Original article

Scand J Work Environ Health 2009;35(2):134-144

doi:10.5271/sjweh.1312

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Refers to the following texts of the Journal: 2004;30(5):390-398 2003;29(3):197-205 2005;31(5):375-386 2001;27(1):49-56 2005;31(6):409-437 2007;33(1):58-65 2000;26(1):7-19

The following article refers to this text: 2010;36(1):1-2

Key terms: combined effect; computer work; etiology; job strain; Karasek's model; musculoskeletal symptom; occupational disease; postural risk factor; prospective study; psychosocial factor; risk factor; self-assessment; self-report; video display unit; workload

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/19308297

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Interaction between postural risk factors and job strain on self-reported musculoskeletal symptoms among users of video display units: a three-year prospective study

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Lapointe J, Dionne CE, Brisson C, Montreuil S. Interaction between postural risk factors and job strain on self-reported musculoskeletal symptoms among users of video display units: a three-year prospective study. *Scand J Work Environ Health.* 2009;35(2):134–144.

Objective This study investigated a possible interaction between postural risk factors and job strain on the incidence proportion of self-reported musculoskeletal symptoms in the regions of the shoulder–neck, lower back, and upper limbs.

Methods A cohort of white-collar workers (N=2431) was assessed with a self-administered questionnaire regarding postural risk factors and job strain at work. After a three-year follow-up, the six-month incidence proportion of musculoskeletal symptoms in the three body regions was measured with a modified version of the Nordic questionnaire. The analyses were stratified for gender. Interaction was defined as a departure from the addition of effects of individual risk factors, and its importance was estimated from the attributable proportion due to interaction and its 95% confidence interval (95% CI).

Results A significant attributable proportion of 0.80 (95% CI 0.23–1.37) due to interaction between postural risk factors and job strain was observed for men in the lower back region. An indication of interaction was found for women with attributable proportions due to interaction of 0.44 (95% CI -0.06–0.94), 0.27 (95% CI -0.34–0.88) and 0.36 (95% CI -0.33–1.05) for the regions of the shoulder–neck, lower back, and upper limbs respectively.

Conclusions The simultaneous presence of postural risk factors and job strain seems to increase the pathogenic effect of each exposure on the incidence proportion of musculoskeletal symptoms. This interaction effect is important for work intervention practices as success in decreasing any of these two risk factors could have the additional benefit of reducing up to 80% of new cases of musculoskeletal symptoms among participants exposed to both risk factors.

Key terms combined effect; computer work; etiology; Karasek's model; occupational disease; psychosocial factor; workload.

Musculoskeletal symptoms are extremely frequent in the working population (1, 2). In Québec, Canada, as in the European Union, the human, social and economic burden associated with this group of health problems is constantly increasing (3, 4). Workers who use a video display unit (VDU) are particularly susceptible to the development of musculoskeletal symptoms, the reported prevalence being as high as 50% (5). Even if current scientific hypotheses support the multifactorial etiology of musculoskeletal symptoms (6), causal mechanisms (such as interaction between risk factors) are not well documented. Researchers have investigated the individual effects of postural risk factors related to VDU work and job strain. Postural risk factors such as static-seated posture, the number of breaks, workstation adjustments, and hours of work at the VDU have been found to be related to musculoskeletal symptoms in review studies (7–9). Job strain, which comprises psychological demands and decision latitude, has also been found to be related to musculoskeletal symptoms in the regions of the shoulder–neck and upper limbs (6), although less clearly in the lower back (10). Social support at work is

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thought to modify the effect of the association between job strain and adverse health outcomes (11).

Until now, research has not singled out any one exposure and has found that the individual impact of either postural risk factors or job strain is modest (6). This impact is probably too modest to explain the high proportion of musculoskeletal symptoms among workers. Consequently, we hypothesized that it is a form of interaction between postural risk factors and job strain that causes the high incidence of observed musculoskeletal symptoms.

Interaction, in epidemiology, defines situations where risk factors "cooperate" to increase disease frequency (12). In public health, interaction based on the additivity of effects is the most relevant to assess a causal mechanism between two risk factors (13). Among interaction measures based on the additivity scale, the attributable proportion due to interaction estimates the proportion of cases of musculoskeletal symptoms caused solely by the interaction mechanism between the two risk factors (14). The objective of our study was to investigate interaction between postural risk factors and job strain on the six-month incidence proportion of self-reported musculoskeletal symptoms in the regions of the shoulder–neck, lower back, and upper limbs among white-collar workers.

