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Risk factors for shoulder pain in a cohort of French workers: A Structural Equation Model

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Running head: Structural equation modeling of shoulder pain

ABSTRACT

Shoulder pain is common in the working population and causes loss of productivity, high economic costs and long periods of absence. Simultaneous evaluation of the complex relationships between work organization, psychosocial and physical risk factors, stress and shoulder pain is rare. The aim of this study was to explore the direct and indirect relationships between workplace risk factors, perceived stress and occurrence of shoulder pain in workers of the Cosali study. A total of 3,710 workers of a French region were randomly included between 2002 and 2005. They completed a self-administered questionnaire about musculoskeletal symptoms, individual factors and exposure to work constraints. In 2007, they responded to a follow-up questionnaire. The study sample contained 1,400 workers free from shoulder pain at baseline. Structural equation models were used. For both genders, exposure to factors related to the work organization had an effect on physical and psychosocial risk factors. Psychological demand was the only psychosocial constraint that increased perceived stress. Shoulder pain was influenced directly by physical risk factors for both genders and perceived stress for men. In view of their distal action, work organization is an important target for strategies in the prevention of shoulder pain in the working population.

KEY WORDS: shoulder pain; musculoskeletal; work; occupational exposure; structural equation modeling

Abbreviations: MSD, musculoskeletal disorder; OP, occupational physician; RMSEA, root mean square error of approximation; RNI, relative noncentrality index; SEM, structural equation modeling; SRMR, standardized root mean square residual; TLI, Tucker-Lewis index

Shoulder pain is common in the working population and causes greater loss of productivity, higher economic costs for employers and longer periods of absence from work than other upper-limb pain (1,2). In France, shoulder disorders accounted for 26% (n=13,445) of occupational diseases in 2015 (3).

Numerous studies have investigated the risk factors for shoulder pain and have shown several associations with individual characteristics, physical and psychosocial factors at work (1,2,4–6). Less attention has been given to work organization (such as work pace, the application of an ISO quality standard) (7,8). Several conceptual models (8–13) proposed to link work organization to musculoskeletal disorders (MSD). In these models, work organization factors were considered as distal risk factors for MSDs influencing exposure to proximal factors such as physical and psychosocial risk factors. For example, temporal (cycle time, work/rest period, etc.) and physical (workstation dimensions, loads and force level required, etc.) characteristics of the work situation determine exposure to physical factors. Similarly, work organization and management practices influence work-related psychosocial factors by determining the human resources allocated to the production activity, and also the quality of work relationships and social support (14). This supports the following hypothesis:

Hypothesis 1: Exposure to factors related to the work organization has an effect on physical and psychosocial risk factors.

According to different conceptual models, psychosocial risk factors, such as high job demand and low decision latitude, can influence shoulder pain through an increase of perceived stress at work (4,10). This supports the following hypothesis:

Hypothesis 2: Exposure to psychosocial constraints increases the risk of perceived stress.

Psychosocial risk factors can also influence shoulder pain in increasing exposure to physical risk factors (9,10,12,13). For example, workers with low decision latitude may be limited in their way to organize their workload, possibly resulting in higher physical exposure. The relationship between social support and physical exposure may be two-way; workers exposed to high physical risk factors may have strong social support from the hierarchy and coworkers to cope with these constraints. High social support could increase cooperation between coworkers during manual handling and reduce the physical exposure. On the other hand, workers with low social support from the hierarchy and coworkers may be exposed to higher physical risk factors. However, few studies have investigated the relationships between psychosocial and physical risk factors (15). These support the following hypothesis:

Hypothesis 3: Decision latitude and psychological demand have an effect on physical risk factors.

Hypothesis 4: Social support and physical risk factors are correlated.

