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Effort–reward imbalance and one-year change in neck–shoulder and upper-extremity pain among call center computer operators

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Objective The literature on psychosocial job factors and musculoskeletal pain is inconclusive in part due to insufficient control for confounding by biomechanical factors. The aim of this study was to investigate prospectively the independent effects of effort–reward imbalance (ERI) at work on regional musculoskeletal pain of the neck and upper extremities of call center operators after controlling for (i) duration of computer use both at work and at home, (ii) ergonomic workstation design, (iii) physical activities during leisure time, and (iv) other individual worker characteristics.

Methods This was a one-year prospective study among 165 call center operators who participated in a randomized ergonomic intervention trial that has been described previously. Over an approximate four-week period, we measured ERI and 28 potential confounders via a questionnaire at baseline. Regional upper-body pain and computer use was measured by weekly surveys for up to 12 months following the implementation of ergonomic interventions. Regional pain change scores were calculated as the difference between average weekly pain scores pre- and post intervention.

Results A significant relationship was found between high average ERI ratios and one-year increases in right upper-extremity pain after adjustment for pre-intervention regional mean pain score, current and past physical workload, ergonomic workstation design, and anthropometric, sociodemographic, and behavioral risk factors. No significant associations were found with change in neck–shoulder or left upper-extremity pain.

Conclusions This study suggests that ERI predicts regional upper-extremity pain in computer operators working ≥20 hours per week. Control for physical workload and ergonomic workstation design was essential for identifying ERI as a risk factor.

Key terms ERI; job stress; musculoskeletal disorder; MSD; occupational epidemiology; prospective study; video display terminal; video display unit.

It is a widely shared concept in occupational epidemiology that musculoskeletal disorders have a multifactorial etiology, involving exposure to both physical and psychosocial working conditions (1–4). Empirical evidence for a causal role of psychosocial working conditions, however, is inconclusive. Until a few years ago, this research area was characterized by an overreliance on cross-sectional studies (5, 6). In recent years, a considerable number of new longitudinal studies have been conducted, but the findings have been inconsistent. A review covering 18 longitudinal studies on psychosocial workplace factors and low-back pain found "insufficient evidence for an association between stress at work and low-back pain" (5, p 9). A review that analyzed 19 studies on psychosocial workplace factors and neck–shoulder symptoms concluded that "this relationship is neither very strong nor very specific" (6, p 290). The two reviews criticized that many studies have not sufficiently controlled for exposure to high physical workload and ergonomic problems (7, 8). Finally, it is notable, that many studies defined psychosocial working conditions based on the demand–control (job strain) model (9) or its expansion, the demand–control–support model (10), and that there is a lack of research on alternative theoretical models of psychosocial workplace stressors.

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Effort–reward imbalance model

In recent years, the model of effort–reward imbalance (ERI) at work has emerged as a new theoretical approach for conceptualizing health-hazardous psychosocial working conditions. The model posits that a "high cost–low gain" situation at work, in which individuals spend high efforts while receiving low rewards (in terms of monetary gratification, career opportunities, esteem, respect, and job security), elicits severe psychological distress that consequently affects both mental and physical health (11–14). It is further assumed in the model that ERI has, in particular, adverse health consequences when it co-occurs with "over-commitment (intrinsic effort)". Over-commitment is conceptualized as a personal disposition that motivates people to spend high efforts even in a situation where the chance for a reward is low.

The ERI model has been tested most intensively in cardiovascular research, where it has been found to be associated with incident cardiovascular events in longitudinal studies (15). For other health outcomes, the empirical evidence has been less comprehensive (for reviews see 13 and 14) although there is increasing evidence that ERI might predict the onset of common mental disorders (16, 17).

The vast majority of research studies on ERI and health endpoints have been conducted in Europe, and there are very few studies that have tested this model in the United States. Burgel et al (18) found that ERI was associated cross-sectionally with severe shoulder pain in hotel room cleaners. Gillen et al (19) found that it was associated with a risk of neck and upper-extremity injury claims in a case-control study among hospital workers in San Francisco, USA. Rugulies & Krause (20) reported that ERI predicted compensated low-back and neck injuries in a 7.5-year prospective study of urban transit operators in San Francisco. However, to our knowledge, there are no published studies in the US that have investigated the health effects of ERI on upper-body, regional pain among computer operators in the rapidly growing call center industry.

