Studying the relationship between low back pain and working postures among those who stand and those who sit most of the working day

Article *in* Ergonomics · November 2009

Impact Factor: 1.56 · DOI: 10.1080/00140130903141204 · Source: PubMed

3 authors:

France Tissot
Institut National de Santé Publique du Qué…
15 PUBLICATIONS **294** CITATIONS
SEE PROFILE

Karen Messing
Université du Québec à Montréal
163 PUBLICATIONS **2,493** CITATIONS
SEE PROFILE

Susan R Stock
Institut National de Santé Publique du Qué…
53 PUBLICATIONS **1,971** CITATIONS
SEE PROFILE

Ergonomics
Vol. 52, No. 11, November 2009, 1402–1418

Taylor & Francis
Taylor & Francis Group

Studying the relationship between low back pain and working postures among those who stand and those who sit most of the working day

F. Tissot[a]*, K. Messing[a,b] and S. Stock[b]

[a]*Centre for the Study of Biological Interactions in Human Health, CINBIOSE, University of Quebec at Montreal, CP 8888, Succ. Centre-Ville, Montréal, Québec, H3C 3P8, Canada;* [b]*Groupe scientifique sur les troubles musculo-squelettiques liés au travail, RBEO, Institut national de santé publique du Québec, and Department of Social and Preventive Medicine, Université de Montréal*

(*Received 12 August 2008; final version received 23 June 2009*)

A relationship between low back pain (LBP) and prolonged standing or prolonged sitting at work has not been clearly shown, despite its biological plausibility. Because sitting and standing postures vary as to duration and freedom to alternate postures, and standing postures vary as to mobility, associations between specific working postures and LBP were explored using multiple logistic regression. Associations between work factors and self-reported LBP during the previous 12 months that interfered with usual activities were examined among 4493 standing workers and 3237 sitting workers interviewed in the 1998 Quebec Health and Social Survey; 24.5% reported significant LBP. Since the same conditions can correspond to different physiological demands for sitting compared with standing workers, analyses were performed separately for the two groups. Standing without freedom to sit was associated with LBP. Different occupational physical and psychosocial factors were associated with LBP in sitting compared with standing populations.

Keywords: low back pain; working postures; prolonged standing; work-related musculoskeletal disorders; gender-based analysis

1. Introduction

Low back pain (LBP) is an important occupational health problem in Canada and in most industrialised countries. In 2002, estimates of the cost of back pain in Quebec ranged from $1.9 to $3.9 billion (Dionne *et al.* 2004). Physical work demands that have been clearly associated with LBP in the scientific literature include heavy physical work, manual materials handling, frequent bending and twisting and whole body vibration (Burdorf and Sorock 1997, Bernard 1997, National Research Council 2001). Systematic reviews of epidemiologic studies have not been able to support a relationship of LBP with prolonged standing or walking (Bernard 1997, Burdorf and Sorock 1997, Hoogendoorn *et al.* 1999) or with prolonged sitting (Hartvigsen *et al.* 2000, Lis *et al.* 2007, Chen *et al.* 2009), despite the biological plausibility of such relationships and evidence for them from laboratory studies (e.g. for prolonged standing: Rys and Konz 1988, Rys and Konz 1989, Konz *et al.* 1990, Zhang *et al.* 1991, Jorgensen *et al.* 1993, Redfern and Chaffin 1995, Hansel *et al.* 1998, Cham and Redfern 2001, Nelson-Wong *et al.* 2008, Gregory and Callaghan 2008; for prolonged sitting: Marras *et al.* 1995, Wilder and Pope 1996, van Deursen *et al.* 1999, Wilke *et al.* 1999, McGill and al. 2000, Callaghan and McGill 2001, Van Dieën *et al.* 2001).

These inconsistent results could arise from a lack of precision in defining sitting and standing postures. In fact, sitting and standing postures at work vary as to duration and freedom to alternate postures, and standing postures vary as to mobility (i.e. the degree to which workers may walk or move their feet while standing), although few studies have measured these parameters of postural differences or taken them into account when studying the association between general working posture and LBP (Van Dieën and Oude Vrielink 1998, Laperrière *et al.* 2005, Tissot *et al.* 2005). For example, many studies have combined standing with walking (Svensson and Andersson 1989, Walsh *et al.* 1989, Pietri *et al.* 1992, Macfarlane *et al.* 1997, Xu *et al.* 1997, Leroux *et al.* 2005, Andersen *et al.* 2007). Some studies that examined the physiological effects of working postures have combined sitting with standing in a category called 'sedentary' or 'static' postures (Brand *et al.* 1988, Van Nieuwenhuyse *et al.* 2006).

Epidemiologic studies that have also examined the relationship between prolonged sitting posture and LBP, did not specify whether the study subjects were

*Corresponding author. Email: tisdufour@videotron.ca

ISSN 0014-0139 print/ISSN 1366-5847 online

DOI: 10.1080/00140130903141204
http://www.informaworld.com

free to move around or to stand (eg: Svensson and Andersson 1989, Walsh *et al.* 1989, Linton 1990, Holmström *et al.* 1992, Johansson and Rubenowitz 1994, Liira *et al.* 1996, Skov *et al.* 1996, Xu *et al.* 1997, Macfarlane *et al.* 1997, Devereux *et al.* 1999, Vingard *et al.* 2000, Ratzon *et al.* 2000, Hoogendoorn *et al.* 2000, Thorbjörnsson 2000, Leroux *et al.* 2005). In bivariate analyses, Svensson and Andersson (1989) found no association between LBP and unscheduled rest breaks or the ability to change postures at work. Van Nieuwenhuyse *et al.* (2006) found that inability to change posture regularly was significantly associated with an increased risk of LBP but the dominant posture (sitting vs. standing) of workers was not identified, so that we do not know whether the risk was present among both categories of workers. Degree of constraint of standing postures has been found to be significantly associated with pain in the distal lower limb in a cross-sectional population study (Messing *et al.* 2008).

To our knowledge, there has been no population-based research on the contribution of different types of sitting and standing postures to LBP. The 1998 Quebec Health and Social Survey (QHSS), a province-wide household survey, contained a self-administered questionnaire (SAQ) that included questions evaluating different types of sitting and standing postures according to mobility and constraint. In the present study, the objectives were (1) to investigate the prevalence of LBP reported to have interfered with usual activities often or all the time over the previous 12 months, in the general working population of Quebec, and (1) to determine whether and which working postures are associated with an increased risk of reporting LBP, while taking into account individual characteristics and other physical and psychosocial demands of work.

Because the same working condition corresponds to different physiological demands among sitting and standing workers and since the two groups are exposed to different work-related risk factors (Aaras *et al.* 1997, Lehman *et al.* 2001, Tissot *et al.* 2005), analyses were performed separately for sitting and for standing workers. As women and men are often assigned different work tasks, and therefore working conditions called by the same name may correspond to different realities for men and women, analyses were stratified by gender (Messing *et al.* 2003).

2. Methods

2.1. *Study design and study sample*

Data were taken from the 1998 Quebec Social and Health Survey (1998 QSHS), a household-based population survey of a weighted random sample of all residents outside institutions and Indian reserves in Quebec, Canada. The survey used a two-stage cluster-sampling plan stratified by region (Daveluy *et al.* 2001). The final population sampled for the 1998 QSHS is estimated to represent 97.3% of the target population. Two data collection instruments were used in this study: An Interviewer-Administered Questionnaire (IAQ) completed by a member of each household (at least 18 years of age) for each member of the household and a SAQ completed by each member of the household aged 15 and over. In all, 30,386 individuals were sampled using the interviewer-administered questionnaire (weighted response rate 82%), and 20,773 respondents completed the self-administered questionnaire (a weighted proportion of 84%). The overall self-administered questionnaire weighted response rate was 69%.

There were 11,735 respondents to the self-administered questionnaire who, at the time of the study, worked full time or part time at a paid job for an employer or who were self-employed. Those who had less than 12 months seniority at their current job, worked less than 25 h/wk, were pregnant, were not aged 18 to 65 or did not answer the questions on general working postures or low back symptoms were excluded from the following analyses. The sample for the current study, meeting the above inclusion and exclusion criteria, comprised 4517 men and 3213 women.