The associations between physical exposure and shoulder pain are well established (1,2,5). Epidemiological evidence of the associations between mental stress and shoulder pain is still scant (16–19). Neurophysiological studies suggest that stress increases the activity of the motor units of shoulder muscles leading to increased muscle tension (7,16–18,20). This supports the following hypothesis:

Hypothesis 5: Exposure to physical risk factors and perceived stress increases the risk of shoulder pain.

In addition, we postulated that psychosocial risk factors are correlated, that age influences shoulder pain, physical risk factors and perceived stress, and that body mass index has a positive influence on shoulder pain (10).

Identifying distal and proximal factors related to shoulder pain is important to help preventers to act on these factors. Several studies have used structural equation modeling (SEM) to study relationships between individual characteristics, workplace risk factors and MSDs (Appendix 1)

(16–18,21–25). However, simultaneous evaluation of the complex relationships between work organization, psychosocial and physical risk factors, stress and MSDs is rare.

Using data from the surveillance program for MSDs implemented in the Pays de la Loire region by Santé publique France, the French Public Health Agency, the aim of this longitudinal study was to explore the distal and proximal relationships between work organization, psychosocial and physical risk factors at baseline and perceived stress and shoulder pain at follow-up in French workers. A conceptual model (Figure 1) was defined, based on the literature and field experience and the expertise of the authors (8–13), in which the hypotheses described above were tested.

METHODS

Study population

The Cosali (COhorte des SAlariés LIgériens, acronym for cohort of workers living in the Pays de la Loire region) study was based on a large sample of workers in the Pays de la Loire region in France (Loire valley area, west central France). Between 2002 and 2005, 83 occupational physicians (OP) volunteered to take part in the study (18% of OPs of the region). They selected 3,710 workers at random (out of 184,600 under surveillance by the 83 OPs, 2.0%). Fewer than 10% of the selected workers were not included (no shows, refusals and duplications). Women were slightly underrepresented in the sample (42% vs. 47% in the region, $P<0.001$). Overall, the distribution of occupations in the sample was close to that of the regional workforce, except for the occupations not surveyed by OPs (e.g., farmers, shopkeepers and self-employed workers). In 2007, a follow-up questionnaire was mailed to subjects. In the case of non-response, they were sent two successive reminder letters. For workers who had not returned the questionnaire in 2007, the OPs were asked to pass on the questionnaire to the workers during a health examination. A total of 2,332 subjects (63%) filled out the second questionnaire.

We excluded subjects with the following characteristics: 1) craftsmen, salesmen and managers and workers in the agriculture sector at baseline because of the low number of subjects in these occupations and economic sector, 2) workers with shoulder pain at baseline, defined as workers with shoulder pain during the preceding 7 days with intensity of pain ≥2 (between 0-10) and/or with shoulder pain for more than 30 days during the preceding 12 months and 3) non-working subjects at follow-up. In addition, 4) non-respondents to the follow-up questionnaire, and 5) workers with missing data for at least one of the variables studied were excluded.

The study received approval from France's National Committee for Data Protection (Commission Nationale de l'Informatique et des Libertés), in 2001 and 2006. Each subject provided informed written consent to participation in this study.

Measurements at baseline

At baseline, workers completed a self-administered questionnaire about their socio-demographic characteristics, musculoskeletal symptoms and their working conditions during a typical working day over the 12 preceding months.

Age was dichotomized at 40 years of age, and body mass index was divided into three categories (underweight or normal weight (<25 kg/m²), overweight (25-30 kg/m²) and obese (≥30 kg/m²)).

Three types of work-related factors were studied (8–13): factors related to the work organization, psychosocial and physical risk factors.

Factors related to the work organization considered were (yes/no): "work pace dependent on customer demand" (*During a typical day, is your work pace imposed by external demand (public, client)?*) and "having industrial work rate constraints". The latter was established by two questions: *During a typical day, is your work pace imposed by the automatic movement of a product or item?* and *During a typical day, is your work pace imposed by the automatic rate of a machine?*.