Call center work

Computer-based customer service work, or call center work, is one of the most rapidly growing occupations in the world (21). The work involves the simultaneous use of a telephone and computer for activities such as airline reservations, banking, sales, insurance, scheduling, billing, and health-related services. Musculoskeletal disorders of the upper extremities and neck are the most common occupational health problem associated with this type of work and account for the majority of work-related lost time (21, 22). Sustained pain in the upper-extremity and neck regions and specific musculoskeletal disorders (such as wrist tendonitis, epicondylitis and trapezius muscle strain) are elevated among computer users. The most consistently observed risk factors are increasing hours of mouse or keyboard use and sustained awkward postures, such as increasing wrist extension and keyboard-above-elbow height (23–28). Other important risk factors include being female and work organizational factors (eg, high work load, low job control) (29, 30). The association of carpal tunnel syndrome with keyboard use is weak, but there is some evidence of increased risk with increasing hours of computer mouse use (31, 32). A randomized controlled study of ergonomic workplace interventions showed a protective effect of forearm support boards for neck–shoulder disorders and a reduction of neck–shoulder and right upper-extremity pain in call center employees after control for psychosocial job factors, individual worker characteristics, medical history, and other confounding factors (33).

Study aims

The aim of this study was to investigate prospectively the independent effects of ERI at work on regional musculoskeletal pain of the neck and upper extremities of call center operators after controlling for (i) physical workload, (ii) leisure-time computer use, (iii) ergonomic workstation design, and (iv) individual worker characteristics.

Methods

Study design and population

This was a one-year prospective study of ERI and upper-body musculoskeletal pain among 165 call center operators who participated in a randomized ergonomic intervention trial with four treatment channels described previously (33). Employees at two customer service center sites of a large health maintenance organization (HMO) in California were eligible for participation if they performed computer-based customer service work for ≥20 hours per week and did not have an active workers' compensation claim involving the neck, shoulders, or upper extremities. At on-site recruitment meetings, between June 2001 and May 2002, the study was explained, and interested employees who met the initial eligibility criteria signed a consent form (N=269). These potential participants filled out a self-administered baseline questionnaire and then, on a weekly basis, completed a one-page questionnaire which assessed pain severity. Employees who completed at least four weekly surveys were eligible for participation in the study (N=182). Participants were randomized to receive one of four interventions; the randomization was done by means of a computer-generated permuted-block sequence and administered by a research associate. The four workplace interventions were: (i) ergonomics training, (ii) trackball and ergonomics training, (iii) forearm-support board and ergonomics training, and (iv) forearm-support board, trackball, and ergonomics training as described in more detail elsewhere (33). This prospective cohort study was a secondary analysis of data gathered during the ergonomic intervention trial and focused on the independent effect of ERI on upper-body musculoskeletal pain rather than the possible modifying effect of ERI on the ergonomic interventions. In fact, the small sample size provides insufficient statistical power for such an investigation of possible interactions. The effects of the ergonomic interventions independent of ERI have been published previously (33). The Committee on Human Research of the University of California at San Francisco and Kaiser Permanente Northern California approved the study protocol.

Out of 182 eligible employees, 17 workers were excluded in this study because they had changed jobs within the HMO (N=5), had left HMO employment (N=4), had opened a claim for workers' compensation (N=2), stated they did not want to continue in a research study (N=1), or chose not to continue in the trial because they did not like the intervention (N=5). As a result, 165 employees with pre- and post-intervention pain scores in all three body regions were included in the analyses.

Customer service operators at the participating sites were either registered nurses or healthcare specialists. Their work involved answering phone calls from HMO members in order to address questions, schedule appointments, save messages, and provide healthcare advice and triage. There is little use of written material; almost all information is handled via the computer. The computer workstations originally used at the sites had independently adjustable keyboard and monitor support surfaces and were typically equipped with a conventional keyboard, computer mouse and a telephone headset. Chairs were adjustable in height with adjustable height armrests. During the worksite intervention, all operators received ergonomic training regarding the adjustment of their workstation, and three quarters of the workstations were equipped with a trackball, a forearm-support board, or both according to randomization. Operators sat in large offices divided into small circular units housing 4–6 operators. Approximately one month after the ergonomic intervention, we made an unannounced visit to participants at their workplace to ensure that the assigned intervention was being used.

Data collection and survey instruments

Using a self-administered baseline questionnaire, we collected information on demographic factors and possible covariates, such as medical history, exercise, hobbies, and psychosocial stressors. In addition, participants completed a weekly survey questionnaire at the end of either of the last two days of each work week for about four weeks prior to the ergonomic intervention and for up to 52 weeks post intervention. The questionnaire assessed pain, work schedule, medication used for pain, acute injury events during the week, and workplace changes during the week.

Measurement of neck and upper-extremity pain

Three body regions (ie, neck–shoulders, right elbow–forearm–wrist–hand and left elbow–forearm–wrist–hand) were assessed for the worst pain during the preceding seven days using a 0–10 point scale (0=no pain; 10=unbearable pain) (24). Mean post-intervention scores were subtracted from the mean pre-intervention scores, so that any positive score reflected an overall increase in self-reported pain from baseline, while a negative score reflected an overall decrease in self-reported pain from baseline. For this analysis, mean post-intervention scores were calculated from surveys collected 8–52 weeks after the intervention in order to minimize the immediate short-term effects caused by the ergonomic training and adaptation to modifications of computer workstations. Missing values for any weekly pain score were replaced by the mean of the scores from adjacent weeks. The method was identical to the method used for the assessment of change in pain in the previously published ergonomic intervention study (33). Pre- and post-intervention pain score averages were used rather than single measures to better capture both acute and chronic pain episodes, including the typical intermittent or recurrent cumulative musculoskeletal pain experience during the entire study period.