Study population and methods

Design

This study used data from a larger study that investigated the effects of preventive interventions on musculoskeletal, cardiovascular, and mental health among white collar workers (15). The population was composed of 2431 employees of three large public service organizations in Québec City, Canada. Their jobs encompassed the full range of white-collar occupations, including senior and middle managers (4.9%), professionals (42.4%), technicians (25.3%), and office workers (27.4%). The collection of baseline data was conducted between June 2000 and June 2003; follow-up data collection was completed between October 2004 and November 2006. The mean follow-up time was 3.2 years (SD 0.95, range 0.6–5.6 years). The initial participation proportion was 76% and the follow-up proportion was 93% (figure 1). Participants were met at their worksite during working hours and completed at both times a self-administered questionnaire on work organization and health. Research personnel measured their height and weight. The study protocol was approved by the Institutional Ethics Board of Laval University and all of the participants gave written informed consent.

Study population

To be eligible for this particular study, participants had to satisfy the following general criteria: (i) aged between 18 and 60 years (inclusively) at the baseline, (ii) working a minimum of 25 hours/week at both measurement times, and (iii) have at least one year of seniority in the organization at the baseline. Pregnancy and musculoskeletal inflammatory diseases (rheumatoid arthritis or ankylosing spondylitis) at the baseline were exclusion criteria. Retired workers and those on leave of absence for less than 60 days at follow-up were included. Furthermore, we applied another set of criteria for each specific anatomical region for the purpose of the analyses. Workers were excluded if they reported a lifetime history of acute injuries in the region under examination (N=47 for shoulder-neck, N=74 for lower back, and N=24 for upper limbs). They also had to be free of musculoskeletal symptoms in the specific body region at the baseline in the analyses involving the regions of the shoulder–neck, lower back, and upper limbs. Musculoskeletal symptoms at the baseline were defined by the reported symptoms with related functional limitations in daily activities in the previous six months. Those with missing data on previous musculoskeletal symptoms were excluded. Thus, the final study population comprised a total of 1342, 1294 and 1466 participants for the analyses of the incidence proportions of musculoskeletal symptoms for the regions of the shoulder–neck, lower back, and upper limbs respectively (figure 1).

Outcome

The outcome of interest was the self-reported six-month incidence proportion of musculoskeletal symptoms at the follow-up with respect to one of the three body regions under study. This incidence proportion definition should be considered as a measure of both incidence and recurrence of musculoskeletal symptoms (16). Upper limb symptoms included those in the forearms, wrists, and hands. A modified version of the Nordic questionnaire was used to measure musculoskeletal symptoms (17). Incident cases were defined by musculoskeletal pain, ache or discomfort in the last six months (answered by yes or no) with related functional limitation at work, at home or during leisure activities. Functional limitations were investigated by the following question: "Did you have to decrease your activities secondary to your musculoskeletal symptoms?" They were measured by a "yes" or "no" answer to each of the three activity categories. A six-month reference period (18) and a composite definition of pain and functional limitations (in comparison with the results of a physical examination) (19) have earlier been found to be appropriate for the measurement of self-reported musculoskeletal symptoms. Pre-shaded manikins were used to help participants identify the