Psychosocial risk factors were assessed according to the validated French version of the Karasek Job Content Questionnaire (26) and studied as continuous: decision authority, skill discretion, psychological demand, supervisor support and coworker support.

Physical risk factors were selected according to previous results in the same database (27–29): working with arms abducted, working with arms at or above shoulder level and perceived physical exertion. The postures were defined according to the criteria document for the evaluation of work-related MSDs (30) and were assessed using pictures to facilitate the workers' understanding. The response categories were presented on a 4-level Likert-type scale, as follows: "never or practically never", "rarely" (<2 hours/day), "often" (2-4 hours/day) and "always" (>4 hours/day). Perceived physical exertion was assessed using the Rating Perceived Exertion (RPE) Borg scale graduated from 6 (''very, very light'') to 20 (''maximum exertion'') and it was studied as continuous.

Measurements at follow-up

Shoulder pain at follow-up was assessed in the same way as at baseline, using a modified version of the standardized Nordic-style questionnaire (31). Workers were asked if they had experienced any aching, discomfort, pain or numbness in the shoulders in the preceding 12 months and in the preceding 7 days. The duration of symptoms during the preceding 12 months was collected (<24 hours, 1-7 days, 8-30 days, >30 days, permanently) and the intensity of pain at the time of the questionnaire was assessed on a visual analog scale ranging from 0 to 10. Shoulder pain during the preceding 7 days with intensity of pain ≥ 2 and shoulder pain lasting more than 30 days during the preceding 12 months were studied.

Perceived stress was assessed on a visual analog scale (VAS) ranging from 0 to 10 and studied as continuous.

Statistical analysis

Chi2 tests for qualitative variables and Student tests for quantitative variables were used to compare men's and women's characteristics.

SEMs were implemented to test the conceptual model (Figure 1 and Web Appendix 1) (32–34) separately for men and women to take into account possible differences in exposure to work constraints between genders (35) and potential differential effects of these constraints in men and women. Two latent variables were considered (i.e. physical factors and shoulder pain). Standardized beta parameters (interpretable in terms of correlation and ranging from −1 for a perfect negative association to 1 for a perfect positive association) were presented and statistical significance was defined as a p-value lower than 0.05. SEMs were performed with the Lavaan package of R software (version 3.2.0; The R Foundation for Statistical Computing, Vienna, Austria) using the WLSMV estimator (weighted least squares estimation with robust standard errors and a mean and variance adjusted test statistic) adapted for categorical variables (36,37). Model fit was assessed using the χ^2 test, root mean square error of approximation (RMSEA), relative noncentrality index (RNI), Tucker-Lewis index (TLI) and standardized root mean square residual (SRMR). The following cut-off values were applied to interpret the quality of the fit (38,39): p-value of the χ^2 test greater than 0.05, value lower than 0.07 for RMSEA, values greater than 0.95 for RNI and TLI and value lower than 0.08 for SRMR.

Finally, a sensitive analysis to examine the effects of a change in job or company during follow-up was performed by excluding workers who had changed job or company since baseline.

RESULTS

The study sample comprised 1,400 workers (840 men and 560 women, Web Figure 1). There were no sex differences between the 1,400 workers who were included in the analyses and the 2,310 who were not (40.3% and 42.6% of women, respectively, P=0.16). However, the included workers were younger (37.8 years (standard deviation=9.3) vs. 39.2 years (standard deviation=10.9), P<0.01) and fewer blue-collar workers were included (39.8% vs. 44.6%, P=0.004). After excluding the agriculture sector, there was no statistically significant difference between economic sectors (P=0.50).

Description of the study population is presented in Table 1. Women more often reported shoulder pain than men: 15.0% of women reported shoulder pain lasting more than 30 days compared to 8.1% of men (P<0.01) and 18.6% of women reported shoulder pain during the preceding 7 days ≥ 2 compared to 10.4% of men (P<0.01).