Measurement of effort–reward imbalance

ERI was measured by a standard questionnaire with 6 items for extrinsic efforts and 11 items for rewards; intrinsic effort (over-commitment) was not measured (12). We generated an ERI ratio by summing the effort items and dividing them by the product of the summed reward score and a multiplier of 0.5454 according to the Siegrist coding protocol (34). Used as a categorical measure, any ratio greater than 1.0 indicates an imbalance between efforts and rewards. Cronbach's alpha was 0.75 for efforts and 0.79 for rewards, comparable to values generally above 0.70 reported in the literature.

Measurement of biomechanical risk factors and other covariates

Exposure to computer work was measured by the average of self-reported computer use (both at work and at home) in hours per week and by the number of months of computer use ≥20 hours/week on and off the job (including current call center work). Computer work station design was determined by intervention group assignment. Additional occupational exposures included occupation (registered nurse or customer service representative), worksite location, self-reported typing speed in words per minute, work rest breaks in minutes/day, and hand discordance with mouse use (ie, if the non-dominant hand operated the mouse).

Questionnaire items assessing sociodemographic factors included: gender, age, ethnicity, marital status, and education (high school, some college, or completed college). Personal factors included: weight, height, current smoking, physical exercise (at least weekly), hand-intensive activities at home (hobbies, sports, gardening, and housecleaning) in hours/week, driving a car in hours/week, and homecare-giving of an elder person or a child <2 years of age. Baseline health was assessed by several variables including: (i) a co-morbidity index based on the number of selected doctor-diagnosed chronic health conditions that may predispose individuals to painful upper-body musculoskeletal or neurological disorders (eg, diabetes, gout, rheumatoid arthritis); (ii) any hormone-related conditions (eg, pregnancy, menopause); (iii) any specific doctor-diagnosed upper-extremity disorder; (iv) any specific doctor-diagnosed neck or shoulder disorder; (v) any surgery on the neck, shoulder, or upper extremities; (vi) the number of doctor-diagnosed low-back disorders; (vii) current use of antidepressant medication; and (viii) the pre-intervention pain status of each upper-body region. We calculated the pre-intervention baseline pain scores for the neck–shoulder region and the right and left upper extremities by averaging the four weekly scores before the intervention.

Missing value replacement

For the key predictors (efforts and rewards at work), missing values were replaced by the mean subscale score of the sample if the participant answered at least 50% of the subscale items. For the 28 covariates evaluated for confounding, sample mean values replaced missing values. Most missing values were found for body weight (N=8) and hours driven per week (N=8). Missing value replacement, therefore, affected 4.8% of the sample for any one variable, and was thus unlikely to lead to any substantial inflation of statistical significance.

Statistical analyses

We evaluated the statistical significance of differences between company sites using Chi-square tests for categorical variables and, after equal variance testing, Student's t-tests for continuous variables. We used multivariate linear regression analyses to determine the independent effects [beta-coefficients and 95% confidence intervals (95% CI)] of different measures of efforts, rewards, and ERI on one-year change in musculoskeletal pain scores by upper-body region.

We selected a set of six covariates based on theoretical grounds and entered (forced) them into all multivariate models; these included (i) age, (ii) gender, (iii) intervention group assignment, (iv) computer use in hours per week (both at work and at home), (v) months of computer use ≥20 hours/week on and off the job (including current call center work), and (vi) pre-intervention regional mean pain score. We examined separately 22 additional potential confounders one at a time in multivariate models that already included the 6 forced-in covariates. If adding the new covariate changed the beta coefficient of the predictor of interest by ≥5%, the covariate was considered a confounder and included in the fully adjusted model for this predictor. This procedure was performed separately for all three regional outcomes.

All analyses used standardized predictor variables (predictor variable divided by its mean). Therefore, the unit of analyses for efforts, reward, and the ERI ratio was the mean of these variables. Using the mean instead of the more commonly used standard deviation (SD) allowed for a direct interpretation of regression coefficients as the mean change in pain score associated with each predictor. For each ERI measure, regression results (beta coefficients, 95% CI and P-values) from three different regression models are presented in: (i) an unadjusted model, (ii) a model including the pre-determined set of ("forced-in") covariates, and (iii) a fully adjusted model including all forced-in and empirically identified confounders together. All data analyses were performed using Stata Version 9.2 (StataCorp LP, College Station, TX, USA).