2.2. *Variables and measures*

2.2.1. *Outcome (LBP)*

The questions concerning musculoskeletal symptoms were adapted from the standardised Nordic questionnaire (Kuorinka *et al.* 1987). Respondents of the SAQ were presented a body map with 11 body sites and asked: 'In the past 12 months, have you had any significant pain in any of the following body sites which interfered with your usual activities? (never, occasionally, fairly often, all the time)'. For the present analyses, the case definition for LBP included subjects who reported significant low back pain during the previous 12 months that interfered with their usual activities 'fairly often' or 'all the time'; these represented 24.5% of the sample (weighted percentage).

2.2.2. *Work postures*

Sitting or standing posture was assessed by the question 'During your normal work day, do you usually work ... (1) standing?; (2) sitting?' Two other questions evaluated the levels of constraint or mobility. Those who reported that they usually stood at work

were asked, 'Which of the following best describes your posture most of the time: 1) Standing in a fixed position with no possibility of moving around; 2) Standing in a relatively fixed position, with the possibility of making one or two steps ; 3) Standing and moving around a little bit (for example, from one machine or desk to another); 4) Standing and moving around a bit more (for example, from one office or building to another); 5) Standing, with the possibility of sitting down whenever you want to. Response categories 1 and 2 were combined and characterise those who work in a fixed or relatively fixed standing posture and response categories 3 and 4 were combined and characterise those who work mostly in a mobile standing posture. (See the following section for explanations of the grounds for the decision to merge adjacent exposure categories.)

Those who reported that they usually sat were asked, 'Which of the following best describes your posture most of the time: 1) Sitting in a fixed position with no possibility of getting up and moving around; 2) Sitting, with the possibility of getting up once in a while; 3) Sitting, with the possibility of getting up whenever I want to. In the present analyses, those who worked standing, with the possibility of sitting down whenever they want to were used as the reference category for workers who work in a standing posture; those who worked sitting with the possibility of getting up at will were the reference category for workers who work in a sitting posture.

2.2.3. *Other physical factors at work*

Five other measures of physical demands were included in the study: repetitive hand or arm movement (assembly line work, work speed determined by a machine, very fast rate of production, etc.); handling heavy loads (lifting or carrying people or objects such as boxes, furniture, etc.); forceful exertion when using tools, machines or equipment; vibration from hand-held or hand-operated tools (hand/arm vibration = HAV) and vibration from large machinery, from vehicles or from the ground (whole body vibration = WBV). The response scale for these measures was categorised as: never or occasionally; fairly often; all the time.

2.2.4. *Psychosocial factors at work*

Work-related psychological demands and decision latitude were assessed with the two 9-item indices from the Karasek Job Content Questionnaire (Karasek 1985), previously validated for Quebec workers (Brisson *et al.* 1998, Larocque *et al.* 1998). For these two indices, respondents were dichotomised according to the median score observed in the 1990 Québec Cardiovascular Health Survey (Daveluy *et al.* 1994) as low/high decision latitude and low/high psychological job demands. Workers exposed to both high psychological job demands and low decision latitude were defined as the high-strain group; workers not exposed to either job constraint composed the low-strain group. These variables were also categorised into terciles to allow comparison of low, medium and high decision latitude and psychological job demands exposure groups.

Four additional workplace psychosocial constraints were examined: physical violence, intimidation at work; unwanted sexual attention and difficult or tense situations with the public. The response scale for violence, intimidation and unwanted sexual attention was dichotomised to the categories: never versus occasionally, often or very often. The response scale for experiencing difficult or tense situations with the public at work was dichotomised to the categories: never, rarely or occasionally versus often or very often.

2.2.5. *Other relevant work variables*

Work hours were grouped so as to have enough people in each group for multivariate analyses. The 'normal' work week set by the Québec Labour Standards Act (article 52) is 40 hours, after which an employee begins to work overtime. But for some groups of workers such as those in the public sector, a 35-hour work week is the norm. The categories of working hours/week were: 25 to 35 hours; 36 to 40 hours; more than 40 hours. Working night shift, irregular shift and exposure to loud noise were also included in the study. The response scale for these measures was categorised as: never or occasionally; fairly often; all the time. A variable combining long hours of paid work per week (>40 hours/week) and living with 2 or more children (<18 years) was created to measure the 'double burden' of combining paid work with family obligations.

2.2.6. *Personal factors*

Sociodemographic variables included age (18–24; 25–39; 40–49; 50–65), education (having a high-school diploma; no high-school diploma), having preschool children and number of children. The sufficiency of family income indicator was calculated using the ratio of household income to the poverty threshold income established by Statistics Canada for household size (quintiles) (Chevalier and Sauvageau 2001). Other individual variables included smoking (non-smoker; ex-smoker; current smoker), leisure time physical

activity (never or once, twice or three times a month; once or twice a week; three times a week or more), body mass index (underweight [<20 kg/m^2]; healthy [≥ 20, <27 kg/m^2]; overweight [≥ 27, <30 kg/m^2] and obese [≥ 30 kg/m^2]).

A 14-item Psychiatric Symptoms Index (Ilfeld 1976) assessed psychological distress. The 14 items describe symptoms associated with depressive and anxiety states, cognitive difficulties and irritability, over the preceding 7 days. The level representing the least distressed 80% of the Québec population in 1987 (Boyer *et al*. 1993) was used as a reference category. The Social Support Index (Camirand *et al*. 1993) includes 11 items on social participation, satisfaction with social relations and size of support network. The lowest quintile was considered as having low social support.

2.3. *Statistical analysis*

All outcome and exposure prevalence estimates presented are weighted estimates. Weights were provided by the Institut de la statistique du Québec to make the sample representative of the population and to correct for nonresponse (Daveluy *et al*. 2001).

Chi-square (χ^2) tests were carried out to assess differences in proportions, for all the potential explanatory work-related variables of the study, between workers who sat most of the time and those who stood most of the time. Using logistic regression, bivariate analyses were conducted, separately for those who usually sat and those who usually stood, to obtain the crude odds ratios (OR) of LBP and the associated p value in relation to each exposure variable. When categories had small numbers, adjacent categories of variables were combined. This was the case for the categories 'fairly often' and 'all the time' for the exposures to forceful exertion and to WBV among the sitting population.

The variable selection process employed was that proposed by Hosmer and Lemeshow (2000), for studies with many potential explanatory variables, whereby variables for which at least one category was associated at $p < .25$ with an increased risk of LBP were retained for the multivariate analyses, with the exception of age and BMI, which were included a priori as potential confounding factors.

A manual stepwise backward deletion approach was used; independent variables which did not meet a level of significance of 0.05 were removed from the multivariate logistic models one variable at a time, provided that the omission did not alter the estimated odds ratio of other variables in the model by more than 10% nor alter the goodness of fit of the model (Sun *et al*. 1996). To identify potential collinearity, the degree of interrelationship of the various risk factors selected for the multivariable analyses was verified using Spearman's rank correlation coefficients. None of the study variables had correlations higher than 0.5. When adjacent categories of a categorical variable exhibited roughly equivalent risks in a multivariate analysis they were combined in order to maximise the statistical power of that analysis when appropriate. Two-way interactions terms were included in the multivariate analyses. Odds ratios and 95% confidence intervals were determined for each variable in the model.

The Hosmer-Lemeshow and deviance χ^2 goodness of fit statistics were used to assess the fit of the final logistic regression models (Hosmer and Lemeshow 2000).

SAS software, version 9.1.3 (SAS Institute, Cary, NC) and SUDAAN software, version 9.0 (Research Triangle Institute, Research Triangle Park, NC) was used for all statistical analyses to account for the complex sampling design.

3. Results

3.1. *Prevalence of LBP and bivariate associations with postures at work*

Table 1 presents the prevalence of working postures and associations with LBP. The overall prevalence of LBP that interfered with usual activities fairly often or all the time over the past 12 months was 24.5%. There was no significant gender difference in prevalence of LBP.

A significantly larger proportion of men than women usually stand at work (58% versus 51%). The prevalence of LBP in male workers was significantly higher among those who work in a standing posture to compared to those who usually work sitting (27.8% versus 21.7%; $p = .001$). The difference was not significant among women (24.8% versus 21.7%; $p = .087$).

Among workers who usually stand at work, women are more likely to work in a fixed position while men are more likely to move around. The prevalence of LBP was significantly higher among those exposed to 'constrained' standing postures (defined as standing postures other than standing with freedom to sit at will) compared to standing with freedom to sit, for both men and women (28.6% for moving around and 30.4% for standing in a fixed posture versus 17.4% for standing with freedom to sit; $p < 0.001$ for both comparisons, total population).