The SEMs showed very good fit for men (X^2 P=0.27, RMSEA=0.011 (95% CI 0.000, 0.027), RNI=0.998, TLI=0.996, SRMR=0.065) and women (X^2 P=0.070, RMSEA=0.023 (95% CI 0.000, 0.039), RNI=0.991, TLI=0.984, SRMR=0.079). For both genders (Web Figures 2 and 3, Web Table 1), the SEMs showed that exposure to industrial work rate constraints increased physical risk factors (standardized beta=0.13, P<0.01 for men and 0.27, P<0.01 for women) and decreased decision latitude (decision authority: -0.19, P<0.01 for men and -0.23, P<0.01 for women; skill discretion: -0.27, P<0.01 for men and -0.21, P<0.01 for women). In contrast, exposure to work pace dependent on customer demand decreased physical risk factors (-0.10 for men, P=0.01 and -

0.12, *P*=0.02 for women) and increased psychosocial risk factors: decision authority (0.19, *P*<0.01 for men and 0.11, *P*=0.01 for women), skill discretion (0.16 for men, *P*<0.01 and 0.13, *P*<0.01 for women) and psychological demand (0.19, *P*<0.01 for men and 0.20, *P*<0.01 for women). Physical risk factors were decreased by skill discretion (-0.13, *P*=0.01 for men and -0.18, *P*<0.01 for women). Psychological demand was the only psychosocial constraint that increased perceived stress (0.18, *P*<0.01 for men and 0.16, *P* <0.01 for women). Shoulder pain was influenced directly by physical risk factors (0.15, *P*=0.03 for men and 0.20, *P*=0.01 for women) and age (0.20, *P*<0.01 for men and 0.22, *P*<0.01 for women).

However, models differed according to gender. For men, physical risk factors were increased by psychological demand (0.10, *P*<0.01) and decreased by age (-0.11, *P*=0.01), and perceived stress directly increased shoulder pain (0.13, *P*=0.01). For women, exposure to industrial work rate risk factors reduced supervisor (-0.14, *P*<0.01) and coworker social support (-0.13, *P*<0.01). Moreover, body mass index directly increased shoulder pain (0.15, *P*=0.01).

When limiting the analysis to the 922 workers who had not changed job or company since baseline, the estimated parameters were less significant but with the same signs of association (Web Table 2). However, the model showed that skill discretion increased perceived stress for men (0.10, *P*=0.05).

DISCUSSION

This prospective study showed the distal and proximal relationships between work organization, psychosocial and physical risk factors, perceived stress and shoulder pain in workers.

Models were stratified by gender following the recommendations of Messing et al. (35). Indeed, there are differences in the prevalence of shoulder pain and exposure to workplace risk factors between men and women, and thus not stratifying the analyses can lead to some associations being overlooked.

Comparison with the literature was difficult because there are a few studies which have used SEM to study the complex relationships between workplace risk factors, stress and MSDs (16–18,21–25) and to our knowledge none had studied associations with work organization.

Our first hypothesis was confirmed in this study, i.e. industrial work rate constraints increased physical risk factors and decreased decision latitude for both genders, and decreased social support for women. A recent study found that machine-paced jobs increased physical and psychosocial factors compared to self-paced jobs (bivariate associations) (40). A review of literature by Koukoulaki et al. found that work pace increased stress and musculoskeletal symptoms, but the associations between work pace and physical and psychosocial factors were not studied (41). In our study, work pace dependent on customer demand decreased physical risk factors and increased decision latitude and psychological demand for both genders. Few epidemiological studies have studied these associations. Having to respond to customers may be firstly associated to more complex tasks than industrial work, and secondly can lead to work faster, sometimes in 'emergency mode' and to feel not having enough time to make a job of good quality (i.e. high psychological demand). Compared to work paced, workers exposed to customer demand may have more operational leeway to adjust their working strategies allowing more decision latitude.