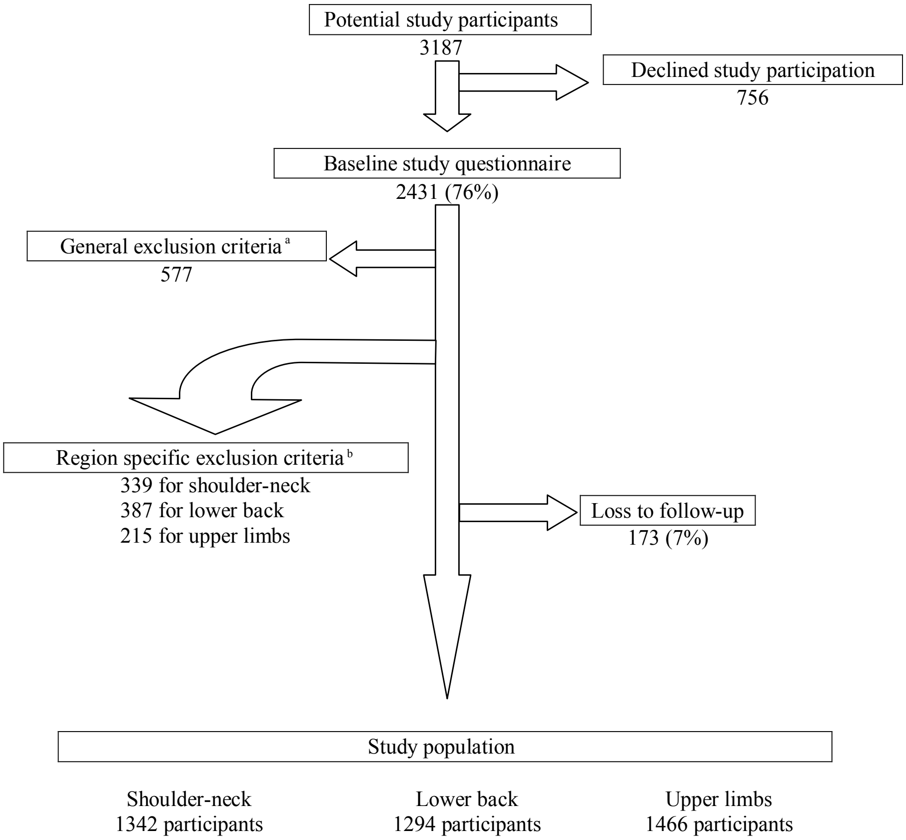

Figure 1. Flow chart of participant recruitment and eligibility for analyses of incident musculoskeletal symptoms.

[a] Aged less than 18 years or more than 60 years, working less than 25 hours a week at one or both measurement times, having less than one year of seniority in the organization, being pregnant or having musculoskeletal inflammatory diseases (rheumatoid arthritis or ankylosis spondilytis), retired, or in leave of absence since more than 60 days at follow-up.
[b] At the specific body region concerned by the analyses: having a lifetime history of past acute injury and/or reporting musculoskeletal symptoms in the previous six months with related functional limitations in daily life activities.

correct body region (20). Those with missing data on one of these outcome definitions were excluded from the analyses pertaining to this outcome.

Job strain

Job strain is a combination of psychological demands and decision latitude and was measured with the French version of Karasek's questionnaire (21), for which good psychometric qualities have been demonstrated (22, 23). Psychological demands reflect the quantity of work, time constraints, and level of intellectual effort required (nine items, score range 9–36). Decision latitude reflects opportunities for learning, autonomy, and participation in the decision-making process (nine items, score range 24–96). Scores were computed according to the algorithms recommended by Karasek (21). Those with missing data on two or fewer items were assigned an average score based on their answered items for that particular scale. Data were imputed for psychological demands and decision latitude for 0.42% and 0.65% of participants respectively. High and low level of exposure to psychological demands and decision latitude were determined by a cut-off point that corresponded to the median observed for the Québec general working population (24); the median value was 24 for psychological demands and 72 for decision latitude. We used the quadrant method proposed by Karasek to classify job strain exposure (11). The high job strain group was composed of workers with median or higher scores on psychological demands and median or lower scores on decision latitude. Subjects in the other three quadrants of exposure were classified altogether in the low job strain group.

Postural risk factors

A minimum of four hours per day of VDU work was deemed necessary for the assessment of postural risk factors, in order to obtain a minimal exposure time to VDU work (25, 26). Participants exposed to less than this amount (N=364) were classified in the low postural risk factors group. No measures of postural risk factors were collected for these participants. Among subjects working on a VDU for four hours per day and more, we measured seven postural risk factors related to the VDU workstation with the self-administered questionnaire. These postural risk factors were based on Health Canada ergonomic guidelines (27) and defined by the following: (i) a static-seated posture (risk was defined by a "yes" answer), (ii) possibility to take regular breaks (risk was defined by a "no" answer), (iii) neck alignment, measured by comparing the top of the screen to the line of vision and according to the use of bifocals glasses or not (risk was defined by a line of vision other than one aligned with the top of the screen when the subject was not using bifocals or by a line of vision other than slightly higher than the top of the screen when the subject was using bifocals), (iv) neck rotation caused by a lateral position of the screen (risk was defined by the presence of a lateral position of the screen), (v) angle of forearms, measured by comparing keyboard height to the height of the elbows (risk was defined by a keyboard height higher than elbow height), and (vi) the use of armrests when working with a keyboard (risk was defined by a "no" answer) or with the mouse (risk was defined by "no" answer). Pictograms accompanied written items in order to improve the psychometric properties of the measures (28, 29).

To calculate the summary index, 1.0 point was given for the presence of a postural risk factor except for the non-use of armrests while working with the keyboard and mouse, which were given 0.5 points each. We retained participants with data missing for only one item measuring postural risk factors (2.5% of the study population). Subjects with more than one missing item were excluded (N=8, 0.5% of the study population). For each subject, we computed the sum of reported postural risk factors and fixed the cut-off point at 2.5 points (the minimum of the upper tertile in our study population). Those with a sum of >2.5 points were classified in the low postural risk factor group along with subjects working <4 hours per day on a VDU. Participants with a sum of ≥2.5 reported postural risk factors were classified in the high postural risk factor group.

