 (0.71–1.54)	1.29 (0.87–1.92)	1.54 (1.04–2.29)[a]
Reward	0.83 (0.71–1.10)	1.08 (0.84–1.40)	1.44 (1.05–1.98)[a]	1.16 (0.82–1.65)	0.94 (0.64–1.36)	0.92 (0.61–1.38)
Overcommitment	1.07 (0.88–1.30)	1.12 (0.90–1.39)	0.94 (0.72–1.23)	1.27 (0.91–1.77)	1.20 (0.85–1.69)	1.74 (1.20–2.52)[b]

Adjusted for individual factors, physical job characteristics, job satisfaction, depressive symptoms, and negative affectivity.
a: $p<0.05$; b: $p<0.01$.

Table 6. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) of neck, shoulder and wrist symptoms by job strain and effort-reward imbalance

	Neck symptoms		Shoulder symptoms		Wrist symptoms	
	Male	Female	Male	Female	Male	Female
Job strain model						
Psychological demads						
Low demands and high control	1.00	1.00	1.00	1.00	1.00	1.00
High demands and high control	1.20 (0.96–1.50)	1.56 (1.07–2.27)[a]	1.21 (0.96–1.52)	1.34 (0.94–1.90)	1.30 (1.03–1.64)[a]	1.29 (0.88–1.88)
Low demands and low control	0.93 (0.77–1.14)	0.92 (0.70–1.21)	1.03 (0.84–1.27)	1.15 (0.87–1.50)	1.22 (0.98–1.50)	1.45 (1.08–1.95)[a]
High demands and low control	1.31 (1.06–1.62)[a]	1.63 (1.16–2.28)[b]	1.40 (1.12–1.74)[b]	1.63 (1.18–2.25)[b]	1.24 (0.99–1.54)	1.55 (1.10–2.17)[a]
Physical demands						
Low demands and high control	1.00	1.00	1.00	1.00	1.00	1.00
High demands and high control	1.01 (0.80–1.27)	1.10 (0.75–1.61)	0.96 (0.76–1.22)	1.14 (0.80–1.63)	0.90 (0.71–1.15)	0.90 (0.62–1.33)
Low demands and low control	0.93 (0.75–1.14)	0.83 (0.62–1.09)	0.89 (0.71–1.11)	1.10 (0.84–1.45)	1.04 (0.83–1.30)	1.23 (0.92–1.66)
High demands and low control	1.11 (0.89–1.39)	1.42 (1.00–2.02)[a]	1.28 (1.02–1.61)[a]	1.50 (1.08–2.09)[a]	1.04 (0.82–1.31)	1.43 (1.01–2.02)[a]
Effort-rewards imbalance model						
Low efforts and high rewards	1.00	1.00	1.00	1.00	1.00	1.00
High efforts and high rewards	1.76 (1.38–2.25)[b]	2.24 (1.52–3.29)[b]	1.58 (1.22–2.04)[b]	1.45 (1.01–2.08)[a]	1.22 (0.94–1.59)	1.35 (0.92–1.99)
Low efforts and low rewards	1.23 (0.98–1.55)	1.20 (0.89–1.61)	1.35 (1.06–1.72)[a]	1.07 (0.79–1.43)	1.08 (0.84–1.38)	1.16 (0.85–1.60)
High efforts and low rewards	1.65 (1.31–2.07)[b]	1.83 (1.31–2.56)[b]	1.69 (1.33–2.15)[b]	1.42 (1.03–1.96)[a]	1.37 (1.08–1.74)[b]	1.49 (1.06–2.09)[a]

Neck symptoms:Adjusted for age, length of service, educational level, BMI, physical job characteristics, job satisfaction, depressive symptoms, and negative affectivity in both genders, and for job title, smoking and drinking in males. Shoulder symptoms: Adjusted for age, length of service, BMI, physical job characteristics, job satisfaction, depressive symptoms, and negative affectivity in both genders, for job title and smoking in males, and for educational level in females. Wrist symptoms: Adjusted for length of service, job title, physical job characteristics, job satisfaction, depressive symptoms, and negative affectivity in both genders, as well as for age and educational level in males, and for BMI in females. a: $p<0.05$; b: $p<0.01$.