Results

Characteristics of study participants and call center jobs

As reported previously, the baseline characteristics of the participants did not significantly differ by intervention group (see table 1 in reference 33). The distribution of sociodemographic, anthropometric, behavioral, health status, ergonomic factors and ERI is listed in table 1, including all 28 covariates examined for confounding.

Table 1. Baseline characteristics of study participants and call center jobs (N=165).

Variable	N	%	Mean	SD	Range
Sociodemographics					
Gender					
Female	158	96	·	·	··
Male	7	4	·	·	··
Age (years)	·	·	40.5	12.1	19–65
Ethnicity					
White	79	48	·	·	··
African American	35	21	·	·	··
Asian/Pacific Islanders	30	18	·	·	··
Hispanic	21	13	·	·	··
Marital					
Single	62	38	·	·	··
Married or partnered	103	62	·	·	··
Education					
High school	41	25	·	·	··
Some college	71	43	·	·	··
Graduated ≥4 years college	53	32	·	·	··
Behavioral factors					
Current smoker					
Yes	22	13	·	·	··
No	143	87	·	·	··
Physical exercise at least once a week					
Yes	99	60	·	·	··
No	66	40	·	·	··
Hand-intensive activities leisure/home (hours/week)	·	·	15.2	12.8	0–80
Driving a car (hours/week)	·	·	9.2	7.0	0–60
Care-giving at home (child <2 years, elder care)					
Yes	25	15	·	·	··
No	140	85	·	·	··
Health status					
Co-morbidity index: number of doctor-diagnosed systemic diseases [a]					
None	124	75	·	·	··
One	36	22	·	·	··
Two	5	3	·	·	··
Doctor-diagnosed upper-extremity disorders [b]					
Yes	83	50	·	·	··
No	82	50	·	·	··
Doctor-diagnosed neck–shoulder disorders [c]					
Yes	78	47	·	·	··
No	87	53	·	·	··
Surgery of neck–shoulder or upper extremities					
Yes	19	12	·	·	··
No	146	88	·	·	··
Number of doctor-diagnosed low-back disorders [d]					
None	93	56	·	·	··
1	40	24	·	·	··
2	25	15	·	·	··
≥3	7	4	·	·	··
Any hormone condition [e]					
Yes	41	25	·	·	··
No	124	75	·	·	··

(continued)

Table 1. Continued.

Variable	N	%	Mean	SD	Range
Currently taking antidepressant medications					
Yes	16	10	·	·	··
No	149	90	·	·	··
Any current pain medication use					
Yes	85	52	·	·	··
No	80	48	·	·	··
Neck–shoulder baseline pain score	·	·	2.57	2.26	0–9
Right upper-extremity baseline pain score	·	·	2.14	2.35	0–10
Left upper-extremity baseline pain score	·	·	1.39	2.02	0–9.5
Days off in last year due to problems in hands, arms, shoulders, or neck	·	·	2.2	11.3	0–105
Anthropometrics					
Height (inches)	·	·	64.6	3.2	59–76
Weight (pounds)	·	·	173.7	48.9	98–350
Body mass index	·	·	29.2	7.6	16–62
Ergonomic factors					
Job title					
Healthcare service representative	89	54	·	·	··
Registered nurse	76	46	·	·	··
Intervention group					
Ergonomic training only	41	25	·	·	··
Ergonomic training and trackball	39	24	·	·	··
Ergonomic training and armrest	44	27	·	·	··
Ergonomic training, trackball, and armrest	41	25	·	·	··
Past and current computer use at work and home ≥20 hours/week (total months)	·	·	79.5	68.9	1–384
Current computer use at work and home (hours/week)	·	·	37.4	9.1	20–80
Rest breaks (minutes/day)	·	·	48.5	21.5	0–90
Typing speed (words/minute)	·	·	45.9	13.3	20–90
Hand discordance regarding mouse use [f]					
No	152	92	·	·	··
Yes	13	8	·	·	··
Effort–reward imbalance (ERI)					
Efforts	·	·	12.2	4.4	6–26
Rewards	·	·	49.5	6.0	26–55
ERI ratio	·	·	0.47	0.22	0.20–1.34
ERI ratio >1	5	3	·	·	··

[a] Doctor-diagnosed systemic health conditions included in the co-morbidity index: diabetes, rheumatoid arthritis, lupus, osteoarthritis, thyroid disorders, chronic renal failure, gout, fibromyalgia.
[b] Regional upper-extremity disorders: tendonitis or muscle strain/sprain in fingers, hands, wrists, forearms or elbows, trigger finger, carpal tunnel syndrome, ulnar neuropathy, and ganglion.
[c] Regional neck–shoulder disorders: tendonitis or muscle strain/sprain in the upper arms/shoulders, neck pain, herniated cervical disk, cervical radiculopathy, rotator cuff injury, and thoracic outlet syndrome.
[d] Low-back disorders: lower-back pain, herniated lumbar disk, and sciatica;
[e] Hormone conditions: current pregnancy, menopause, history of oopherectomy
[f] Hand discordance: right-hand dominant and using left hand for computer mouse or vice versa.