Among those who work seated, men are more likely to work in a fixed position (5.9% of men versus 1.2% of women). The prevalence of LBP among men was significantly higher among those few workers who

Table 1. Prevalence of standing and sitting postures by gender and association with significant low back pain that interfered fairly often or all the time with usual activities over the previous 12 months, 1998 Quebec working population aged 18 to 65, working at least 25 hours per week.

Usual posture ($N = 7730$)	Men $N = 4517$ %[a]	Women $N = 3213$ %[a]	Whole sample %[a]	Low back pain %[a] Men	Women	Whole sample
Sitting ($N = 3237$)	38.8	52.4	44.3	21,7	21,7	21,7
Standing ($N = 4493$)	61.2	47.6	55.7	27,8	24,8	26,7
Total population				25,4	23,2	24,5
Detailed standing postures ($N = 4394$[b])	Men $n = 2790$ %[a]	Women $n = 1604$ %[a]	Standing population %[a]			
Standing with the possibility of sitting down at will	17.4	19.6	18.2	18.3	15.9	17.4
Moving around	71.8†	66.5†	70.0	29.4	27.0	28.6
Standing in a fixed or relatively fixed position[c]	10.8*	13.9*	11.8	33.4	25.8	30.4
Detailed sitting postures ($N = 3227$[b])	Men $n = 1663$ %[a]	Women $n = 1564$ %[a]	Sitting population %[a]			
Sitting with the possibility of getting up at will	78.2	81.5	79.8	20.2	20.5	20.4
Sitting with the possibility of getting up once in a while	15.9	17.3	16.6	24.3	26.9	25.6
Sitting in a fixed position[d]	5.9§	1.2§	3.7	34.1	35.0	34.2

[a]All estimates are weighted to reflect the population and adjusted for the sampling design with SUDAAN.
[b]Denominators vary because of missing values.
[c]Standing in a fixed position with no ability to move around or in a relatively fixed position, with the ability to make one or two steps.
[d]With no possibility of getting up and moving around.
*$p < 0.05$, †$p \leq 0.01$, ‡$p \leq 0.005$, §$p \leq 0.001$ for difference between men and women.

worked in a fixed position compared with those who could get up at will (34.1% versus 20.2%; $p < 0.001$). Among women, the difference in prevalence of LBP in these two groups was borderline, possibly because the number of exposed women was so small (35.0% among workers in a fixed position vs. 20.5% among those who could stand at will; $p = .087$).

3.2. *Bivariate associations between usual working posture and workplace factors*

Men and women who usually stood at work reported more frequent exposure to other physical risk factors than those who usually sat, with the exception of whole body vibration (WBV) (Table 2). Women who usually stood also reported more frequent exposure to intimidation, unwanted sexual attention, physical violence and tense situations with the public than women who worked sitting. Compared with men who usually sat, men who stood most of the time also reported more exposure to unwanted sexual attention at work but less exposure to difficult or tense situations with the public. Both men and women who stood at work reported more frequent exposure to low decision latitude, but less frequent exposure to high psychological job demands compared to those who usually sat.

3.3. *Factors associated with LBP in multivariate models*

Few women who usually sat reported working night shifts, being exposed to HAV or WBV, physical violence or working long hours of paid work per week while living with 2 or more children under 18 (prevalence <3%). Thus, these risk factors could not be included in the multiple logistic regression (MLR) analysis for women. Other categories with very small counts included being exposed to WBV among women who stood and being exposed to unwanted sexual attention among men who stood.

Table 3 presents the final MLR models for those who usually worked sitting and Table 4 presents the final MLR models for those who usually worked standing. Different occupational risk factors for LBP were found among standing and sitting populations and among men and women.

Among sitting workers, physical and organisational risk factors associated with LBP included forceful exertion for both men and women and WBV and night shift which were significant for men only. Constrained sitting postures were not associated with LBP among sitting workers.

Table 2. Relationships between workplace factors and usual working posture by gender.

	Men			Women		
	Sitting %[a]	Standing %[a]	p (χ^2)	Sitting %[a]	Standing %[a]	p (χ^2)
Physical factors						
Repetitive work						
Never or occasionally	90.7	73.1	<0.001	85.6	72.3	<0.001
Fairly often	4.4	10.2	<0.001	4.8	10.4	<0.001
All the time	5.0	16.6	<0.001	9.5	17.3	<0.001
Handling heavy loads						
Never or occasionally	94.0	66.0	<0.001	97.9	80.3	<0.001
Fairly often	4.3	21.6	<0.001	1.7	12.7	<0.001
All the time	1.7	12.4	<0.001	0.4	7.0	<0.001
Forceful exertion						
Never or occasionally	90.4	61.6	<0.001	97.9	88.7	<0.001
Fairly often	6.2	23.1	<0.001	0.7	8.0	<0.001
All the time	3.4	15.4	<0.001	1.4	3.4	<0.005
Hand-arm vibration						
Never or occasionally	96.4	78.8	<0.001	98.5	96.9	<0.01
Fairly often	2.4	14.0	<0.001	0.6	1.6	<0.05
All the time	1.2	7.2	<0.001	0.9	1.5	ns
Whole body vibration						
Never or occasionally	91.0	90.2	ns	99.5	99.1	ns
Fairly often	3.2	6.7	<0.001	0.2	0.6	ns
All the time	5.8	4.4	ns	0.3	0.3	ns
Psychosocial factors						
Difficult or tense situations with public						
Never, rarely, occasionally, no contact with public	71.0	75.8	<0.01	75.5	63.9	<0.001
Often or very often	29.0	24.2		24.5	36.1	
Physical violence at work						
Never	97.8	96.9	ns	99.1	93.7	<0.001
Occasionally, often or very often	2.2	3.1		0.9	6.3	
Intimidation at work						
Never	83.8	82.0	ns	83.0	77.6	<0.005
Occasionally, often or very often	16.2	18.0		17.0	22.4	
Unwanted sexual attention at work						
Never	99.1	97.9	<0.05	94.7	90.1	<0.001
Occasionally, often or very often	0.9	2.1		5.4	9.9	
Decision latitude (DL)						
Low	39.1	56.7	<0.001	59.0	62.8	ns
High	60.9	43.4		41.0	37.2	
Psychological job demands (JD)						
Low	46.7	53.9	<0.001	50.5	54.7	ns
High	53.3	46.1		49.5	45.3	
Job strain						
Low strain JD^- DL^+	22.8	20.5	ns	17.9	18.6	ns
Passive JD^- DL^-	23.8	33.4	<0.001	32.6	36.1	ns
Active JD^+ DL^+	38.1	23.0	<0.001	23.3	18.6	<0.05
High strain JD^+ DL^-	15.3	23.1	<0.001	26.3	26.6	ns
Decision latitude (terciles)						
High	48.3	33.8	<0.001	27.6	26.6	ns
Medium	32.2	31.9	ns	37.6	32.1	<0.05
Low	19.6	34.3	<0.001	34.8	41.3	<0.01
Psychological job demands (terciles)						
Low	26.7	32.7	<0.001	28.0	35.2	<0.005
Medium	32.1	35.2	ns	33.5	33.9	ns
High	41.3	32.1	<0.001	38.5	30.9	<0.001
Worktime and workhours						
Irregular schedule						
Never or occasionally	63.0	69.5	<0.005	86.3	72.3	<0.001

(*continued*)

Table 2. (*Continued*).

	Men			Women		
	Sitting %[a]	Standing %[a]	p (χ^2)	Sitting %[a]	Standing %[a]	p (χ^2)
Fairly often	21.8	16.9	<0.01	9.0	16.6	<0.001
All the time	15.2	13.6	ns	4.6	11.1	<0.001
Night shift						
Never or occasionally	88.5	85.0	<0.05	98.7	90.9	<0.001
Fairly often	7.9	7.1	ns	1.0	4.0	<0.001
All the time	3.6	7.9	<0.001	0.3	5.1	<0.001
Length of work week						
25–35 hours	16.9	11.7	<0.001	46.7	42.6	ns
36 to 40 hours	46.0	56.7	<0.001	44.0	44.3	ns
>40 hours	37.0	31.6	<0.005	9.3	13.1	<0.005
Loud noise						
Never or occasionally	91.1	73.7	<0.001	97.5	92.2	<0.001
Fairly often	5.4	14.9	<0.001	1.6	4.4	<0.001
All the time	3.5	11.3	<0.001	0.9	3.4	<0.001

NS = not significant.
[a]All estimates are weighted to reflect the population and adjusted for the sampling design with SUDAAN.