Table 7. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) of neck, shoulder and wrist symptoms by job strain and effort-reward imbalance

Variables	Male			Female		
	One symptoms	Two symptoms	Three symptoms	One symptoms	Two symptoms	Three symptoms
Job strain (job strain model)						
Psychological demands						
Low demands and high control	1.00	1.00	1.00	1.00	1.00	1.00
High demands and high control	1.09 (0.82–1.43)	1.35 (1.00–1.83)	1.47 (1.01–2.14)[a]	1.34 (0.78–2.30)	1.75 (1.06–2.89)[a]	1.50 (0.83–2.70)
Low demands and low control	0.96 (0.76–1.21)	1.03 (0.78–1.35)	1.09 (0.77–1.54)	1.69 (1.18–2.43)[b]	1.06 (0.72–1.57)	1.41 (0.92–2.17)
High demands and low control	1.08 (0.83–1.41)	1.58 (1.18–2.11)[b]	1.47 (1.04–2.09)[a]	1.60 (0.98–2.62)	2.11 (1.32–3.37)[b]	2.46 (1.45–4.17)[b]
Physical demands						
Low demands and high control	1.00	1.00	1.00	1.00	1.00	1.00
High demands and high control	0.83 (0.63–1.10)	0.82 (0.60–1.13)	0.90 (0.61–1.34)	0.87 (0.51–1.50)	1.06 (0.63–1.78)	0.95 (0.54–1.67)
Low demands and low control	0.77 (0.60–0.99)[a]	0.92 (0.70–1.22)	0.81 (0.55–1.18)	1.41 (0.98–2.04)	0.97 (0.66–1.43)	1.23 (0.79–1.90)
High demands and low control	1.09 (0.83–1.44)	1.12 (0.82–1.53)	1.19 (0.82–1.75)	1.77 (1.07–2.93)[a]	1.76 (1.06–2.94)[a]	2.07 (1.20–3.56)[b]
Effort-reward imbalance (ERI model)						
Low efforts and high rewards	1.00	1.00	1.00	1.00	1.00	1.00
High efforts and high rewards	1.31 (0.98–1.75)	1.74 (1.25–2.43)[b]	1.91 (1.23–2.96)[b]	1.27 (0.74–2.21)	2.01 (1.18–3.41)[b]	2.09 (1.17–3.74)[a]
Low efforts and low rewards	0.94 (0.73–1.22)	1.17 (0.86–1.60)	1.49 (0.98–2.26)	1.45 (0.99–2.13)	1.20 (0.80–1.82)	1.11 (0.69–1.78)
High efforts and low rewards	1.20 (0.91–1.57)	1.80 (1.32–2.47)[b]	2.54 (1.70–3.81)[b]	1.42 (0.89–2.28)	1.71 (1.05–2.77)[a]	1.85 (1.12–3.06)[a]

Adjusted for individual factors, physical job characteristics, job satisfaction, depressive symptoms, and negative affectivity.
a: $p<0.05$; b: $p<0.01$.

toms, respectively. Previous studies also found inconsistent results about the effects of social support and job control on musculoskeletal symptoms[2, 3, 11, 13, 14, 16, 23, 49]. Association between physical demands and musculoskeletal symptoms were found in our study, although effects of psychological demands were larger than that of physical demands. To our knowledge, this dimension of the job strain model wasn't included in the previous studies. This novel job strain aspect, i.e. the combination of high physical demands with low job control deserves further study and seems a promising way to overcome the academic narrow focus of job stress researchers on psychological demands only although it has been known for some time that both psychological and physical job demands tend to occur together in the real world and that the traditional JCQ questions regarding psychological demands have been interpreted partially as referring physical demands, especially by blue collar workers. In this study, psychological demands was found to related to physical demands (r=0.51). Possible conceptual overlap between the psychological demands and physical demands of the JCD model needs to be explored in further studies.

Our study found that job strain was a work-related predictor for neck, shoulder and wrist symptoms. The combination of high demands and low control, i.e., high job strain, seemed to have more impact on neck/shoulder symptoms than on wrist symptoms except for shoulder symptoms in women.

Effort-reward imbalance

Our study found that workers reporting a mismatch between their efforts and rewards showed even more pronounced risks of neck, shoulder, and wrist symptoms, compared to workers reporting job strain. The present results corroborate earlier findings of these associations[10, 25]. Additionally and importantly, current findings show that high effort and high rewards of effort-reward associations calls for attention. The corresponding odds ratios show differential associations between high effort and high rewards and the neck and shoulder symptoms. The results indicated occupational reward could be more important factor for health effects and preventive measurements of occupational stress than the other dimensions of ERI model. Our finding indicated that overcommitment was related to an increased risk of musculoskeletal symptoms. These findings are in line with the previous results in Asia[33, 34], but contrary to the findings by several western researchers[50–52]. A review by van Vegchel et al.[53] showed that inconsistent results might be due to a different outcome indicator. In addition, cultural factors may contribute to different results.

