Job Stress and Work-Related Musculoskeletal Symptoms Among Intensive Care Unit Nurses: A Comparison Between Job Demand-Control and Effort-Reward Imbalance Models

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Background *The aims of this study were to compare job demand-control (JDC) and effort-reward imbalance (ERI) models in examining the association of job stress with work-related musculoskeletal symptoms and to evaluate the utility of a combined model.*
Methods *This study analyzed cross-sectional survey data obtained from a nationwide random sample of 304 intensive-care unit (ICU) nurses. Demographic and job factors were controlled in the analyses using logistic regression.*
Results *Both JDC and ERI variables had strong and statistically significant associations with work-related musculoskeletal symptoms. Effort-reward imbalance had stronger associations than job strain or iso-strain with musculoskeletal symptoms. Effort-reward imbalance alone showed similar or stronger associations with muscusloskeletal symptoms compared to combined variables of the JDC and ERI models.*
Conclusions *The ERI model appears to capture the magnitude of the musculoskeletal health risk among nurses associated with job stress at least as well and possibly better than the JDC model. Our findings suggest that combining the two models provides little gain compared to using effort-reward imbalance only.* Am. J. Ind. Med. 57:214–221, 2014.
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KEY WORDS: job stress; job strain; effort-reward imbalance; musculoskeletal symptom; nurses

INTRODUCTION

Epidemiological studies have shown that job stress is associated with increased risks of musculoskeletal injuries or symptoms [Bernard, 1997; Joksimovic et al., 2002; Gillen et al., 2007; Burgel et al., 2010; Eatough et al., 2012; Yu et al., 2012]. In measuring job stress, the job demand-control (JDC) model [Karasek et al., 1998] and the effort-reward imbalance (ERI) model [Siegrist, 1996] have been widely used as theoretical models, with derived measurement tools. Two compelling models, however, raise a question to researchers: which model should be selected to better assess job stress in the study population of interest, or is it preferable to use both models to measure job stress more comprehensively?

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The JDC model defines job stress with task-level work characteristics of psychological job demands and job control which reflects the levels of skill discretion and decision authority [Karasek et al., 1998]. High job strain is produced through high job demands combined with low job control. Social support at work from both supervisors and coworkers has been added to the JDC model as a buffer against job strain [Johnson and Hall, 1988]; this three-dimensional version is called the iso-strain model.

The ERI model is based on social exchange theory and defines job stress in a broader sociological context including employment conditions and job prospects [Siegrist, 1996]. Putting in high effort but receiving low reward in terms of money, esteem, job security and career opportunities triggers job stress. The ERI model also includes a third component, overcommitment, which reflects excessive personal dedication to work as a coping style and also difficulty unwinding from work. Overcommitment was originally proposed as an intrinsic personal characteristic, but it may be also viewed as the outcome of a stressful work environment and employment conditions. Overcommitment is proposed to increase job stress through interaction with the imbalance between effort and reward [Siegrist et al., 2004].

The two models overlap in concepts with regard to job demand and effort, and incorporate these concepts with different aspects of psychosocial work environments. Given their differences, some studies used both models to examine their effects on health outcomes independently [Bosma et al., 1998; de Jonge et al., 2000; Li et al., 2006; Niedhammer et al., 2006; Ota et al., 2009; Chen et al., 2011; Maina et al., 2011]. For musculoskeletal outcomes, two studies found that only ERI was significantly associated with musculoskeletal symptoms, specifically with neck or upper extremity injuries among hospital workers [Gillen et al., 2007] and shoulder pain among hotel room cleaners [Burgel et al., 2010]. Another study of Chinese workers in various types of factories found significant associations of both models with musculoskeletal symptoms, but overall, the associations were stronger with the ERI model [Yu et al., 2012]. From these studies, it appears that the ERI model may better capture job stress factors associated with musculoskeletal outcomes.