Our second hypothesis was partially confirmed by the present study. Only high psychological demand increased perceived stress in both genders. This finding is concordant with the studies by Larsman et al. using SEM among different occupational groups (15–17). The authors studied the different dimensions of the Copenhagen Psychosocial Questionnaire (16,18) and Job Content Questionnaire (17) and they showed that high work demand had a direct effect on stress. Another epidemiological study among assembly workers, using logistic regression, found that psychological demands and social support were associated with high stress, but not decision latitude (42).

Our study showed that physical risk factors were increased by high psychological demand in men and decreased by high skill discretion in both genders. The association between coworker support and physical risk factors was of borderline significance in women (P=0.06) suggesting that workers exposed to high physical load have more social support from their colleagues. Our third and fourth hypotheses were thus partially confirmed. Few studies have investigated the relationships between physical and psychosocial risk factors (15). Park et al. found that job stress factors had a direct effect on physical factors using SEM (24).

Our results partially confirmed the fifth hypothesis; exposure to physical risk factors at baseline increased the risk of shoulder pain at follow-up in workers. This is consistent with the literature (5,6,43). However, Eatough et al. found that physical demands did not have a significant effect on shoulder pain using SEM (22). The path between perceived stress and shoulder pain was significant only for men. Previous epidemiological studies using logistic regression (19,42) and SEM (18) support this finding, but analyses were not stratified by gender. Psychosocial stress is known to increase neck and shoulder muscle tension and modify the recruitment of the motor unit of the neck and shoulder muscles. This can lead to muscle pain and lack of motor coordination, decreasing the efficiency of postures (44). Larsman et al. showed that the relationship between stress and neck/shoulder pain was mediated by perceived muscle tension in medical secretaries (16).

Our study showed that older age increased the occurrence of shoulder pain in both genders. This is consistent with the degenerative changes in aging rotator cuff tendons and with literature using logistic regression modeling (19,27,45). The results showed that older age decreased physical risk factors only in men. It is possible that physical work is distributed differently between older and younger workers in companies. Older workers perform tasks for which their skills acquired by longer experience are more useful rather than their physical ability. This distribution of physical work can come from the workers themselves or the company.

High body mass index increased the occurrence of shoulder pain in women. This is consistent with previous results using logistic regression modeling (27). Two other longitudinal studies found this association, but analyses were not stratified by gender (19,46).

The prospective design was a major strength of this study and the random selection of workers during a health examination at baseline was designed to ensure a representative sample of the region's workforce. However, the sample counted less women than the general population. This could be explained by the lack of occupational physicians in two economic sectors highly populated by women, i.e., education and health. Moreover, the percentage of loss to follow-up was high (39%). The follow-up period coincided with a major economic downturn in the region, during which insecure workers changed jobs, and it was thus difficult to follow them up. In addition, selection bias linked to the "healthy worker effect" cannot be excluded, leading to under-estimation of associations.

SEM was used in this study offering the possibility of studying several outcomes simultaneously, and allowing exploration of interrelationships between different risk factors and identifying their respective distal and proximal roles in the prediction of outcomes, unlike the logistic regressions used conventionally. As previous shoulder pain is a strong predictor of future shoulder pain, analyses were performed only on data from workers free of shoulder pain at baseline, as conventionally reported in the literature (19,45,46). In our conceptual model based on the literature, some associations are assumed to be causal. However, SEMs estimate associations only.