Table 3. Risk factors associated with significant low back pain that interfered with usual activities in the previous 12 months among men, women and total population: results of the final logistic regression models, 1998 Quebec working population aged 18 to 65, working at least 25 hours per week and working mostly in a sitting posture.

	Adjusted OR (95%CI)		
	Men[a]	Women[a]	Total sitting population[a]
Gender			
Male			1.0
Female			1.39 (0.95–2.04)
Age group (y)			
25–39	1.0	1.0	1.0
18–24	0.92 (0.36–2.33)	3.39 (1.55–7.42)[‡]	0.92 (0.41–2.03)
40–49	1.42 (0.98–2.05)[b]	0.80 (0.56–1.14)	1.42 (0.98–2.05)[b]
≥50	1.13 (0.74–1.73)	0.75 (0.44–1.30)	1.10 (0.73–1.66)
Age group (y) BY gender (interaction)			
18–24 by gender			3.73 (1.19–11.63)*
40–49 by gender			0.58 (0.35–0.97)[†]
≥50 by gender			0.72 (0.37–1.40)
Household income			
Higher income	1.0		
Upper middle income	0.78 (0.50–1.21)		
Lower middle income	1.41 (0.87–2.27)		
Poor or very poor	0.93 (0.37–2.35)		
BMI			
Healthy weight (20 to 26.9)	1.0	1.0	1.0
Underweight (<20)	0.84 (0.26–2.76)	0.67 (0.40–1.12)	0.68 (0.43–1.08)
Overweight (27 to 29.9)	1.14 (0.73–1.78)	0.83 (0.48–1.42)	1.00 (0.72–1.40)
Obese (≥30)	1.19 (0.77–1.84)	1.43 (0.87–2.35)	1.22 (0.88–1.69)
Leisure physical activities			
Three times a month or less	1.0	1.0	
Once or twice a week	0.90 (0.63–1.29)	1.44 (0.99–2.08)[c]	
3 times a week or more	1.29 (0.83–1.99)	1.24 (0.79–1.95)	
Night shift			
Never or occasionally	1.0		1.0
Fairly often	0.93 (0.53–1.64)		1.08 (0.62–1.85)
All the time	2.25 (1.08–4.69)*		2.25 (1.21–4.18)*

(*continued*)

Table 3. (*Continued*).

	Adjusted OR (95%CI)		
	Men[a]	Women[a]	Total sitting population[a]
Forceful exertion			
Never or occasionally	1.0	1.0	1.0
Fairly often or all the time	1.82 (1.12–2.96)*	3.02 (1.05–8.65)*	2.43 (1.61–3.66)[§]
Whole body vibration			
Never or occasionally	1.0		
Fairly often or all the time	1.70 (0.97–2.99)[b]		
Difficult or tense situations with public			
Never, rarely, occasionally or no contact with public	1.0	1.0	1.0
Often or very often	1.69 (1.20–2.37)[‡]	1.79 (1.27–2.52)[§]	1.74 (1.40–2.17)[§]
Job strain			
Low strain PD^- DL+	1.0	1.0	1.0
Passive PD^- DL^-	1.21 (0.73–2.02)	1.20 (0.69–2.06)	1.22 (0.84–1.78)
Active PD+ DL+	1.04 (0.65–1.69)	1.36 (0.78–2.37)	1.15 (0.81–1.62)
High strain PD+ DL^-	1.37 (0.78–2.40)	1.81 (1.06–3.09)*	1.58 (1.10–2.27)*
Psychological distress			
Low	1.0	1.0	1.0
Elevated	2.22 (1.50–3.27)[§]	1.98 (1.37–2.88)[§]	2.08 (1.60–2.72)[§]

Weighted data analysed with the SUDAAN logistic regression procedure.
[a]Hosmer and Lemeshow goodness of fit test: $P = 0.910$ for the model for male workers; $P = 0.150$ for the model for female workers; $P = 0.363$ for the model for the total study population.
[b]P-value ≤ 0.065.
[c]P-value $= 0.054$.
*$p < 0.05$, [†]$p \leq 0.01$, [‡]$p \leq 0.005$, [§]$p \leq 0.001$.

Psychosocial risk factors associated with LBP included exposure to difficult or tense situations at work, among both men and women; and high job strain among women only.

Among standing workers, standing without freedom to sit at will was associated with LBP among men. But the association between LBP and a more fixed (versus freedom to sit down at will) standing posture did not reach significance among women. Other physical risk factors associated with LBP among standing workers included handling heavy loads all the time among men and women and handling heavy loads fairly often and hand-arm vibration among men only. Psychosocial risk factors associated with LBP in standing workers included high psychological job demands among both men and women and exposure to difficult or tense situations with the public and unwanted sexual attention at work among women only. Intimidation was significant in the model for the total standing study population and borderline for men (Table 4).

Differences in personal risk factors for LBP were also found among standing and sitting populations and among men and women. Among women who worked sitting, LBP was associated with age under 25 and being physically active during leisure time once or twice a week. Significantly more men with a lower middle-level income reported LBP than men with an upper middle-level income.

Among standing workers of both sexes, being physically active during leisure time less than once a week was associated with an increased risk of LBP; LBP was also associated with being overweight among women only and with current smoking among men only. Among women, LBP was associated with age under 25 years for both sitting and standing workers. LBP was significantly associated with psychological distress in both men and women, whether they worked sitting or standing.

There was no average gender effect in either total population model. Among the sitting population, there was a gender effect in the younger population (18–24) (OR = 5.19, $p = 0.004$), female gender being associated with more LBP among young workers.

4. Discussion

One of the main findings of this study is that standing at work without freedom to sit down at will is associated with low back pain in both men and women. As far as we are aware, our study is the first to examine the associations between different types of standing postures and LBP in a study population with a stratum including only workers who usually work standing.

Other major findings concern the differences between work-related physical and psychosocial

Table 4. Risk factors associated with significant low back pain that interfered with usual activities in the previous 12 months among men, women and total population: results of the final logistic regression models, 1998 Quebec working population aged 18 to 65, working at least 25 hours per week and working mostly in a standing posture.

	Adjusted OR (95%CI)		
	Men[a]	Women[a]	Total standing population[a]
Gender			
Male			1.0
Female			1.16 (0.76–1.78)
Age group (y)			
25–39	1.0	1.0	1.0
18–24	1.11 (0.72–1.71)	1.88 (1.07–3.29)*	1.44 (1.02–2.03)*
40–49	0.94 (0.71–1.24)	0.72 (0.48–1.10)	0.88 (0.69–1.13)
≥50	1.23 (0.88–1.72)	1.03 (0.64–1.64)	1.21 (0.91–1.60)
BMI			
Healthy weight (20 to 26.9)	1.0	1.0	1.0
Underweight (<20)	1.46 (0.77–2.78)	1.36 (0.81–2.29)	1.38 (0.93–2.06)
Overweight (27 to 29.9)	1.15 (0.86–1.53)	2.01 (1.21–3.33)†	1.26 (0.98–1.62)
Obese (≥30)	1.04 (0.72–1.51)	0.78 (0.46–1.32)	0.93 (0.67–1.27)
Leisure physical activities			
Three times a month or less	1.0	1.0	1.0
Once or twice a week	0.69 (0.52–0.93)*	0.64 (0.44–0.93)*	0.68 (0.54–0.86)‡
3 times a week or more	1.01 (0.72–1.42)	0.59 (0.39–0.92)*	0.89 (0.68–1.17)
Smoking status			
Non–smoker	1.0	1.0	1.0
Ex–smoker	1.34 (0.97–1.86)	0.94 (0.63–1.39)	1.42 (1.02–1.97)*
Current smoker	1.59 (1.16–2.17)‡	0.64 (0.42–0.98)*	1.60 (1.17–2.21)‡
Smoking status BY gender (interaction)			
Ex–smoker by female			0.65 (0.40–1.06)
Current smoker by female			0.43 (0.25–0.72)‡
Long hours of paid work (>40 hrs/wk) and 2 or more children (<18 yr) at home			
No		1.0	1.0
Yes		3.08 (1.36–6.99)*	0.99 (0.64–1.53)
Long hours of paid work (>40 hrs/wk) and 2 or more children (<18 yr) at home BY gender (interaction)			2.99 (1.04–8.57)*
Detailed working posture			
Standing with the possibility of sitting down at will	1.0	1.0	1.0
Moving around	1.66 (1.13–2.44)†	1.61 (1.00–2.60)*	1.62 (1.19–2.20)‡
Standing in a fixed or relatively fixed position	2.02 (1.22–3.34)†	1.48 (0.80–2.74)	1.67 (1.12–2.48)*
Handling heavy loads			
Never or occasionally	1.0	1.0	1.0
Fairly often	1.34 (1.01–1.78)*	1.06 (0.66–1.71)	1.27 (0.99–1.62)[b]
All the time	1.64 (1.12–2.40)*	2.83 (1.50–5.34)‡	1.83 (1.31–2.55)§
Hand-arm vibration			
Never or occasionally	1.0		1.0
Fairly often	1.72 (1.23–2.41)‡		1.77 (1.29–2.44)§
All the time	1.70 (1.11–2.61)*		1.64 (1.10–2.45)*
Difficult or tense situations with public			
Never, rarely, occasionally or no contact with public		1.0	1.0
Often or very often		1.58 (1.11–2.25)*	0.98 (0.73–1.31)
Difficult or tense situations with public BY gender (interaction)			1.62 (1.04–2.52)*
Unwanted sexual attention at work			
Never		1.0	
Occasionally, often or very often		1.94 (1.10–3.40)*	
Intimidation at work			
Never	1.0		1.0
Occasionally, often or very often	1.33 (0.96–1.84)		1.30 (1.01–1.67)*
Psychological job demands			
Low	1.0	1.0	1.0
Medium	1.21 (0.89–1.64)	1.67 (1.12–2.48)*	1.34 (1.05–1.71)*
High	1.49 (1.10–2.02)†	1.68 (1.12–2.52)*	1.50 (1.17–1.92)‡