Combined effects of the two models have also been examined in some studies. Dragano et al. [2008] found that ERI and overcommitment each combined with low job control were significantly associated with depressive symptoms among the general working population and also a significant synergistic interaction between overcommitment and job control. Ostry et al. [2003] also examined the combination of ERI and job control and reported that the combined model had better explanatory power than each model alone for self-reported health status and chronic health conditions. Three other studies examined the combination of ERI and job strain and found increases in the strength of association with cardiovascular diseases [Peter et al., 2002; Xu et al., 2011] or self-reported poor health among nursing workers [Griep et al., 2011]. On the other hand, Calnan et al. [2004] reported that combining dimensions of the two models had no stronger explanatory power than the ERI model alone and concluded that there is little benefit in combining the two models.

Given the limited investigations and inconsistent observations, the evidence is inconclusive regarding the utility of complementary use of the JDC and ERI models. Due to practical limitations of survey length, researchers have to decide which job stress constructs to select for their investigations. To our knowledge, the effect of a combined model has never been examined for musculoskeletal disorders and few studies have assessed both models simultaneously for comparison. The purpose of this study was to compare the JDC and ERI models in examining the association of job stress with work-related musculoskeletal symptoms among nurses and evaluate the utility of a combined model.

METHODS

Sample

This analysis used data from a cross-sectional study of critical-care nurses conducted in 2006 [Lee et al., 2010]. The study questionnaires were mailed to a random sample of 1,000 nurses selected from the American Association of Critical-Care Nurses (AACN) membership list. The sampling was conducted within selected categories of the AACN membership list so that the sample could include mostly nurses who were currently employed in hospitals and were likely to perform patient handling tasks. Completed surveys were received from 412 AACN members consisting of intensive care unit (ICU) nurses ($n = 318$), nurses working in other units ($n = 89$), those not employed in hospital settings ($n = 18$), and those not currently employed as nurses ($n = 5$). This study restricted data analysis to ICU nurses. We excluded non-ICU nurses because the small group of non-ICU nurses with the AACN membership is not likely to be representative of nurses in non-critical care settings. Moreover, ICU nurses serve as a more homogeneous sample. Of 318 ICU nurse respondents, 14 cases were excluded in the analysis because musculoskeletal symptom outcome data were missing. This secondary data analysis, which used de-identified data, received an exemption of review by the Committee on Human Research at the University of California, San Francisco.

Variables and Measures

Job stress variables included psychological job demands (five items), job control (nine items), and social support (eight items) measured by the job content questionnaire (JCQ) [Karasek et al., 1998] and effort (six items), reward (11 items), and overcommitment (six items) measured by the ERI questionnaire [Siegrist et al., 2004]. The scale items are provided in Appendix. The JCQ used a 4-point Likert scale (1 = strongly agree to 4 = strongly disagree); the ERI questionnaire used a 5-point scale for effort and reward (1 indicating no stressful experience to 5 = very distressed) and a 4-point Likert scale (1 = strongly agree to 4 = strongly disagree) for overcommitment. Reliability as measured by Cronbach's alpha coefficients was acceptable in our sample for job demands (0.76), job control (0.70), social support (0.85), effort (0.80), rewards (0.81), and overcommitment (0.78). Three summary variables were derived according to the JDC and ERI models. *Job strain* was calculated as the ratio of job demands to job control and *iso-strain* was calculated by dividing job demands by the sum of job control and social support [Burgel et al., 2010]. *ERI ratio* was calculated by dividing effort by reward multiplied by 0.5455 to correct for the item number difference in the two scales [Siegrist et al., 2004].

Musculoskeletal symptoms in the low back, neck, or shoulders were assessed by the question "During the past 12 months, did you have pain, aching, stiffness, burning, numbness, or tingling in the area shown on the diagram?" [Trinkoff et al., 2002] For low back pain, we included radiating pain in the question and asked about "pain, aching, stiffness, burning, numbness, or tingling in the low back area or pain radiating into your leg." Work-relatedness was assessed by two questions: "Do you think the problem was (a) caused by work? (b) made worse by working?" Yes on either or both questions were defined as work-related symptoms. This interpretation was based on the definition by the Occupational Safety and Health Administration [2001].