Overall, the proportions of subjects exposed to postural risk factors were: (i) 34.0% for a static-seated posture, (ii) 73.1% for the impossibility of taking regular breaks, (iii) 50.1% for an inadequate neck alignment (either overextension or overflexion), (iv) 8.2% for the presence of neck rotation caused by a lateral position of the screen, (v) 28.2% for an angle of forearms above the horizontal line, and (vi) 24.0% and 28.3% for the non-usage of armrests when working with the keyboard or mouse, respectively. Among those highly exposed to postural risk factors (N=642), the most frequent combinations of factors were: (i) a static-seated posture, an

Table 1. Selected characteristics of the baseline study population following the general inclusion/exclusion criteria, by gender.

Characteristics	Men (N=761)		Women (N=1093)	
	N	%	N	%
Age groups	..	.	..	.
<35 years	74	9.7	115	10.5
35–44 years	262	34.4	454	41.5
45–60 years	425	55.9	524	48.0
Education (highest level completed)	..	.	..	.
High school or less	119	15.7	373	34.1
College [a]	214	28.1	331	30.3
University	428	56.2	389	35.6
Marital status	[0.8] [f]		[0.6] [f]	
Married	362	47.6	434	39.7
Living as married	199	26.2	326	29.8
Divorced	79	10.4	151	13.8
Single	111	14.6	163	14.9
Widow	3	0.4	12	1.2
Stressful life events in the past 12 months	[0.5] [f]		[2.4] [f]	
0	421	55.3	496	45.4
1	243	31.9	378	34.6
≥2	93	12.3	192	17.6
Self-assessed health status	[0.1] [f]		[0.1] [f]	
Excellent	106	13.9	138	12.6
Very good	292	38.4	400	36.6
Good	260	34.2	402	36.8
Average	87	11.4	130	11.9
Poor	15	2.0	22	2.0
Psychological distress [b]	[0.1] [f]		[0.2] [f]	
No	562	73.9	664	60.8
Yes	198	26.0	427	39.0
Social support at work [c]	[1.1] [f]		[0.5] [f]	
High	327	43.0	442	40.4
Low	426	55.9	646	59.1
Job strain [d]	[0.6] [f]		[0.6] [f]	
Low	623	81.9	830	75.9
High	133	17.5	256	23.5
Postural risk factors [e]	[0.4] [f]		[0.6] [f]	
Low	490	64.4	713	65.2
High	268	35.2	374	34.2

[a] In the province of Quebec, college refers to pre-university or vocational studies.
[b] Psychological distress was defined by a score ≥26.19 on the French version of the 14-item Psychiatric Symptom Index.
[c] Low social support was defined by a score ≤34 on the French version of the 11-item Karasek questionnaire.
[d] Job strain was categorized according to the quadrant method of Karasek. High job strain was the combination of high psychological demands and low decision latitude. Low job strain comprised the exposition of the three other quadrants.
[e] Postural risk factors were computed from seven defined criteria. High postural risk factors were defined as an exposure level equal or higher than the median value of this study population.
[f] Percent of missing data within brackets.

inadequate neck alignment, and an angle of forearms above the horizontal (11.6%) and (ii) the impossibility of taking regular breaks, a static-seated posture, and inadequate neck alignment (9.4%).

Covariables

We measured social support at work, which is hypothesized to modify the effect of the association between job strain and health outcomes (11), with the 11-item scale proposed by Karasek (21) (score range 11–44). Categorization was determined by the median of an external Québec reference population (24), the value of which was 34. Information on demographic and individual variables was collected at the baseline. The following covariables were chosen according to the evidence related to musculoskeletal symptoms reported in review studies (6, 9, 30, 31) or studies on the general population (32, 33): age, marital status, formal education (highest level completed), number of children, smoking status (smokers were defined by ≥1 cigarette/day), job category, organizational seniority, sedentary behavior (engaged in physical activity ≤1 time/week during the previous six months), stressful life events during the prior 12 months, and menopausal status. Body mass index was computed from direct measurements of subjects' height and weight taken at the baseline and follow-up (≥27 kg/m² for obesity).

Personality factors related to impatience or irritability (one item) and inability to withdraw from work obligations (five items) were measured at follow-up with the six-item overcommitment scale recommended by Siegrist et al (34). Those who scored in the upper tertile of the distribution in our study population were considered at risk. Self-assessed health status was measured at the baseline and follow-up with the question: "Compared with others of the same age, would you say that your own health is, in general, excellent, very good, good, fair, or poor?" Psychological distress was measured with the validated French version of the 14-item Psychiatric Symptom Index (35). Only the baseline measure was used in the final model. A total score was calculated for this scale on the basis of a range of 0 to 100. Patients with scores of ≥26.19, which represents the minimum of the highest quintile observed in the general population of Québec (24), were considered to have psychological distress.