Subjects were nearly exclusively female (96%), ethnically diverse, on average 41 years old, and 75% were college educated. Computer use at home and at work combined ranged from 20–80 hours per week (average 37 hours). Five participants (3%) experienced ERI (defined as an ERI ratio >1). Significant differences between study sites included: age, ethnicity, marital status, computer use at work/home in hours/week, work rest break minutes/day, weekly physical exercise, and the number of doctor-diagnosed low-back and neck–shoulder conditions (data not shown). Compared to site A, participants from site B were significantly younger, more ethnically diverse, less often single, used the computer at work or home about 6 hours per week less, took 16 minutes less rest break each day, engaged in more physical exercise, and reported fewer neck–shoulder and low-back diagnoses at baseline. However, baseline ERI, pre-intervention pain scores and pain medication use did not significantly differ across the two sites. Likewise, missed days of work from upper-extremity problems, current functional status, sleeping and any self-report of housekeeping problems did not significantly differ between sites (data not shown).

Prevalence and one-year change of upper-body regional pain

Mean neck–shoulder pain scores for all participants in all treatment interventions decreased among 64% of participants, did not change in 11%, and increased in 25%. The respective proportions for the right upper extremity were 53%, 10%, and 37%, and 43%, 21%, and 36% for the left upper extremity. The average pre- minus post-intervention pain scores were -0.88 (SD 1.64, range -8.73–3.07) for the neck–shoulder region; -0.48 (SD 1.82, range -7.09–6.33) for the right upper extremity; and -0.26 (SD 1.46, range -7.09–4.79) for the left upper extremity. Over the 52 weeks of the study, 112 of the 165 participants (68%) reported upper-body pain levels of >5 (on a scale from 0–10) or use of pain medication for ≥2 days for upper-body pain in the week preceding the weekly survey and became eligible for a medical physical examination. The resulting medical diagnoses of these musculoskeletal disorders have been reported elsewhere (33).

Effort–reward imbalance and one-year change in neck–shoulder pain

Table 2 shows standardized beta coefficients with 95% CI and P-values for the effect of efforts, rewards, and the ERI ratio on one-year change in neck–shoulder pain. Neither crude nor adjusted coefficients showed any statistically significant effects. Effect sizes changed considerably after adjustment for covariates; effects changed in the expected direction.

Effort–reward imbalance and one-year change in right upper–extremity pain

Table 3 shows standardized beta coefficients with 95% CI and P-values for the effect of efforts, rewards, and the ERI ratio on one-year change in right upper-extremity pain. There was a statistically significant linear relationship between efforts at work and change in pain scores – average efforts were associated with a 0.82 increase in the right upper-extremity pain score from pre- to post intervention. For rewards received at work, the results were not statistically significant, although the P-value was rather small (0.057) and a substantial effect was observed in the expected direction, ie, higher reward scores were associated with decreased pain change scores (-1.76) in the fully adjusted model. The ERI ratio significantly predicted change in right upper-extremity

Table 2. Effort–reward imbalance (ERI) and one-year change in neck–shoulder pain among call center operators. Results from linear regression analyses. (95% CI= 95% confidence interval)

Job factor	N	Model 1 (unadjusted)			Model 2 (adjusted for forced-in covariates only) [a]			Model 3 (fully adjusted) [b]		
		Coefficient	95% CI	P-value	Coefficient	95% CI	P-value	Coefficient	95% CI	P-value
Efforts [c]	164	-0.43	-1.08–0.21	0.189	-0.20	-0.78–0.38	0.501	0.09	-0.58–0.76	0.783
Rewards [c]	164	1.97	-0.11–4.04	0.063	0.57	-1.32–2.47	0.553	-0.11	-2.27–2.05	0.920
ERI ratio [c]	163	-0.40	-0.92–0.11	0.125	-0.19	-0.65–0.27	0.420	0.06	-0.48–0.60	0.821
ERI ratio >1	163	-0.48	-2.08–1.10	0.544	-.32	-1.63–1.00	0.635	0.03	-1.43–1.49	0.970

[a] Model 2: adjusted for age, gender, intervention group, computer hours/week at both work and home, months of computer use ≥20 hours/week in previous jobs and current call center job; mean pre-intervention pain score for neck–shoulder region

[b] Model 3: model 2 plus adjustment for ethnicity, education, marital status, body mass index, current smoking, leisure time physical activity, driving hours/week, co-morbidity index, surgery on neck/upper extremities, low-back disorders, hand discordance regarding mouse use, typing speed in words/minute, and job title (registered nurse or service representative)

[c] This continuous exposure measure was standardized by dividing each value by the mean. Therefore the unit of analysis for this measure equals the average exposure in this sample.