For covariates, we screened individual, employment and workplace factors and physical workload, reflecting the multifactorial etiology of musculoskeletal disorders [National Research Council and Institute of Medicine, 2001]. Specific items included age, gender, race, marital status, education, body mass index, years worked as a nurse, job title, work schedule, work status, work hours per shift, type of hospital, and availability of lifting devices on the unit. Physical workload was measured by the 19-item Physical Workload Index Questionnaire that assessed the frequency of body postures and lifting, pushing, pulling, or carrying of loads during a work day using a 5-point scale (1 = never to 5 = very often) [Hollmann et al., 1999]. The physical workload index represents the cumulative load on the spine. A higher index indicates higher physical workload. The questionnaire was validated by the developer and Cronbach's alpha coefficient was 0.82 in our sample.

Statistical Analysis

Data analyses were conducted using SPSS 17.0 (SPSS, Inc., Chicago, IL). For job stress variables using multi-item measures, missing data were substituted by the case mean of each measure when at least 75% of items were answered. Missing values were not substituted for other covariates. Chi-square tests for categorical variables and Student's *t*-tests for continuous variables were used to examine statistical differences in study variables between those with musculoskeletal symptoms and those without symptoms. The associations of job stress variables with work-related musculoskeletal symptoms were examined by logistic regression analysis. Job stress variables were categorized by tertiles to examine independent effects and also dichotomized at the most adverse tertile (e.g., highest tertile for demands and effort and lowest tertile for control and reward) to create combined variables [Calnan et al., 2004; de Jonge et al., 2000]. Combined variables had three categories (e.g., both high ERI and high job strain, either high ERI or high job strain, both low ERI and low job strain). As job demands and effort were considered similar constructs, this study excluded the combination of these two variables in the examination of combined effects. All covariates were examined for confounding with three independent variables of job strain, iso-strain, and ERI ratio. A covariate was defined as a confounder if at least a 10% change in effect size was observed in any of the analyses when it was removed from the initial analysis including all covariates. Our final multivariable analyses included age and sex *a priori*, covariates identified as confounders, and variables that had $P < 0.05$ in bivariate analyses. Job tenure was excluded because of multicollinearity with age (correlation $r = 0.80$) and in order to avoid overadjustment for cumulative occupational exposure indicated by length of employment. Statistical significance was set at $P < 0.05$. Odds ratios (OR) and 95% confidence intervals (CI) were obtained.

RESULTS

Sample Characteristics

The study sample included 304 ICU nurses. Of these, 92% were female, 84% were White, 71% received bachelor or higher education, 67% were staff nurses, 76% worked full time, 56% worked day shifts, and 54% worked in non-profit community hospitals. The mean age was 46.7 years and the mean job tenure in nursing was 21.8 years. ICU nurses in this study were not significantly different from the AACN population in sex, race, and education; however, this study sample included significantly higher proportions of staff nurses and nurses 50 years or older. Table I presents the sample characteristics by work-related musculoskeletal symptom experience.

Associations of JDC and ERI Variables With Musculoskeletal Symptoms

Table II presents the associations of JDC and ERI model variables with work-related musculoskeletal symptoms,