A variable named "musculoskeletal symptoms in other body region(s)" was constructed to account for the presence of baseline symptoms in a body region other than the one under study. For example, in the analyses for the shoulder–neck region, subjects with baseline musculoskeletal symptoms in the lower back and/or upper limbs were classified as having "musculoskeletal symptoms in other body regions". Musculoskeletal symptoms were defined by the presence of self-reported symptoms in the last six months, accompanied by related functional limitations.

Statistical analyses

As recommended for the study of the interaction between two risk factors (14), the following four exposure groups were created: (i) high postural exposure and high job strain, (ii) high postural exposure and low job strain, (iii) low postural exposure and high job strain, and (iv) low postural exposure and low job strain. Subjects in the fourth category composed the reference group. Unconditional logistic regression was used to estimate the crude and adjusted odds ratio (OR) with a 95% confidence interval for each exposure group as it is robust to small cell numbers (36). The effect modification of social support at work was tested by using stratification and the Breslow-Day test (37). Age was forced into the adjusted models either as a continuous variable or into categories (<35, 34–44, >44 years) according to the best fit of the logistic regression models (38).

To create the adjusted model, we began by entering exposure groups and age. Then, we adjusted for covariables that brought about a change of ≥10% for at least one of the exposure OR, using a forward stepwise strategy. When the model needed adjustment for a variable measured both at the baseline and follow-up, the model's tolerance and variance inflation factors were examined to assure that mutual dependency was not introduced (36). If this was the case, only the variable bringing about the greatest change in exposure OR was kept in the model. All of the analyses were performed separately for men and women. Each body region was considered individually. Deviance statistics and influence diagnostics were examined to achieve an adequate goodness of fit (38). The analyses were performed with the SAS 9.1 package (SAS Institute, Cary, NC, USA).

Assessment of interaction

In order to assess the presence of interaction, when two risk factors cooperate to increase disease frequency beyond the addition of their individual effects (12), the attributable proportion due to interaction is used. In this case, the attributable proportion was interpreted as the proportion of musculoskeletal symptoms cases solely due to the interaction process among subjects exposed to both risk factors (14). The attributable proportion is, among the other interaction measures, the most robust one when OR are used to approximate risk proportions (39). The attributable proportion and its 95% confidence interval (40) were computed directly from the OR obtained by logistic regression (14). The attributable proportion was calculated with the following formula: $[(OR_{11} - OR_{01}$

Table 2. Effect of postural risk factors and job strain on the six-month incidence proportion of musculoskeletal symptoms among white-collar men. (OR = odds ratio, 95% CI = 95% confidence interval)

	Total number	Number of cases	Crude model		Adjusted model		Atributable proportion [a]	95% CI
			OR	95% CI	OR	95% CI		
Shoulder-neck								
Low postural / low job strain	294	14	1.00	Reference	1.00 [b]	Reference	·	··
Low postural / high job strain	39	4	2.29	0.71–7.33	2.32	0.70–7.66	·	··
High postural / low job strain	151	13	1.88	0.86–4.12	2.08	0.93–4.62	·	··
High postural / high job strain	41	6	3.43	1.24–9.50	2.94	0.97–8.94	-0.15	-1.62–1.32
Lower back								
Low postural / low job strain	282	28	1.00	Reference	1.00 [c]	Reference	·	··
Low postural / high job strain	40	2	0.48	0.11–2.09	0.36	0.07–1.70	·	··
High postural / low job strain	144	14	0.98	0.50–1.92	0.97	0.47–2.02	·	··
High postural / high job strain	41	7	1.87	0.76–4.60	1.66	0.61–4.55	0.80	0.23–1.37
Upper limbs								
Low postural / low job strain	320	14	1.00	Reference	1.00 [d]	Reference	·	··
Low postural / high job strain	46	8	4.60	1.81–11.68	4.76	1.72–13.14	·	··
High postural / low job strain	159	7	1.01	0.40–2.55	1.12	0.43–2.89	·	··
High postural / high job strain	48	3	1.46	0.40–5.27	1.48	0.40–5.46	-2.30	-7.08–2.48

[a] Attributable proportion due to interaction computed from odds ratios of adjusted models.
[b] Adjusted for age and musculoskeletal symptoms to other body regions at baseline.
[c] Adjusted for age, health perception at follow-up, stressful life events at baseline, and musculoskeletal symptoms to other body regions at baseline.
[d] Adjusted for age and musculoskeletal symptoms to other body regions at baseline.