(*continued*)

Table 4. (*Continued*).

	Adjusted OR (95%CI)		
	Men[a]	Women[a]	Total standing population[a]
Psychological distress			
Low	1.0	1.0	1.0
Elevated	1.73 (1.28–2.35)[§]	2.19 (1.52–3.17)[§]	1.88 (1.47–2.41)[§]

Weighted data analysed with the SUDAAN logistic regression procedure.
[a]Hosmer and Lemeshow goodness of fit test: $P = 0.748$ for the model for male workers; $P = 0.394$ for the model for female workers; $P = 0.834$ for the model for the total study population.
[b]P-value = 0.055.
*$p \leq 0.05$, [†]$p \leq 0.01$, [‡]$p \leq 0.005$, [§]$p \leq 0.001$.

factors associated with LBP in sitting compared to standing populations. Standing and sitting workers are exposed to very different working conditions (Tissot *et al.* 2005). In a large population-based study such as this one, not all relevant exposures can be measured, so separating standing and sitting populations was a way to minimise variation in unmeasured exposures within each stratum, increasing the precision of our analysis.

The results also highlight the importance of physical work load and low back pain for both men and women, particularly among standing workers. Even in sitting workers, frequent forceful exertion was very strongly associated with LBP, particularly among women. In both men and women, psychological working conditions such as difficult or tense situations with the public, intimidation at work, unwanted sexual attention at work and high psychological job demands were also quite significantly related to LBP. Significant gender differences in the relationship between age and LBP were found in both sitting and standing workers, with young female workers being at higher risk for LBP in both postures.

4.1. *Associations between LBP and working postures*

'Constrained' standing is associated with an increase in frequency of LBP in this study. Both standing in a fixed posture and walking, compared to standing with freedom to sit at will, emerged as risk factors in the multivariate analyses of this study. Explanations for the increasing perceived discomfort in the low back associated with prolonged standing include muscle fatigue from the effort required to maintain an upright posture, fatigue in the ligaments or other passive structures of the spine, intervertebral disc stress from excessive lordosis, spinal shrinkage owing to spinal loading, agonist-antagonist muscle co-activation and spinal transmission of heel impact (Radin 1973, Voloshin and Wosk 1982, Jorgensen *et al.* 1993, Whistance *et al.* 1995, Leivseth and Drerup 1997, Beynon and Reilly 2001, Nelson-Wong *et al.* 2008).

The results strongly suggest that freedom to sit down at will (being able to alternate postures) may be important in preventing LBP. This finding is supported by those of other studies (Van Dieën *et al.* 1998, Beynon and Reilly 2001). There was no evidence for an association between standing in a fixed posture and LBP among women, but the beta value of this association was 0.64, indicating a 64% probability of accepting a false null hypothesis of no difference between those who stood in a fixed posture and those who stood but were able to sit at will. Only 12.5% of the study population of standing women reported working in a fixed posture.

In the present study, constrained sitting was not a risk factor for LBP in the multivariate models. However it should be noted that, unlike standing workers, only 3.7% of those sitting (5.9% of men, 1.2% of women) work in a fixed position with no possibility of getting up and moving around; the sample size for the constrained group was quite small for men and too small to include in analyses among women. There may well be risks associated with very fixed sitting postures in specific occupational groups with exceptionally high levels of exposure, such as sewing machine operators (Jin *et al.* 2004). The results should therefore not be construed as indicating an absence of risk from constrained sitting in highly exposed occupational cohorts.

4.2. *Associations between LBP and physical work demands among sitting and standing workers*

Physical risk factors at work associated with LBP differed between sitting workers and standing workers. Handling heavy loads and HAV were associated with LBP among standing workers while forceful exertion and WBV were associated with LBP among sitting workers. Few sitting workers were exposed to frequent

and high physical work demands such as handling heavy loads or HAV vibration. Nonetheless those exposed to frequent forceful exertion of arms and hands had a 2-fold increased risk of LBP among women and close to a two-fold increase in risk (1.8) among men. It should be noted that the questionnaire definition of heavy loads included people as well as objects. Manual materials handling has long been recognised as a risk factor for LBP (e.g. Burdorf and Sorock 1997, Hoogendoorn *et al.* 1999, Punnett and Wegman 2004).

Little is known about the differences in vibration transmission when standing versus sitting nor about potential differences in associated health risks (Salmoni 2002). Also, HAV and WBV, although associated to some degree in our data set, often correspond to different sources and types of vibration. Being exposed to HAV was strongly associated with LBP among men who usually work in a standing posture. We found only one study that investigated the prevalence of LBP among various groups of subjects exposed to hand-arm transmitted vibration (Mirbod *et al.* 1997). It is possible that HAV may represent a proxy for other risk factors not measured in this study, such as non-neutral postures.

Among men who usually worked sitting, there was a strong tendency associating exposure to WBV with LBP, but no such tendency was observed among men who worked standing. WBV exposure has been widely recognised as a risk factor for LBP since many smaller-scale industry-based investigations have provided evidence on back disorders among those exposed to WBV, despite the fact that population-based surveys which have examined the risk of LBP from WBV while adjusting for other occupational risk factors have found only weak associations (Xu *et al.* 1997, Vingard *et al.* 2000, Palmer *et al.* 2003). Two reviews (Lings and Leboeuf 2000, Lis *et al.* 2007) suggest that WBV and prolonged sitting may only be risk factors for LBP when combined. Tiemessen *et al.* (2008) found that total hours of exposure to WBV was the most important parameter of WBV involved in driving-related LBP, and therefore suggested that the relationship between WBV and LBP could be attributed to sitting in a constrained position, as necessary when driving, for long periods, rather than to the exposure to WBV. At the time of our survey, truck driver, a job characterised by prolonged sitting and by exposure to WBV, was the most common job for men in Québec (Institut de la statistique du Québec 2007). If this is representative of the situation in other countries, the association between WBV, sitting and LBP found in some population-based studies may be caused by the combined exposures in this common occupation.

4.3. *Associations between LBP and psychosocial work factors among sitting and standing workers*

Psychosocial risk factors at work associated with LBP differed among sitting and standing workers. Significant associations were observed between high job strain and LBP for all strata in the bivariate analyses (not shown), but the relationship was significant in the multivariate analysis only for women who usually sat at work. Only two studies have looked for an association between high job strain and LBP (regardless of posture), one did find an association (IJzelenberg and Burdorf 2005) the other did not (Clays *et al.* 2007). Posture was not evaluated in these studies.

High psychological job demands was highly associated with LBP among standing workers in the multivariate analysis. Some studies have found an association between high psychological job demands and LBP (Krause *et al.* 1998, Johnston *et al.* 2003, Trinkoff *et al.* 2003) while others have found no association (Josephson and Vingard 1998, Kerr *et al.* 2001, Clays *et al.* 2007) or a very weak association (Hoogendoorn *et al.* 2001, Jansen *et al.* 2004). In this study, standing and sitting workers may have interpreted the items of the Karasek psychological job demands scale differently. It is therefore possible that for standing workers, who are more likely to be exposed to important physical work demands (Table 2) (Tissot *et al.* 2005), the psychological demands scale may have behaved as a measure of both physical and psychological demands of work. This scale includes items that can be interpreted as measuring either physical or psychological demands (e.g., 'work fast', 'work hard', 'hectic work') (Kerr *et al.* 2001, MacDonald *et al.* 2001, Stock *et al.* 2006).