TABLE I. Study Sample Characteristics by Work-Related Musculoskeletal Symptoms

Variable	Total (n = 304)[a] n (%) or mean ± SD	Work-related symptoms Yes (n = 219)	No (n = 85)	*P*-value
Individual factors				
Age (year)	46.7 ± 8.7	46.6 ± 8.5	46.9 ± 9.3	0.794
Sex (female)	278 (92)	204 (93)	74 (89)	0.252
Race (White)	253 (84)	193 (89)	60 (71)	0.000
Marital status (married)	222 (73)	157 (72)	65 (77)	0.431
Education				
Diploma/associate	88 (29)	66 (30)	22 (26)	0.727
Bachelor	172 (56)	121 (55)	51 (60)	
Master/doctoral	44 (15)	32 (15)	12 (14)	
BMI (kg/m^2)	26.7 ± 5.8	26.9 ± 5.8	26.3 ± 5.9	0.444
Employment/workplace factors				
Years worked as a nurse	21.8 ± 9.2	21.7 ± 9.0	22.0 ± 9.8	0.802
Hours worked per shift	11.6 ± 1.8	11.7 ± 1.8	11.4 ± 1.9	0.359
Job title				
Staff nurse	205 (67)	156 (71)	49 (58)	0.025
Charge nurse	38 (13)	25 (11)	13 (15)	
Both staff and other role	43 (14)	30 (14)	13 (15)	
Manager or other	18 (6)	8 (4)	10 (12)	
Work schedule				
Day	171 (56)	133 (61)	38 (45)	0.042
Evening	14 (5)	9 (4)	5 (6)	
Nights	85 (28)	52 (24)	33 (39)	
Rotating	33 (11)	24 (11)	9 (11)	
Work status (full time)	231 (76)	168 (77)	63 (75)	0.754
Types of hospital				
Non-profit community hospital	163 (54)	124 (57)	39 (46)	0.345
Profit community hospital	48 (16)	33 (15)	15 (18)	
University medical center	57 (19)	37 (17)	20 (24)	
Other	34 (11)	23 (11)	11 (13)	
Lift devices on the unit (yes)	155 (51)	107 (49)	42 (49)	0.931
Physical work factor				
Physical workload index (0–56.2)	29.8 ± 11.2	31.6 ± 10.2	25.2 ± 12.2	0.000
Psychosocial work factors				
Job demands (12–48)	37.1 ± 5.7	38.2 ± 5.6	34.1 ± 5.0	0.000
Job control (24–96)	74.1 ± 8.7	73.9 ± 8.2	74.7 ± 9.7	0.474
Social support (8–32)	23.7 ± 3.7	23.6 ± 3.9	23.9 ± 3.4	0.541
Effort (6–30)	15.9 ± 4.8	16.9 ± 4.6	13.3 ± 4.5	0.000
Reward (11–55)	48.5 ± 7.1	47.7 ± 7.7	50.6 ± 4.8	0.002
Overcommitment (6–24)	13.1 ± 3.1	13.6 ± 3.1	11.8 ± 2.9	0.000
Job strain (0.125–2.0)	0.51 ± 0.10	0.52 ± 0.10	0.46 ± 0.09	0.000
Iso-strain (0.094–1.5)	0.38 ± 0.08	0.40 ± 0.08	0.35 ± 0.07	0.000
Effort-reward imbalance (0.2–5.0)	0.64 ± 0.33	0.69 ± 0.35	0.49 ± 0.19	0.000

Numbers in parentheses indicate the full possible range of the scale score.
[a]Sample sizes for variables vary due to missing data (up to missing n = 21).

TABLE II. Associations of Job Stress Model Variables With Work-Related Musculoskeletal Symptoms Among Intensive Care Unit Nurses

Variable	Total N	Work-related symptoms	
		OR	95% CI
Job Demand-Control Model			
Demands			
Low	114	1.00	
Intermediate	101	2.37*	1.20–4.69
High	85	5.53***	2.26–13.6
Control			
Low	83	0.96	0.47–1.96
Intermediate	110	1.03	0.52–2.04
High	110	1.00	
Social support			
Low	98	0.94	0.43–2.06
Intermediate	107	0.38*	0.18–0.80
High	95	1.00	
Job strain			
Low	101	1.00	
Intermediate	101	2.32*	1.17–4.59
High	98	3.35**	1.54–7.27
Iso-strain			
Low	101	1.00	
Intermediate	100	1.46	0.76–2.83
High	98	3.55**	1.59–7.96
Effort-Reward Imbalance Model			
Effort			
Low	96	1.00	
Intermediate	109	2.87**	1.40–5.85
High	81	3.80**	1.60–9.04
Reward			
Low	85	1.68	0.79–3.60
Intermediate	100	1.11	0.58–2.15
High	108	1.00	
Overcommitment			
Low	135	1.00	
Intermediate	78	1.98	0.98–4.00
High	90	4.30***	1.96–9.43
Effort-reward imbalance			
Low	89	1.00	
Intermediate	98	1.86	0.90–3.85
High	96	5.41***	2.23–13.1

Multivariable analysis adjusted for age, sex, race, full-time status, job title, shift, work hours per shift, and physical workload (Due to missing data, sample sizes varied between 262 and 281).
*$P < 0.05$,
**$P < 0.01$,
***$P < 0.001$.

controlled for age, sex, race, job title, full-time status, shift, work hours, and physical workload. All variables except for job control and reward showed statistically significant elevated odds of musculoskeletal symtpoms in at least one of the tertile categories. Job demands (highest tertile) alone showed the strongest association with musculoskeletal symptoms (OR = 5.53, 95% CI 2.26–13.6) that was comparable to that of ERI (OR = 5.41, 95% CI 2.23–13.1). ERI had stronger associations with musculoskeletal symptoms than job strain and iso-strain. Confidence intervals, however, overlapped between all these measures. The odds of reporting work-related musculoskeletal symptoms was five times higher in nurses experiencing high ERI (highest tertile) than nurses experiencing low ERI (lowest tertile) and three times higher in nurses experiencing high job strain or iso-strain than nurses experiencing low strain.