To our knowledge, this is the first report that using combination of musculoskeletal symptoms. The results showed that the effects of psychological demands on symptoms in women, effort and effort-reward imbalance on symptoms among both genders were increased as the number of regions with symptoms increased. The current study supports the hypothesis which combination of symptoms should provide a more complete explanatory power than one symptom alone.

Model comparison

In order to better guide the psychosocial factors intervention at workplace, we compared the risks of two models and their dimensions on musculoskeletal symptoms. Findings showed that the odds ratios concerning effort-reward imbalance were mostly higher than odds ratios concerning job strain. When dimensions of the two job stress models were simultaneously controlled, effort was the strongest risk factors of neck, shoulder and wrist symptoms. Strikingly, low job control was a lower risk factor; furthermore it didn't enter the equation of neck and shoulder symptoms. This finding is similar to those of several other studies[34, 38, 51, 54], but dependent variables in these studies were cardiovascular disease, injury and mental health. Results indicate that ERI model is more sensitive than the job strain model in identifying psychosocial risk factors of musculoskeletal symptoms. Intervening psychosocial risk factors at workplaces, reducing effort and increasing rewards may be more effective and important than increasing job control in Chinese workplaces. Correlations between dimensions from the two models were found to be low, with the exception of a moderate correlation between psychological demand, physical demand and effort. No overlap between measures of the two models existed in our analyses—that is, the two models represent distinct conceptual and operational approaches, this is consistent with our previous research[34].

Mechanisms that mediate relationships between psychological factors at work and WMSDs were not apparent from this study. But the findings that the impact of psychological demands, effort, and overcommitment on symptoms was increased as the number of body regions with symptoms increased indicated that cumulative psychological stress at work may increase the musculoskeletal symptoms, while it may also be true that these symptoms increase perception of stress.

Limitations of the study

Several limitations of this study need to be taken into account. First, the study design was cross-sectional, making it possible to identify only associations, but not causal relationships. A possible selection bias from the healthy worker effect cannot be excluded. Since the analysis was limited to currently working employees, workers who had left jobs or were limiting their work due to musculoskeletal symptoms may have been excluded from the study and the healthy worker effect might occur. Thus, the data may underestimate reported symptoms and the association of perceived demands with musculoskeletal symptoms. Second, because the alpha value for rewards was rather low, associations between variables might be underestimated and the amount of explained variance could be reduced. Third, the variables were measured by self-reports, which can lead to inflated correlations attributed to common method variance (i.e., variance that is attributable to the measurement method rather than to the constructs the measures represent)[55]. Musculoskeletal symptoms and job stress were estimated by self-report, which may introduce recall/ reporting bias. Measuring job stress by self-report may cause workers with symptoms to estimate their job stress scores higher than those without symptoms. In this study, however, by limiting the recall period for reported symptoms to the past 12 months, the time over which data needed to be recalled was restricted. Fourth, because of the reduced power of analyses using dichotomous variables compared with analyses using continuous measures, a reduction of variance could occur in the associated findings. Fifth, although our sample was of a large size, the participants came from workers in thirteen factories, and wasn't representative of the various sectors of the Chinese workforce. The present findings should be replicated in various occupational settings and populations to examine the influence of possible selection biases and to generalize the present findings.

This study also has a number of strengths. It was conducted in a large sample of women and men from thirteen factories. The response rate is reasonably high (79.6%). Psychosocial factors at work were evaluated with a validated Chinese version of the Karasek Job Content Questionnaire and the Effort-Reward Imbalance questionnaire[34, 40]. The measurement of neck, shoulder and wrist symptoms was done with a previously validated instrument[56]. A large number of potential confounders including negative affectivity, job dissatisfaction and depression symptoms were taken into account.

In conclusion, despite the fact that job stress and musculoskeletal symptoms were assessed by self-report, as well as other limitations, the present study showed that the findings add to accumulating evidence of adverse effects on musculoskeletal symptoms produced by job strain and effort-reward imbalance. The predictive power of the effort/reward imbalance model was greater than that of the demand-control model for symptoms in three body regions. Our study gained some important new findings, i.e. the new constellations of two models (high physical demands/low job control, and high efforts/high rewards) were associated with elevated risks of neck, shoulder, and wrist symptoms. This result should be replicated in prospective studies and in other populations.

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