4.4. *Other risk factors at work associated with LBP*

Night shifts were associated with LBP among men who sat at work. There was a positive bivariate association also among men who stood at work but it was not significant in the multivariate model. In the study of Eriksen and colleagues (2004) night shift work was associated with an increased risk of intense low back symptoms in nurses' aides. Night shifts could have negative effects on the quantity and quality of sleep which could elevate muscle tension and thus favour back pain in this population (Josephson and Vingard 1998).

Working more than 40 hours per week while having two or more children at home was significantly associated with LBP among women (only) who usually worked in a standing posture. Few women among the sitting population were exposed to this combination of

conditions. It is quite possible that the combined physical and psychological demands of paid and unpaid work could elevate muscle tension and fatigue, increasing the risk of LBP. Work overload at home may also affect reactions to workplace conditions and vice versa (Bergqvist *et al.* 1995, Brisson *et al.* 1999).

4.5. LBP and gender

Interestingly, among Quebec workers in this study there is no significant difference in prevalence in LBP between men and women. There was however a higher prevalence of pain among younger women who usually sat at work. This general result is consistent with those from the quite similar Ontario Health Survey (Liira *et al.* 1996), and with the findings of a 1997 review (Burdorf and Sorock 1997). More recently, studies of some working populations have found that LBP occurred more often among women (Alcouffe *et al.* 1999, Schneider *et al.* 2005) and that women ran a greater risk of a first-ever episode of LBP (Macfarlane *et al.* 1997).

To explain their results suggesting that women might suffer more back pain than men, Schneider *et al.* (2005) suggested that unassessed psychosocial workplace factors might be associated with higher prevalence of pain in women. And in fact, unlike the situation with the present study, information on psychosocial conditions at work had not been measured in those recent studies showing a gender difference. Thus, when found, apparent gender differences in prevalence of LBP in population-based studies may be related to the level of detail obtained concerning exposures in jobs usually assigned to one or the other gender (Messing *et al.* 2003, 2009).

4.6. Non-occupational factors associated with LBP

Younger age was associated with LBP among women only. Younger workers are generally more often assigned tasks that require less experience but have heavier physical demands (Breslin *et al.* 2007). The higher prevalence among younger women could be partly caused by dysmenorrhea, which is known to affect many young women (Guo *et al.* 1995, Tissot and Messing 1995, Burnett *et al.* 2005). Studies of the prevalence and etiology of LBP should take into account or exclude perimenstrual back pain. Unfortunately this study did not allow us to exclude back pain associated with menses.

In the analysis of the standing population, smoking was associated with LBP among men, but women showed the opposite effect. The reasons for this are unclear, but male smokers in this subpopulation smoked more cigarettes per day than women smokers, possibly leading to intrastratum confounding. Previous studies provide evidence that smoking is associated with back pain (Brage and Bjerkedal 1996, Leino-Arjas *et al.* 1998, Leboeuf-Yde 1999, Goldberg *et al.* 2000, Miranda *et al.* 2002), but mechanisms have not been established. It cannot be ruled out, especially in this study, that the association is attributable to a spurious correlation, in which smoking is associated with other, unmeasured elements of an unhealthy lifestyle (Kristiansdottir and Rhee 2002); both smoking and lack of exercise are associated with a standing posture among men (Tissot *et al.* 2005).

Being overweight (27 to 29.9 kg/m^2), but not obese ($\geq$30 kg/m^2) was associated with LBP among women who usually stood. A relationship between back pain and overweight/obesity ($\geq$27 kg/m^2) has been reported among women workers in a population-based study (Leino-Arjas *et al.* 1998), but a systematic review of the epidemiologic studies published between 1965 and 1997 found no evidence for supporting or rejecting the association between overweight and LBP nor for a gender difference in this relationship (Leboeuf-Yde 2000).

Being physically active during leisure time was associated with a decreased risk of LBP among those who usually stood at work but not those who sat. Evidence from other studies is conflicting, but some suggests a favourable effect of physical activities on LBP (Hildebrandt *et al.* 2000, Schneider *et al.* 2005). The present study is cross-sectional, and it is possible that workers highly exposed to physical work (standing workers) who experience pain may diminish their activity level.

Psychological distress (not necessarily work-related) was found to be strongly associated with LBP in both women and men and among both sitting and standing workers. Psychological distress and depression have been found to predict musculoskeletal morbidity of the low back (Leino and Magni 1993, Nahit *et al.* 2003).

4.7. Study limitations

Some potential limitations to the study should be acknowledged. It is cross-sectional, so directions of causality cannot be presumed.

Not all relevant work exposures previously shown to be related to LBP could be measured in this study (e.g. non-neutral trunk postures, driving a vehicle at work). Moreover, none of the exposures were observed or measured directly. The limits of self-reports of physical work demands have been reviewed (Stock *et al.* 2005); most of the physical work demand

exposure measures in this study have been shown to have fair to good validity when compared to observations or direct measurements (Wiktorin *et al.* 1993, Torgen *et al.* 1999, Ainsworth *et al.* 1999, Stock *et al.* 2005, Laperrière *et al.* 2005).

Recall bias is a possibility, since musculoskeletal diseases are considered by many workers to be work-related (Thorslund *et al.* 1992, Johansson 1994). There are inconsistent results regarding the effect of the presence of MSD on self-reported estimates of physical exposure. A review by Stock *et al* (2005) found that most studies showed that those with MSD appear to be less accurate than those without MSD in estimating physical work demands when their reports were compared to observations or direct measurement. However, studies on the effect of the presence of back pain on self-reported estimates of physical exposure have shown either an underestimate or no effect at all (Burdorf 1992, Viikari-Juntura *et al.* 1996, Wiktorin *et al.* 1999, Leijon *et al.* 2002, Stock *et al.* 2005).

Only broad postural categories could be assessed. Respondents whose posture might have varied greatly over the workday or over the working week or season had to choose a single most-frequent posture. The wording of the question on the type of standing postures forced a choice between mobility and constraint and it is not certain that those workers who said they moved around while standing could not also sit at will. For the seated position, there was no ambiguity in the question. Future exposure measures for standing postures should more adequately distinguish between freedom to sit at will and mobility (Laperièrre *et al.* 2005). Future surveys should also include validated questions on the placement and length of break times (Van Dieën and Oude Vrielink 1998).

This study has nonetheless demonstrated that not to be able to sit at will at work is a risk factor for LBP among those who stand at work and that different physical and psychological risk factors were associated with LBP among sitting and standing workers. Therefore it is useful to study the relationships between risk factors at work and LBP separately among sitting and standing workers.

Acknowledgements

This study was made possible through the kind assistance of Santé Québec, a division of the Institut de la statistique du Québec (ISQ), and its research data access centre, the Centre d'accès aux données de recherche (CADRISQ), in providing the survey data and technical help. We especially thank Lucie Gingras, coordinator of CADRISQ. We also thank the Quebec Inter-University Centre for Social Statistics (QICSS) and especially Danielle Forest for her help with the calculation of beta values. Karen Messing was the recipient of a Senior Investigator Award from the Canadian Institutes of Health Research and an operating grant from the Social Sciences and Humanities Research Council of Canada. This study is part of a series of studies being conducted by the Scientific Working Group on Work-related Musculoskeletal Disorders of the Québec National Institute of Public Health.

References

Aaras, A., Fostervold, K.I., Ro, O., Thoresen, M., and Larsen, S., 1997. Postural load during VDU work: a comparison between various work postures. *Ergonomics*, 40, 1255–1268.

Ainsworth, B.E., Richardson, M.T., Jacobs, D.R. Jr, Leon, A.S., and Sternfeld, B., 1999. Accuracy of recall of occupational physical activity by questionnaire. *Journal of Clinical Epidemiology*, 52, 219–227.

Alcouffe, J., Manillier, P., Brehier, M., Fabin, C., and Faupin, F., 1999. Analysis by sex of low back pain among workers from small companies in the Paris area: severity and occupational consequences. *Occupational and Environmental Medicine*, 56, 696–701.

Andersen, J.H., Haahr, J.P., and Frost, P., 2007. Risk factors for more severe regional musculoskeletal symptoms: a two-year prospective study of a general working population. *Arthritis and Rheumatism*, 56, 1355–1364.