Table 3. Effort–reward imbalance (ERI) and one-year change in right upper-extremity pain among call center operators. Results from linear regression analyses. (95% CI=95% confidence interval)

Job factor	N	Model 1 (unadjusted)			Model 2 (adjusted for forced-in covariates only) [a]			Model 3 (fully adjusted) [b]		
		Coefficient	95% CI	P-value	Coefficient	95% CI	P-value	Coefficient	95% CI	P-value
Efforts [c]	164	0.13	-0.60–0.87	0.719	0.55	-0.21–1.30	0.156	0.82	0.01–1.62	0.046
Rewards [c]	164	0.80	-1.20–2.80	0.429	-1.42	-3.40–0.56	0.158	-1.76	-3.5–0.05	0.057
ERI ratio [c]	163	0.02	-0.49–0.54	0.930	0.51	-0.08–1.09	0.091	0.73	0.1–1.32	0.018
ERI ratio >1	163	0.34	-0.80–1.49	0.553	0.98	-0.66–2.61	0.240	1.02	-0.61–2.66	0.217

[a] Model 2: adjusted for age, gender, intervention group, computer hours/week at both work and home, months of computer use ≥20 hours/week in previous jobs and current call center job; mean pre-intervention pain score for right upper extremity

[b] Model 3: model 2 plus adjustment for ethnicity, marital status, body mass index, current smoking, weekly leisure time physical activity, surgery on neck/upper extremities, hand discordance regarding mouse use, typing speed in words/minute, and job title (registered nurse or service representative)

[c] This continuous exposure measure was standardized by dividing each value by the mean. Therefore the unit of analysis for this measure equals the average exposure in this sample.

Table 4. Effort–reward imbalance (ERI) and one-year change in left upper-extremity pain among call center operators. Results from linear regression analyses. (95% CI= 95% confidence interval)

Job factor	Model 1 (unadjusted)			Model 2 (adjusted for forced-in covariates only) [a]			Model 3 (fully adjusted) [b]		
	Coefficient	95% CI	P-value	Coefficient	95% CI)	P-value	Coefficient	95% CI	P-value
Efforts [c]	-0.20	-0.75–0.36	0.484	0.05	-0.51–0.61	0.859	0.24	-0.33–0.76	0.404
Rewards [c]	0.54	-1.02–2.10	0.498	-0.48	-1.98–1.01	0.524	-0.77	-2.28–0.74	0.314
ERI ratio [c]	0.14	-0.55–0.28	0.508	0.14	-0.30–0.58	0.522	0.29	-0.15–0.74	0.195
ERI ratio >1	0.16	-0.76–1.08	0.736	0.73	-0.41–1.87	0.210	0.71	-0.53–1.95	0.257

[a] Model 2: adjusted for age, gender, intervention group, computer hours/week at both work and home, months of computer use ≥20 hours/week in previous jobs and current call center job; mean pre-intervention pain score for left upper extremity

[b] Model 3: model 2 plus adjustment for education, marital status, body mass index, current smoking, weekly leisure time physical activity, hand discordance regarding mouse use, typing speed in words/minute, job title (registered nurse or service representative), and care-giving at home

[c] This continuous exposure measure was standardized by dividing each value by the mean. Therefore the unit of analysis for this measure equals the average exposure in this sample.

pain. The mean ERI ratio was associated with an average increase of 0.73 units of pain change scores. The dichotomous measure of ERI ratio >1 showed a slightly larger effect (1.02), but this result was not statistically significant, most likely due to the very small number of subjects with an ERI ratio >1 (N=5). For all measures (efforts, rewards, and ERI ratios), effect sizes changed considerably after adjustment for covariates, and, in the case of rewards, also the direction of the effect changed after adjustment.

Effort–reward imbalance and one-year change in left upper-extremity pain scores

Table 4 shows standardized beta coefficients with 95% CI and P-values for the effect of efforts, rewards, and ERI ratio on one-year change in left upper-extremity pain. Neither crude nor adjusted coefficients showed any statistically significant effects, although, all adjusted effects were in the expected direction. Again, effect sizes changed considerably after adjustment for covariates.

Discussion

Prevalence of effort–reward imbalance

The average ERI ratio score observed in call center computer operators was 0.47 (SD 0.22) at both work sites. This ratio is slightly lower but still comparable to a group of Japanese information technology/computer operators working overtime [ERI ratio score 0.50, SD 0.42 (35)], a representative sample of the Danish workforce [0.53, SD 0.18 (36)], municipal employees in Norway [0.60, SD 0.30 (37)], and injured hospital employees [0.61, SD 0.34 (unpublished data 19)]. Slightly higher ERI ratios can be calculated for European nurses in hospitals (0.69), nursing homes (0.63), and home care settings (0.51) using data provided by the NEXT (nurses' early exit) study (38). Substantially higher ERI ratios were reported for young Swiss physicians [0.78, SD 0.28 (39)], San Francisco public transit operators [0.81, SD 0.44 (20)], and Las Vegas hotel room cleaners [1.33, SD 0.95 (40)].