Certain methodological issues warrant attention. Due to the length of our self-administered questionnaire, no questions were asked about perceived muscle tension, family status, sports or life events. Park et al. (24) found that lifestyle factors (smoking, drinking and exercise) had distal effects on musculoskeletal pain through physical and job stress factors. In our study, only one dimension (i.e. perceived stress) was used to measure psychological health in contrast to several studies that used other dimensions such as depression, frustration and anxiety (22,23,25) . Another limitation of this study was that all data were self-reported and this could have introduced bias. However, standardized questionnaires were used. Shoulder pain was assessed by means of the Nordic questionnaire, it permits sensitive and reproducible assessment of the prevalence and incidence rates of musculoskeletal symptoms (47). Assessment of shoulder postures was requested for a typical workday in the preceding 12-month period and was based on the recommendations of the European consensus to standardize the diagnoses of specific MSDs and the definition of their risk factors (30). Pictures were used to facilitate workers' understanding and increase the validity of self-assessment of posture. The French version of the Job Content Questionnaire was used (26), and the questions regarding industrial work rate constraints and work pace dependent on customer demand came from large French studies of DARES (Directorate for Research, Studies, and Statistics) (48). Lesage et al. showed that visual analog scale is an efficient tool to assess stress (49).

Shoulder pain is common in the working population and identifying distal and proximal factors related to shoulder pain is important to prevent them. Our study encourages the use of SEM to improve understanding of the relationships of different risk factors with complex interactions. We showed that factors related to the work organization influenced both psychosocial and physical risk factors that in turn influenced shoulder pain. The results need to be tested in others populations. Work organization is an important target for strategies for the prevention of shoulder pain in the working population. More research, implicating researchers from various disciplines (ergonomics, epidemiology, etc.), is needed to determine if organizational measures increasing decision latitude combined with technical measures decreasing the physical workload may prevent shoulder pain.

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LEGENDS OF THE FIGURES

Figure 1: Conceptual model linking work-related and personal factors to shoulder pain. H: Hypothesis tested.

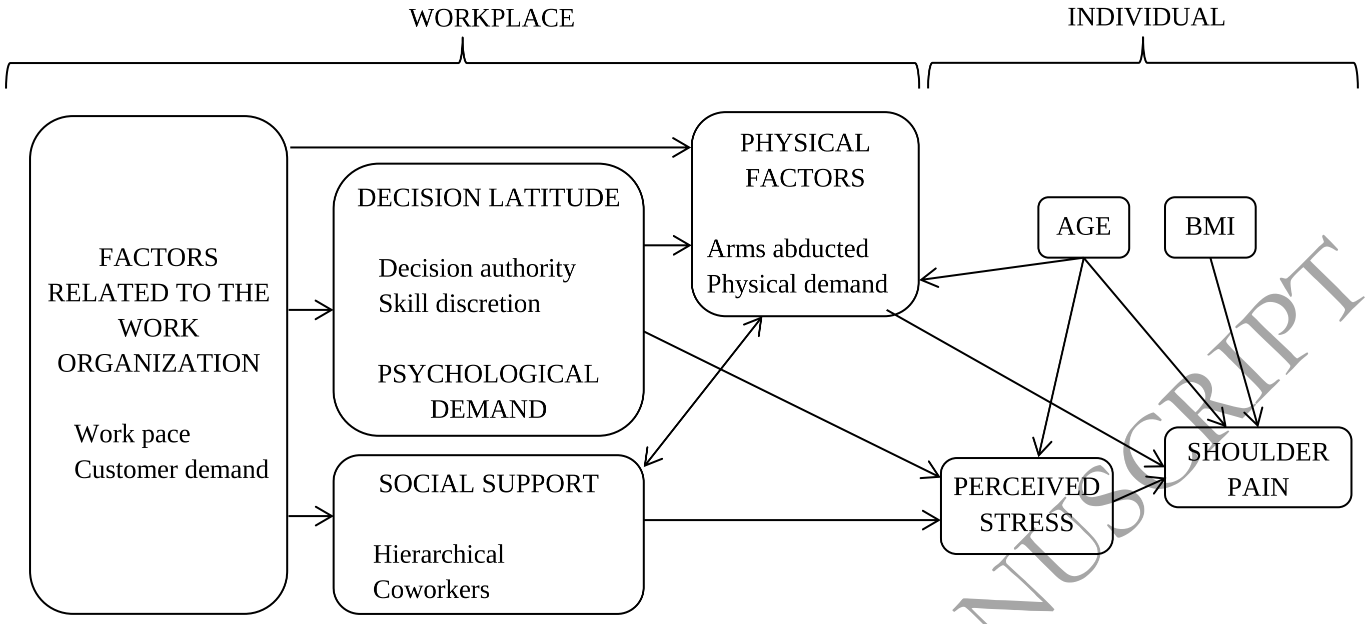
Table 1: Comparison of workers characteristics according to gender, Cosali (COhorte des SAlariés Ligériens) survey (n=1,400), 2002–2009