Table 3. Effect of postural risk factors and job strain on the six-month incidence proportion of musculoskeletal symptoms among white-collar women. (OR = odds ratio, 95% CI = 95% confidence interval)

	Total number	Number of cases	Crude model		Adjusted model		Atributable proportion [a]	95% CI
			OR	95% CI	OR	95% CI		
Shoulder-neck								
Low postural / low job strain	356	32	1.00	Reference	1.00 [b]	Reference	·	··
Low postural / high job strain	118	17	1.70	0.91–3.20	1.77	0.91–3.43	·	··
High postural / low job strain	198	19	1.07	0.59–1.95	1.11	0.60–2.06	·	··
High postural / high job strain	57	13	2.99	1.46–6.13	3.38	1.58–7.22	0.44	-0.06–0.94
Lower back								
Low postural / low job strain	341	22	1.00	Reference	1.00 [c]	Reference	·	··
Low postural / high job strain	107	13	2.01	0.97–4.13	2.53	1.09–5.85	·	··
High postural / low job strain	197	24	2.01	1.10–3.69	2.51	1.23–5.09	·	··
High postural / high job strain	62	16	5.04	2.47–10.30	5.51	2.33–13.03	0.27	-0.34–0.88
Upper limbs								
Low postural / low job strain	378	26	1.00	Reference	1.00 [d]	Reference	·	··
Low postural / high job strain	116	10	1.28	0.60–2.73	1.26	0.57–2.77	·	··
High postural / low job strain	214	16	1.09	0.57–2.09	1.17	0.61–2.26	·	··
High postural / high job strain	59	8	2.12	0.91–4.94	2.25	0.94–5.40	0.36	-0.33–1.05

[a] Attributable proportion due to interaction computed from odds ratios of adjusted models.
[b] Adjusted for age and musculoskeletal symptoms to other body regions at baseline.
[c] Adjusted for age and stressful life events at baseline and at follow-up, number of children, education level, and musculoskeletal symptoms to other body regions at baseline.
[d] Adjusted for age, psychological distress at baseline and musculoskeletal symptoms to other body regions at baseline.

$- OR_{10} + 1)/ OR_{11}]$ where OR_{11} represents the OR for the high postural and high job strain group, OR_{01} represents the low postural and high job strain group, and OR_{10} represents the high postural and low job strain group. Null or negative values of the attributable proportion were interpreted as an absence of interaction (13, p341).

Results

For men, the incidence proportion of musculoskeletal symptoms with associated functional limitations in the last six months was 7.0% for shoulder-neck, 10.0% for lower back and 5.6% for upper limbs. For women, these proportions were 11.1%, 10.6% and 7.6% for shoulder–neck, lower back, and upper limbs, respectively. The proportions of musculoskeletal symptoms reported in body regions other than the one concerned by the site-specific analyses (men and women combined) were the following: 18.0% (241 : 1342) for the shoulder–neck region, 14.8% (192 : 1294) for the lower back region, and 21.7% (318 : 1466) for the upper limb region. Social support did not modify the effect of job strain exposure in the analyses (data not shown). Generally, the high postural and high job strain groups displayed the highest OR; this was the case for men in the regions of the shoulder–neck and lower back, and for women in all three body regions.

We observed a significant crude effect in shoulder-neck in the high postural and high job strain group in men (table 2), but this association disappeared after adjustment. We did not find any significant OR in the lower back region but observed a significant OR for symptoms in the upper limbs in the low postural and high job strain group. For women (table 3) the crude effect for the high postural and high job strain group was significant in the shoulder–neck and the lower back region and these associations remained after adjustment. Computed from adjusted models, the attributable proportion varied between -2.30–0.80. For men, a significant attributable proportion was observed for the lower back region (0.80). For women, all three body regions had a potential, although not significant, interaction with the highest attributable proportion being found for the shoulder–neck region.

Discussion

Main results

Our study investigated the interaction between postural risk factors and job strain on the incidence of self-reported musculoskeletal symptoms in the regions of the shoulder–neck, lower back, and upper limbs. For men, we found a significant interaction between postural risk factors and job strain on the incidence of musculoskeletal symptoms in the lower back region. For women, all three body regions showed an indication of interaction. Social support did not modify the association between job strain exposure and musculoskeletal symptoms.

Comparison with previous research

To our knowledge, only seven studies have investigated the interaction between physical and psychosocial risk factors of work (41–47). Among these studies, only four have computed the attributable proportion (41, 42, 46, 47). It was, however, possible for us to compute the attributable proportion from the results of two other studies (43, 45). The remaining study (44) did not use any of the recommended interaction measures (12) and it was not possible to compute the attributable proportion from the data provided.