Those call center employees in the upper quartile of the ERI ratio had a mean ratio of 0.79 (SD 0.18) (data not shown). Only 3% of call center operators had an ERI ratio >1. This is similar to the prevalence among hospital nurses (4.5%) and lower compared to other hospital staff (10.6%) in San Francisco (unpublished data 19). The prevalence of ERI ratio >1 varies considerably across occupations. For example, ERI prevalence was 7.34% among nearly 3000 female employees, aged 35–50 years, at a French electric utility company (41). On the other hand, among low-wage hotel room cleaners at unionized hotels in Las Vegas the proportion was 54% (40). These differences are likely a reflection of different work environments. HMO call center employees receive higher salaries for their professional skill set compared to low-wage service workers. Respect from others may be higher for professional and/or highly skilled workers; employees in a HMO call center work in positions that match their educational background, thereby lowering the potential for imbalance in this sample. Call center employees of this HMO performed medical triage and gave patients advice and were less involved in billing tasks that are characteristic for call center employees in the financial services sector. Although they also performed routine patient visit scheduling tasks, our results may not be generalizable to call center employees in other industries.

Prevalence and severity of upper-body regional pain

Most studies of musculoskeletal problems among computer users reported the prevalence of any pain in the prior year and did not gather information on pain severity. A study of 206 engineers used a 10-point scale to report pain severity similar to the one used in our study (42). Compared to our call center employees, these engineers (who had more control of their work tasks than call center operators) reported lower pain severity in the neck–shoulder (1.9 versus 2.4), right upper extremity (1.7 versus 2.3), and left upper extremity (0.7 versus 1.5).

Our case definition for regional musculoskeletal disorders (eg, pain >5 or use of pain medications for ≥2 days in past week) was also used in a study of 632 newly hired computer users (clerical, professional, etc) (24). Compared to the call center operators, they reported a similar prevalence of moderate or severe neck–shoulder pain (10% versus 13%) but a lower prevalence of upper-extremity cases (4% versus 17%). These differences may be due to differences in hours per week of computer use or number of years using a computer.

Association between ERI and upper-body regional pain

A significant relationship was found between the average ERI ratio and one-year change in right upper-extremity pain with an average increase of 0.73 units on the 0–10 unit pain scale. Given that the average right upper-extremity pain score at baseline was only 2.14, this change represented a 30% increase in average pain levels. This increase in pain was comparable in size to the opposite (protective) effect of the successful ergonomic armboard intervention which led to a reduction of 0.48 units on the 0–10 right upper-extremity pain scale in this population (33). No significant effects were observed on left upper-extremity or neck–shoulder pain, although the non-significant effects of ERI were in the same direction for all upper-body regional pain.

To our knowledge, this is the first prospective study on the relationship between ERI and upper-body regional pain. A cross-sectional study of hotel room cleaners found significant relationships between ERI and severe shoulder pain – room cleaners with an ERI ratio >1 were three times as likely to report severe or very severe shoulder pain (adjusted odds ratio 2.99, 95% CI 1.95–4.59, P=0.000) (18). In a case-control study among hospital workers, those with an ERI ratio >1 were 1.3 times as likely to have a neck or upper-extremity injury (OR 1.3, 95% CI 1.1–1.7), after adjusting for educational level, annual family income, job strain, ergonomic assessment, and job group (19).

Biological plausibility

According to recent reviews (6, 43) there is empirical evidence for several possible pathways for psychosocial factors leading alone or in combination to these outcomes. Laboratory studies have shown that biomechanical load may increase with simulated work environment stressors even if the external exposure is kept constant or is reduced (44). This increased muscle force production under conditions of psychosocial stress may hamper relaxation of the muscle fibers during (micro) pauses and impair circulation and the supply of oxygen to tissues as hyperventilation can do. Stress may also lead to increased and sustained muscle forces due to inadequate unwinding (45) and altered movement patterns (46). In addition, prolonged stress may degrade tissue quality and the ability of tissues to recover due to hormonal processes (44). For pain outcomes, other authors have also mentioned decreased pain thresholds as a plausible mechanism (47, 48).