Characteristic	Together (n=1,400)			Men (n=840)			Women (n=560)			*P*
	No.	%	Mean (SD)	No.	%	Mean (SD)	No.	%	Mean (SD)	
Baseline characteristics (2002-2005)										
Age ≥40	628	44.9		382	45.5		246	43.9		0.57[a]
Body mass index[b]										<0.01[a]
Underweight-Normal (<25)	907	64.8		490	58.3		417	74.5		
Overweight (25-30)	382	27.3		288	34.3		94	16.8		
Obesity (≥30)	111	7.9		62	7.4		49	8.8		
Industrial work rate constraints	190	13.6		128	15.2		62	11.1		0.03[a]
Work pace dependent on customer demand	652	46.6		389	46.3		263	47.0		0.81[a]
Arms above shoulder level										<0.01[a]
Never or almost never	925	66.1		521	62.0		404	72.1		
Rarely (< 2 hours a day)	338	24.1		234	27.9		104	18.6		
Often (2 to 4 hours a day)	107	7.7		71	8.4		36	6.4		
Most of the time (≥ 4 hours a day)	30	2.1		14	1.7		16	2.9		
Arms abducted										<0.01[a]
Never or almost never	990	70.7		560	66.7		430	76.8		
Rarely (< than 2 hours a day)	234	16.7		170	20.2		64	11.4		
Often (2 to 4 hours a day)	122	8.7		78	9.3		44	7.9		
Most of the time (≥ 4 hours a day)	54	3.9		32	3.8		22	3.9		
Perceived physical demand (Borg's RPE)			11.4 (3.1)			11.9 (3.0)			10.8 (3.1)	<0.01[c]
Decision authority			36.7 (7.1)			37.3 (6.8)			35.9 (7.3)	<0.01[c]
Skill discretion			34.7 (6.4)			35.5 (6.2)			33.6 (6.5)	<0.01[c]
Psychological demand			21.5 (3.6)			21.4 (3.6)			21.5 (3.5)	0.57[c]
Supervisor support			11.6 (2.1)			11.5 (2.1)			11.8 (2.1)	0.03[c]
Coworker support			12.6 (1.8)			12.5 (1.8)			12.7 (1.9)	0.13[c]
Follow-up characteristics (2007-2009)										
Stress			3.9 (2.4)			3.7 (2.3)			4.2 (2.4)	<0.01[c]
Shoulder pain lasting more than 30 days during the preceding 12 months	152	10.9		68	8.1		84	15.0		<0.01[a]
Shoulder pain during the preceding 7 days with intensity level higher than 2	191	13.6		87	10.4		104	18.6		<0.01[a]

Abbreviation: SD, standard deviation; RPE, Rating Perceived Exertion.

[a]Chi2 test comparing characteristics according to sex.

[b]Weight (kg)/height (m)^2.
[c]Student's t-test comparing characteristics according to sex.


WORKPLACE
INDIVIDUAL
FACTORS RELATED TO THE WORK ORGANIZATION
Work pace
Customer demand
DECISION LATITUDE
Decision authority
Skill discretion
PSYCHOLOGICAL DEMAND
SOCIAL SUPPORT
Hierarchical
Coworkers
PHYSICAL FACTORS
Arms abducted
Physical demand
AGE
BMI
PERCEIVED STRESS
SHOULDER PAIN