Comparisons with these studies are difficult to make due to the marked differences in exposure assessment, populations, and designs. These studies were mainly cross-sectional (41–43, 46), only one had a study population specific to VDU work (47), and none had a comparable definition of postural risk factors related to VDU work. A majority of these studies combined men and women in their analyses (41–43, 47) and only one computed confidence intervals for the attributable proportion (42). Varied attributable proportion values were reported from these studies, ranging from 0.06 to 0.70, and no systematic patterns seemed to emerge. Overall, there were nine positive attributable proportion values versus one null value observed in these studies. This finding corresponds to our results, in which we obtained a majority of positive attributable proportion. These results suggest that an interaction is present between postural risk factors and job strain even if its effect is still not sufficiently supported by significant results. Studies with greater statistical power will be necessary to support this observation.

Few studies have used a definition of musculoskeletal symptoms that includes both pain and functional limitations, despite its relevant informative value (48). One study measured the six-month prevalence of lower back symptoms with functional limitations (49) and observed a 12.3% figure. Two studies measured the 12-month incidence proportion of musculoskeletal symptoms with related functional limitations, observing values of 11.6% for the lower back region (50) and 11% for the neck region (51). These results are similar to the incidence proportions found in our study.

The fact that we did not observe effect modification by social support in our study contradicts the findings of other studies (52, 53). On the other hand, the absence of association between social support at work and musculoskeletal symptoms has been reported in some reviews (6, 10) and prospective studies with VDU workers (54, 55). It is possible that our cut-off point was not the most appropriate for defining low social support, since a large percentage of participants were categorized in the low social support group (table 1). However, in additional analyses, we redefined the low social support group by using the lower tertile of its distribution in our study population. These analyses led to the same conclusion (ie, an absence of effect modification by social support [data not shown]).

In our study, the adjustment for musculoskeletal symptoms in other body regions generally resulted in a slight increase in the strength of the associations of interest (data not shown). Even if this variable was observed to create overadjustment by systematically lowering the associations between measured risk factors and musculoskeletal symptoms in a previous study (45), our analyses revealed that it was not the case for our study population.

Methodological considerations

Our study had several methodological strengths. It was an inception prospective cohort study. The participation proportions were high at both the baseline and follow-up. We considered multiple possible confounders in the model adjustments and assessed three body regions in order to encompass the global phenomenon of musculoskeletal symptoms (56, 57). We also conducted separate analyses for men and women, since the literature shows that the associations of risk factors with musculoskeletal symptoms have great gender differences (9, 58).

Our outcome definition was another strength of our study. Defining musculoskeletal symptoms by their presence in the last six months, accompanied by related functional limitations, captured symptoms with an important impact on the worker's quality of life. Moreover, it also resulted in a decrease of the incidence proportions of musculoskeletal symptoms close to or lower than 10% and thus allowed the use of the OR obtained from the logistic regression to be used as valid estimates of risk ratios. Finally, it is important to note that the six-month recall period is less-commonly used than the 12-month period. However, in the absence of consensus on the best timeframe for measuring musculoskeletal symptoms, we postulated that a six-month recall period is comparable with, if not superior to, 12 months, as a shorter recall period reduces recall bias (59).

Nevertheless, our study had several limitations. First, the precision of estimates was low for some associations as shown by large confidence intervals. The actual sample size of this study, which had an impact on precision, was influenced by our application of restriction criteria. According to Rothman (14, p.110), restriction criteria are particularly effective in controlling confounding. Along these lines, we restricted participation in the study to subjects free of the main characteristics found to introduce confounding in the literature (see figure 1 for inclusion and exclusion criteria). However, in order to ascertain the validity of our restriction criteria, we analyzed the impact of integrating excluded workers in the cohort on our associations by proceeding systematically, one criterion at a time (data not shown). For every restriction criterion, the integration of these subjects resulted in a change greater than 10% on estimates for the associations of interest, which we determined, a priori, as the cut-off for confounding. These complementary analyses confirmed the choice of our restriction criteria and indicated that the internal validity would have suffered from changing these criteria even though increasing the study size would have resulted in greater precision.

We did not have information on postural risk factors for the participants who worked at the VDU for <4 hours per day (N=364). Therefore, part of our control group (33.8%) was, to an unknown extent, exposed to postural risk factors that could have introduced an underestimation of the strength of the associations we observed. In making this choice, we hypothesized that persons working <4 hours per day on the VDU have more possibilities to change their posture at work and thus have a lower risk of developing musculoskeletal symptoms. To check this point, we conducted complementary analyses including only subjects for whom information on postural risk factors was complete (N=1317). For these analyses, the strength of associations was lower. This last observation indicates that those with <4 hours per day of VDU work report musculoskeletal symptoms less frequently due to either a shorter amount of time in VDU work or a lower number of postural risk factors due to exposure to VDU work. This finding supports the choice of the control group definition used in our study.