Strengths and limitations

The prospective design of this study allowed for a causal interpretation of results. Another important strength of this study was the comprehensive adjustment for possible confounding factors in multivariate models, especially for physical workload and ergonomic factors. In fact, ergonomic factors were directly monitored and partly controlled by the investigators because the study population was enrolled in a randomized controlled ergonomic intervention trial with investigators adjusting work stations and evaluating work time and work station changes through site visits and weekly questionnaires during follow-up. In addition, the adjusted regression models controlled for typing speed and current and past exposure to computer work both at work and at home thus taking both past and current physical workload into account. Together with the fact that all participants performed virtually identical jobs, the possible effects of biomechanical risk factors were tightly controlled in this study, addressing an important methodological problem in the literature on psychosocial job factors as mentioned in the introduction. The importance of adequate adjustment for physical workload is stressed by the fact that the effects of efforts and rewards without adjustment for physical workload have been in the opposite direction as expected and, as our adjusted models show, would not have been detected without adequate adjustment for biomechanical factors. As an aside, this study provides an example of negative confounding where the unadjusted effect estimate is pushed closer to the null hypothesis (ie, the presence of confounding minimizes the true effect size and introduces a conservative bias) (49). This type of confounding often goes undetected because researchers tend to abandon multivariate adjusted analyses when unadjusted analyses show no significant effect.

In addition, our study controlled for physical demands at home in terms of the number of individuals in the household (young children or elderly) requiring care, which was relevant for a nearly exclusive female worker population, resulting in slightly stronger effects of ERI on upper-extremity pain (4–10%, data not shown).

Adjustment for individual health behaviors and body mass index may be considered "over-adjustment" because these "individual worker characteristics" may in part be caused by work stressors or reflect attempts to cope with them. In fact, several prospective studies have shown that psychosocial job factors predict these behavioral factors (50, 51). Similarly, adjustment for low-back disorders may be considered as over-adjustment because low-back pain itself has been predicted by ERI in another prospective study controlling for physical workload (20). Adjustment for history of surgery or pre-existing conditions in the upper-body region is also a rather conservative approach because these conditions may have been caused by the same type of work. Adjustment for baseline pre-intervention regional pain scores, however, is necessary because it determines the possible change in pain scores and reduces the influence of regression to the mean. Systematic chronic diseases may predispose workers to painful upper-extremity or neck–shoulder disorders and have been accounted for by adjustment for any history of hormone-related conditions (eg, current pregnancy, menopause, history of oopherectomy) and doctor-diagnosed rheumatoid arthritis, lupus, osteoarthritis, fibromyalgia, gout, diabetes, thyroid disorders, and chronic renal failure.

Limitations of this study included its relatively small sample size and limited variation of exposure within a single occupation. The former tends to limit statistical power and the latter reduces the chance to detect substantial effects. In fact, ERI ratios were comparatively low and ERI (defined by an ERI ratio >1) was nearly absent in this population. The lack of a statistically significant effect of ERI on left upper-extremity pain was in large part due to the small sample size and should be interpreted with caution because the observed effect size of ERI was still positive and only moderately smaller than the one observed for the right extremity. Since the majority of computer operators reported right-hand dominance (92%) and right-hand mouse use (98%), the right hand is, therefore, expected to be at higher risk for the development of musculoskeletal problems. In fact, one of the most severe hand disorders, such as carpal-tunnel syndrome, has previously been shown to be significantly associated with mouse but not keyboard use (32). The observed effect of ERI on neck or shoulder pain, on the other hand, was two orders of magnitude smaller then the effects on the upper extremities. Therefore, even if this effect had become statistically significant in a study with a much larger sample size, its small size would probably still render it clinically insignificant.

Another limitation of the study was that both ERI and health outcomes were assessed by self-report, which may introduce common method variance bias if participants were reporting bad health or poor working conditions due to a third factor, such as social desirability, a tendency to complain, or negative affectivity (52, 53). The ERI questionnaire asks not only about factual efforts and rewards at work, but also accounts for the extent to which the worker feels distressed by these facts. In the original formulation of the ERI instrument, a third scale known as "work-related over-commitment" was developed to account for differences in workers that may influence or interact with perceived working conditions. Following common practice among other ERI researchers and because of space limitations, our survey did not include this extra scale. However, adjustment for over-commitment may have been of questionable value given that over-commitment effects were previously only observed in men but not women (41). In addition, what has been conceptualized as a personality trait similar to Type A behavior or "workaholism" may be interpreted, itself, as a response to job stressors. ERI is also strongly associated with burnout among nurses in several countries (54). However, in order to account for some possible determinants of reporting behavior, we controlled for age, gender, marital status, ethnicity, education, job title, and seniority. In addition, the high study participation rate of 68% and small loss to follow-up (9%) make it unlikely that our sample constituted a special group of individuals who tend to complain for no reason. Therefore, we believe that the association between ERI and upper-extremity pain needs to be considered mostly a reflection of working conditions rather than individual workers' character traits.

Concluding remarks

This was the first study investigating prospectively the effect of ERI on upper-body regional pain among call center computer operators. A significant relationship was found between the average ERI ratio and a one-year change in right upper-extremity pain even after adjustment for several factors (ie, pre-existing pain and health conditions, job title, current and past physical workload, ergonomic workstation design, typing speed, and several anthropometric, sociodemographic, and behavioral risk factors). Control for confounding, especially physical workload and ergonomic work station design, was essential for the identification of ERI as a risk factor for increased right upper-extremity pain at work.

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