Bergqvist, U., Wolgast, E., Nilsson, B., and Voss, M., 1995. Musculoskeletal disorders among visual display terminal workers: individual, ergonomic, and work organizational factors. *Ergonomics*, 38, 763–776.

Bernard, B.P., ed. 1997. *Musculoskeletal Disorders and Dorkplace Dactors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back*. Cincinnati: National Institute for Occupational Safety and Health; US Department of Health and Human Services (DHHS), publication no. 97–141.

Beynon, C. and Reilly, T., 2001. Spinal shrinkage during a seated break and standing break during simulated nursing tasks. *Applied Ergonomics*, 32, 617–622.

Boyer, R., Préville, M., Legaré, G., and Valois, P., 1993. Psychological distress in a noninstitutionalized population of Quebec: normative results of the Quebec health survey. *Canadian Journal of Psychiatry*, 38, 339–343.

Brage, S. and Bjerkedal, T., 1996. Musculoskeletal pain and smoking in Norway. *Journal of Epidemiology and Community Health*, 50, 166–169.

Brand, F.N., Dannenberg, A.L., Abbott, R.D., and Kannel, W.B., 1988. The epidemiology of varicose veins: the Framingham Study. *American Journal of Preventive Medicine*, 4, 96–101.

Breslin, F.C., Polzer, J., Maceachen, E., Morrongiello, B., and Shannon, H., 2007. Workplace injury or 'part of the job'? Towards a gendered understanding of injuries and complaints among young workers. *Social Science and Medicine*, 64, 782–793.

Brisson, C., Dion, G., Guimont, C., Moisan, J., Blanchet, C., Vinet, A., Vézina, M., Dagenais, G., and Mâsse, L., 1998. Reliability and construct validity of the psychological demand and decision latitude scales of the Karasek Job Content Questionnaire. *Work and Stress*, 12, 322–336.

Brisson, C., Laflamme, N., Moisan, J., Milot, A., Mâsse, B., and Vézina, M., 1999. Effect of family responsibilities and job strain on ambulatory blood pressure among white-collar women. *Psychosomatic Medicine*, 61, 205–213.

Burdorf, A., 1992. Sources of variance in exposure to postural load on the back in occupational groups. *Scandinavian Journal of Work, Environment and Health*, 18, 361–367.

Burdorf, A. and Sorock, G., 1997. Positive and negative evidence of risk factors for back disorders. *Scandinavian Journal of Work, Environment and Health*, 23, 243–256.

Burnett, M.A., Antao, V., Black, A., Feldman, K., Grenville, A., Lea, R., Lefebvre, G., Pinsonneault, O., and Robert, M., 2005. Prevalence of primary dysmenorrhea in Canada. *Journal of Obstetrics and Gynaecology Canada*, 27, 765–770.

Callaghan, J.P. and McGill, S.M., 2001. Low back joint loading and kinematics during standing and unsupported sitting. *Ergonomics*, 44, 280–294.

Camirand, J., Massé, R., Frenette, C., and Tousignant, M., 1993. *Rapport de la mi-enquête : analyse et demande de tableaux*. Groupe environnement social, Enquête Santé Québec 1992–1993.

Cham, R. and Redfern, M.S., 2001. Effect of flooring on standing comfort and fatigue. *Human Factors*, 43, 381–391.

Chen, S.M., Liu, M.F., Cook, J., Bass, S., and Lo, S.K., 2009. Sedentary lifestyle as a risk factor for low back pain: a systematic review. *International Archives of Occupational and Environmental Health*, 82, 797–806.

Chevalier, Y. and Sauvageau, Y., 2001. Caractéristiques de la population. In *Enquête sociale et de santé 1998*. 2nd ed. Montréal: Institut de la statistique du Québec, 26–27. Available at: http://www.stat.gouv.qc.ca/publications/sante/pdf/e_soc98v2-2.pdf

Clays, E., De Bacquer, D., Leynen, F., Kornitzer, M., Kittel, F., and De Backer, G., 2007. The impact of psychosocial factors on low back pain: longitudinal results from the Belstress study. *Spine*, 32, 262–268.

Daveluy, C., Chénard, L., Levasseur, M., and Émond, A., 1994. *Et votre coeur, ça va? Rapport de l'enquête québécoise sur la santé cardiovasculaire 1990*. Montréal: Ministère de la Santé et des Services Sociaux.

Daveluy, C., Pica, L., Audet, N., Courtemanche, R., Lapointe, F., Côté, L., and Baulne, J., 2001. Enquête sociale et de santé 1998 – *Cahier Technique et Méthodologique: Documentation Générale*. Montréal: Institut de la statistique du Québec. Available at: http://www.stat.gouv.qc.ca/ methodologie/default.htm.

Devereux, J.J., Buckle, P.W., and Vlachonikolis, I.G., 1999. Interactions between physical and psychosocial risk factors at work increase the risk of back disorders: an epidemiological approach. *Occupational and Environmental Medicine*, 56, 343–353.

Dionne, C., Bourbonnais, R., Frémont, P., Rossignol, M., and Stock, S., 2004. Le pronostic occupationnel des travailleurs aux prises avec des affections vertébrales, Rapport R-356, Montréal, IRSST. Available from: http://www.irsst.qc.ca/fr/_publicationirsst_100017.html

Eriksen, W., Bruusgaard, D., and Knardahl, S., 2004. Work factors as predictors of intense or disabling low back pain; a prospective study of nurses' aides. *Occupational and Environmental Medicine*, 61, 398–404.

Goldberg, M.S., Scott, S.C., and Mayo, N.E., 2000. A review of the association between cigarette smoking and the development of nonspecific back pain and related outcomes. *Spine*, 25, 995–1014.

Gregory, D.E. and Callaghan, J.P., 2008. Prolonged standing as a precursor for the development of low back discomfort: an investigation of possible mechanisms. *Gait Posture*, 28, 86–92.

Guo, H.R., Tanaka, S., Cameron, L.L., Seligman, P.J., Behrens, V.J., Ger, J., Wild, D.K., and Putz-Anderson, V., 1995. Back pain among workers in the United States: national estimates and workers at high risk. *American Journal of Industrial Medicine*, 28, 591–602.

Hansen, L., Winkel, J., and Jorgensen, K., 1998. Significance of mat and shoe softness during prolonged work in upright position: based on measurements of low back muscle EMG, foot volume changes, discomfort and ground force reactions. *Applied Ergonomics*, 29, 217–224.

Hartvigsen, J., Leboeuf-Yde, C., Lings, S., and Corder, E.H., 2000. Is sitting-while-at-work associated with low back pain? A systematic, critical literature review. *Scandinavian Journal of Public Health*, 28, 230–239.

Hildebrandt, V.H., Bongers, P.M., Dul, J., van Dijk, F.J., and Kemper, H.C., 2000. The relationship between leisure time, physical activities and musculoskeletal symptoms and disability in worker populations. *International Archives of Occupational and Environmental Health*, 73, 507–518.

Holmström, E.B., Lindell, J., and Moritz, U., 1992. Low back and neck/shoulder pain in construction workers: occupational workload and psychosocial risk factors. Part 1: Relationship to low back pain. *Spine*, 17, 663–671.

Hoogendoorn, W.E., Bongers, P.M., de Vet, H.C., Douwes, M., Koes, B.W., Miedema, M.C., Ariens, G.A., and Bouter, L.M., 2000. Flexion and rotation of the trunk and lifting at work are risk factors for low back pain: results of a prospective cohort study. *Spine*, 25, 3087–3092.

Hoogendoorn, W.E., Bongers, P.M., de Vet, HC, Houtman, IL, Ariëns, GA, van Mechelen, W, and Bouter, LM, 2001. Psychosocial work characteristics and psychological strain in relation to low-back pain. *Scandinavian Journal of Work, Environment and Health*, 27, 258–267.

Hoogendoorn, W.E., van Poppel, M.N., Bongers, P.M., Koes, B.W., and Bouter, L.M., 1999. Physical load during work and leisure time as risk factors for back pain. *Scandinavian Journal of Work, Environment and Health*, 25, 387–403.

Hosmer, D. and Lemeshow, S., 2000. *Applied logistic regression*. 2nd ed. New York: Wiley.

IJzelenberg, W. and Burdorf, A., 2005. Risk factors for musculoskeletal symptoms and ensuing health care use and sick leave. *Spine*, 30, 1550–1556.