A healthy worker effect could have occurred in our study, secondary to the exclusion of subjects with musculoskeletal symptoms at the baseline, thus leaving a healthier study population (60). Those with musculoskeletal symptoms at baseline have been excluded in many prospective studies (45, 54, 61–64). Actually, some studies have observed that baseline musculoskeletal symptoms are strong predictors of future musculoskeletal symptoms regardless of the work exposure level (33, 65–67). In addition, a review (29) concluded that subjects with musculoskeletal symptoms rate their work exposure differently than asymptotic subjects. Moreover, in complementary analyses, we observed that symptomatic participants seemed to introduce confounding in our data (data not shown). In fact, for these symptomatic subjects, we observed that the proportion of musculoskeletal symptoms in the reference group was much higher than in asymptomatic subjects. Their inclusion resulted in a general lowering of our associations by >10%. Thus, we are confident that this healthy worker effect mechanism did not contribute to a reduction in our associations.

A healthy worker effect could also have occurred if highly exposed participants at the baseline decreased their exposure to postural risk factors or to job strain during the follow-up period. Using a McNemar test, we tested this hypothesis by comparing the number of subjects who decreased their exposure level between baseline and follow-up versus those who increased it. We observed that, although keyboard height was more appropriate and head rotation was less frequent at follow-up, the reported duration of VDU work was higher while the possibility to take regular breaks was lower. No changes between the baseline and follow-up were observed for the other postural risk factors and job strain. Overall, the exposure levels to postural risk factors and job strain have stayed stable over time in our study population (data not shown). We thus conclude that this last aspect of a healthy worker effect is not a major concern in our study either.

The 7-point combined index that we used to measure postural risk factors had some limitations: it was self-reported and combined different postural exposures. Firstly, self-report measures have the tendency to overestimate the duration of VDU work (28, 68), although not always (29). On the other hand, a previous study has found that subjects correctly identified the absence of postural risk factors, but incorrectly identified their presence (28). Secondly, no validated self-report scales are available with which to assess postural risk factors specific to VDU work. We therefore selected the seven most important postural risk factors according to the available evidence (in the scientific literature) on VDU work (53, 69). According to a review by Stock et al (29) on the reproducibility and validity of workers' self-reporting of physical work demands, the questions we used to measure the duration of VDU work and keyboard height have good psychometric properties (29). Thirdly, combining different postural risk factors resulted in a measure with a limited discriminatory power to relate specific postural exposures to the body region analyzed. However, this measure allowed us to discriminate between participants at greater risk (those who identified the presence of three or more postural risk factors) and subjects at lower risk (those who identified only one or two postural risk factors).

Another potential limitation of this study was related to the outcome measure. Musculoskeletal symptoms were measured after a three-year follow-up, but this measure covered only the last six months. This definition has left a gap period during which study participants could have suffered from musculoskeletal symptoms and recovered without being identified in our analyses. This is particularly problematic with musculoskeletal symptoms because of their transient nature. The effect of such a gap on our estimates was not possible to ascertain because it depended on the distribution of events between exposure categories. We assumed that our six-month measure was efficient in capturing the recurring musculoskeletal symptoms.

Concluding remarks

The interaction between postural risk factors and job strain must be considered in occupational settings as workers are often simultaneously exposed to both types of risk factors in their work environment. This simultaneous exposure seems to increase the pathogenic effect of each individual risk factor on the development of musculoskeletal symptoms. Since targeting the elimination of every risk factor at work is a utopia, this interaction effect is thus of primary importance for work intervention practices. Success in reducing any one of these two types of risk factors will likely have the additional benefit of decreasing the part of the incidence proportion of musculoskeletal symptoms that is the direct effect of the interaction.

In our cohort, there was a considerable proportion (62.8%) of participants who were in customer service. Due to the very nature of this type of work, it would be difficult to eliminate all psychosocial constraints. Nevertheless, an optimal adjustment of the workstation would decrease the associated risk of musculoskeletal symptoms and also lower the interaction effect that results from the synergy between psychosocial and postural risk factors. Another example is the case of on-the-road technicians. It would be very difficult to design a perfect VDU workstation for them since their computer and monitor are integrated in their vehicle. However, by assuring that the psychosocial risk factors of their work (latitude and demands) are minimized, we could have a great impact on the part of the risk that comes from the synergy between postural and psychosocial risk factors. Finally, in light of the actual high prevalence of musculoskeletal symptoms among workers, even small reductions in the pathogenic effect of risk factors would likely create a considerable positive impact on public health.

Acknowledgments

The authors thank the study subjects and the work organizations that participated in this study, which was funded by the US National Institute for Occupational Safety and Health (NIOSH), grant number OH07647.

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Received for publication: 16 July 2008