Associations of Combined JDC and ERI Variables With Musculoskeletal Symptoms

Table III provides multivariable model findings of combined dimensions from the two models. All combined variables examined showed significant ORs for musculoskeletal symptoms in at least one category. All three variables of job strain, iso-strain, and ERI showed stronger associations when combined with high overcommitment than any other combinations with complementary dimensions; however, the ORs of such combinations (max 4.84) were not greater than the OR of high ERI alone (max 5.41). The OR of the combination of ERI and job strain (max 5.05) was not greater than the OR of high ERI alone.

DISCUSSION

This study compared the JDC and ERI models and their combined variables in the associations with work-related musculoskeletal symptoms among ICU nurses. In the evaluation of each model variables, job strain and ERI showed significant associations with musculoskeletalsymptoms, after adjustment for a comprehensive set of covariates including demographic and job factors. Between the two models, ERI showed stronger associations with musculoskeletal symptoms, but confidence intervals of all measures overlapped widely. Combined JDC and ERI variables showed signficiant associations with musculoskeletal symptoms, but we did not find a distinct benefit of combining the two models.

Our findings show that both JDC and ERI models are useful in examining risk of job stress associated with musculoskeletal disorders; but also suggest that the ERI model may be better than the JDC model in capturing musculoskeletal health risks associated with job stress among

TABLE III. Associations of Combined Variables of Job Stress Models With Work-Related Musculoskeletal Symptoms Among Intensive Care Unit Nurses

Variable	Total N	Work-related symptoms OR	95% CI
Job strain × Reward			
Both low strain and high reward	161	1.00	
Either high strain or low reward only	75	2.53*	1.20–5.31
Both high strain and low reward	54	2.05	0.84–5.05
Job strain × Overcommitment (OC)			
Both low strain and low OC	159	1.00	
Either high strain or high OC only	95	4.29***	2.02–9.13
Both high strain and high OC	46	2.99*	1.11–8.01
Iso-strain × Reward			
Both low iso-strain and high reward	165	1.00	
Either high iso-strain or low reward only	67	2.50*	1.15–5.42
Both high iso-strain and low reward	57	2.51*	1.02–6.14
Iso-strain × OC			
Both low iso-strain and low OC	161	1.00	
Either high iso-strain or high OC only	90	4.84***	2.19–10.7
Both high iso-strain and high OC	48	3.63*	1.36–9.72
Effort-reward imbalance (ERI) × OC			
Both low ERI and low OC	154	1.00	
Either high ERI or high OC only	78	4.67***	2.02–10.8
Both high ERI and high OC	50	4.12**	1.53–11.1
ERI × Control			
Both low ERI and high control	142	1.00	
Either high ERI or low control only	106	1.96*	1.01–3.77
Both high ERI and low control	34	3.76*	1.03–13.7
ERI × Social support			
Both low ERI and high support	148	1.00	
Either high ERI or low support only	77	1.57	0.80–3.10
Both high ERI and low support	55	4.00**	1.41–11.3
Job Strain × ERI			
Both low strain and low ERI	157	1.00	
Either high strain or high ERI only	56	2.04	0.92–4.54
Both high strain and high ERI	67	5.05**	1.80–14.2

Multivariable analysis adjusted for age, sex, race, full-time status, job title, shift, work hours per shift, and physical workload (Due to missing data, sample sizes varied between 260 and 278).
*$P < 0.05$,
**$P < 0.01$,
***$P < 0.001$.

ICU nurses. We found a strong association of job demands of the JDC model with musculoskeletal symptoms, but in comparisons of the composite job stress variable proposed by each model, ERI demonstrated a stronger association than job strain or iso-strain. This finding is in line with the reports of other studies on musculoskeletal disorders [Gillen et al., 2007; Burgel et al., 2010; Yu et al., 2012] and other physical and mental health outcomes [Bosma et al., 1998; de Jonge et al., 2000; Calnan et al., 2004; Li et al., 2006; Dragano et al., 2008; Maina et al., 2011; Xu et al., 2011; Wang et al., 2012]. It has been suggested that the ERI model has more explanatory power than the JDC model for service, professional, or managerial occupations [Calnan et al., 2004; Li et al., 2006]. Our study of ICU nurses supports this notion.

In our study, combined variables of JDC and ERI complementary dimensions, in general, did not have stronger associations than ERI alone with musculoskeletal symptoms among ICU nurses. Our findings are consistent with the findings by Calnan et al. [2004]. The combination of ERI and job strain showed a similar effect size to using ERI alone. Two other studies found improvements in risk estimation for cardiovascular diseases by the combined measure of job strain and ERI [Peter et al., 2002; Xu et al., 2011]. In the study by Peter et al. [2002], the combined effect of ERI and job strain on myocardial infarction showed greater ORs (up to 28%) than using ERI alone in men although the combined effect was not significant among women. In the study by Xu et al. [2011], the combined measure showed up to 2.4 times greater ORs than ERI alone for coronary heart diseases. With respect to ERI and overcommitment, our study findings suggest that the benefit of combining ERI and overcommitment is equivocal compared to using ERI alone for musculoskeletal health risk. Unlike our findings, two other studies reported significant interaction effects between ERI and overcommitment on employee well-being or mental health [de Jonge et al., 2000; Li et al., 2012].

Study findings should be interpreted cautiously due to the following limitations. First, causal relationships cannot be established with cross-sectional study designs. While work stress may increase the risk of musculoskeletal symptoms, having symptoms, especially if perceived as work-related, may also increase the likelihood of self-reporting of increased job stress. Our study cannot exclude reverse causation; however, other prospective studies have provided evidence of causal effects of job stress factors on musculoskeletal disorders [Rugulies and Krause, 2008; Krause et al., 2010; Kraatz et al., 2013]. Second, the relatively small sample size, low response rate (42%), and potential selection bias might also limit the validity and generalizability of the study findings. Third, this study relied on self-report measures for both exposures and outcomes. Common method variance may lead to bias inflating correlations between these variables. We did not assess common method bias, but some studies suggested that common method variance did not play a major role in the associations between job stress and health symtpoms [Dragano et al., 2008; Krause et al., 2010]. Another concern may be raised on our analytic approach that did not adjust for multiple comparisons. Multiple comparisons can inflate Type I error, but making adjustments to reduce Type I error increases Type II error. Several researchers do not recommend such adjustment for multiple comparisons that are based on the universal null hypothesis paradigm and may nullify meaningful results and may lead to incorrect conclusions [Rothman, 1990; Savitz and Olshan, 1995; Perneger, 1998]. In particular, this study was to compare two job stress models and to explore combined effects in their associations with musculoskeletal symptoms rather than to confirm relationships between variables. In addition, observed effect sizes in this study were often substantial. This may counterbalance the concern of Type I error inflation.

CONCLUSIONS

The JDC and ERI models have provided researchers with useful theoretical and methodological tools. Evaluation of the independent effect of each job stress domain can help identify the root cause of the problem and to design an intervention program while evalution of the combined effects of complementary components can help understanding of the aggregate impact of job stress on health. Based on our findings, the ERI model appears to capture at least as well and possibly better than the JDC model the magnitude of the association of job stress with musculoskeletal health risk among ICU nurses. Compared to using ERI alone, combining complementary variables from the two models did not have stronger associations with work-related musculoskeletal symptoms among ICU nurses and therefore, the combined model appears to provide little gain. Our findings are consistent with the conclusion by Calnan et al. [2004]. Using the ERI model alone can be an efficient and practical choice to measure job stress in studies of musculoskeletal disorders. Also, the single composite variable of ERI is considered a parsimonious measure with good predictive power in occupational health research, particularly when the main interest is the adverse health impact of job stress. Future research, especially using a prospective design, is recommended to validate the utility of ERI and JCQ instruments and their combinations.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article.