Ilfeld, F.W., 1976. Further validation of a psychiatric symptom index in a normal population. *Psychological Reports*, 39, 1215–1228.

Institut de la statistique du Québec, 2007. Les 20 principales professions féminines et masculines, Québec, 1991 et 2001. Available at : http://www.stat.gouv.qc.ca/donstat/societe/march_travl_remnr/cat_profs_sectr_activ/professions/recens2001/tabwebprof_juin03-1.htm [Accessed 2 December 2007].

Jansen, J.P., Morgenstern, H., and Burdorf, A., 2004. Dose-response relations between occupational exposures to physical and psychosocial factors and the risk of low back pain. *Occupational and Environmental Medicine*, 61, 972–979.

Jin, K., Sorock, G.S., and Courtney, T.K., 2004. Prevalence of low back pain in three occupational groups in Shanghai, People's Republic of China. *Journal of Safety Research*, 35, 23–28.

Johansson, J.A., 1994. Work-related and non-work-related musculoskeletal symptoms. *Ergonomics*, 25, 248–251.

Johansson, J.A. and Rubenowitz, S., 1994. Risk indicators in the psychosocial and physical work environment for work-related neck, shoulder and low back symptoms: a study among blue- and white-collar workers in eight companies. *Scandinavian Journal of Rehabilitation Medicine*, 26, 131–142.

Johnston, J.M., Landsittel, D.P., Nelson, N.A., Gardner, L.I., and Wassell, J.T., 2003. Stressful psychosocial work environment increases risk for back pain among retail material handlers. *American Journal of Industrial Medicine*, 43, 179–187.

Jorgensen, K., Hansen, L., Lundager, K., and Winkel, J., 1993. Low back muscle reactions to constrained standing in relation to chock absorbing properties of floor and shoes. *In*: R. Nielsen and K. Jorgensen, eds. *Advances in industrial ergonomics and safety V*. London: Taylor and Francis, 279–283.

Josephson, M. and Vingard, E., 1998. Workplace factors and care seeking for low-back pain among female nursing personnel. MUSIC-Norrtalje Study Group. *Scandinavian Journal of Work, Environment and Health*, 24, 465–472.

Karasek, R., 1985. *Job Content Questionnaire and User's Guide*. Los Angeles: University of Southern California, Department of Industrial and System Engineering).

Kerr, M.S., Frank, J.W., Shannon, H.S., Norman, R.W., Wells, R.P., Neumann, W.P., Bombardier, C., and Ontario Universities Back Pain Study Group, 2001. Biomechanical and psychosocial risk factors for low back pain at work. *American Journal of Public Health*, 91, 1069–1075.

Konz, S., Bandla, V., Rys, M., and Sambavisan, J., 1990. Standing on concrete vs. floor mats. *In*: B. Das, ed. *Advances in Industrial Ergonomics and Safety II*. Abington: Taylor and Francis, 991–998.

Krause, N., Ragland, D.R., Fisher, J.M., and Syme, S.L., 1998. Psychosocial job factors, physical workload, and incidence of work-related spinal injury: a 5-year prospective study of urban transit operators. *Spine*, 23, 2507–2516.

Kristjansdottir, G. and Rhee, H., 2002. Risk factors of back pain frequency in schoolchildren: a search for explanations to a public health problem. *Acta Paediatrica*, 91, 849–854.

Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., and Biering-Sorensen, F., 1987. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Applied Ergonomics*, 18, 233–237.

Laperrière, E., Couture, V., Stock, S., and Messing, K., 2005. Validation of questions on working posture among standing workers in Québec. *International Journal of Industrial Ergonomics*, 35, 371–378.

Larocque, B., Brisson, C., and Blanchette, C., 1998. Cohérence interne, validité factorielle et validité discriminante de la traduction française des échelles de demande psychologique et de latitude décisionnelle du 'Job Content Questionnaire' de Karasek. *Revue d'Épidémiologie et de Santé Publique*, 96, 371–381.

Leboeuf-Yde, C., 2000. Body weight and low back pain. A systematic literature review of 56 journal articles reporting on 65 epidemiologic studies. *Spine*, 25, 226–237.

Leboeuf-Yde, C., 1999. Smoking and low back pain. A systematic literature review of 41 journal articles reporting 47 epidemiologic studies. *Spine*, 24, 1463–1470.

Lehman, K.R., Psihogios, J.P., and Meulenbroek, R.G., 2001. Effects of sitting versus standing and scanner type on cashiers. *Ergonomics*, 44, 719–738.

Leijon, O., Wiktorin, C., Härenstam, A., Karlqvist, L., and the MOA Research Group, 2002. Validity of a self-administered questionnaire for assessing physical work loads in a general population. *Journal of occupational and environmental Medicine*, 44, 724–735.

Leino-Arjas, P., 1998. Smoking and musculoskeletal disorders in the metal industry: a prospective study. *Occupational and Environmental Medicine*, 55, 828–833.

Leino, P. and Magni, G., 1993. Depressive and distress symptoms as predictors of low back pain, neck-shoulder pain, and other musculoskeletal morbidity: a 10-year follow-up of metal industry employees. *Pain*, 53, 89–94.

Leivseth, G. and Drerup, B., 1997. Spinal shrinkage during work in a sitting posture compared to work in a standing posture. *Clinical biomechanics (Bristol, Avon)*, 12, 409–418.

Leroux, I., Dionne, C.E., Bourbonnais, R., and Brisson, C., 2005. Prevalence of musculoskeletal pain and associated factors in the Quebec working population. *International Archives of Occupational and Environmental Health*, 78, 379–386.

Liira, J.P., Shannon, H.S., Chambers, L.W., and Haines, T.A., 1996. Long-term back problems and physical work exposures in the 1990 Ontario Health Survey. *American Journal of Public Health*, 86, 382–387.

Lings, S. and Leboeuf-Yde, C., 2000. Whole-body vibration and low back pain: a systematic, critical review of the epidemiological literature 1992–1999. *International Archives of Occupational and Environmental Health*, 73, 290–297.

Linton, S.J., 1990. Risk factors for neck and back pain in a working population in Sweden. *Work and Stress*, 4 (1), 41–49.

Lis, A.M., Black, K.M., Korn, H., and Nordin, M., 2007. Association between sitting and occupational LBP. *European Spine Journal*, 16, 283–298.

MacDonald, L.A., Karasek, R.A., Punnett, L., and Scharf, T., 2001. Covariation between workplace physical and psychosocial stressors: evidence and implications for occupational health research and prevention. *Ergonomics*, 44, 696–718.

Macfarlane, G.J., Thomas, E., Papageorgiou, A.C., Croft, P.R., Jayson, M.I., and Silman, A.J., 1997. Employment and physical work activities as predictors of future low back pain. *Spine*, 22 (10), 1143–1149.

Marras, W.S., Lavender, S.A., Leurgans, S.E., Fathallah, F.A., Ferguson, S.A., Allread, W.G., and Rajulut, S.L., 1995. Biomechanical risk factors for occupationally related low back disorders. *Ergonomics*, 38, 377–410.

McGill, S.M., Hughson, R.L., and Parks, K., 2000. Lumbar erector spinae oxygenation during prolonged contractions: implications for prolonged work. *Ergonomics*, 43, 486–493.

Messing, K., Punnett, L., Bond, M., Alexanderson, K., Pyle, J., Zahm, S., Wegman, D., Stock, S.R., and de Grosbois, S., 2003. Be the fairest of them all: challenges and recommendations for the treatment of gender in occupational health research. *American Journal of Industrial Medicine*, 43, 618–629.

Messing, K., Tissot, F., and Stock, S., 2008. Distal lower-extremity pain and work postures in the Quebec population. *American Journal of Public Health*, 98, 705–713.

Messing, K., Stock, S., and Tissot, F., 2009. Should studies of risk factors for MSDs be stratified by gender? Lessons from analyses of musculoskeletal disorders among respondents to the 1998 Québec Health Survey. *Scandinavian Journal of Work Environment and Health*, 35 (2), 96–112.

Miranda, H., Viikari-Juntura, E., Martikainen, R., Takala, E.P., and Riihimaki, H., 2002. Individual factors, occupational loading, and physical exercise as predictors of sciatic pain. *Spine*, 27, 1102–1109.

Mirbod, S.M., Inaba, R., and Iwata, H., 1997. Low back pain among different groups of subjects exposed to hand-arm transmitted vibration. *Industrial Health*, 35, 212–221.

Nahit, E.S., Hunt, I.M., Lunt, M., Dunn, G., Silman, A.J., and Macfarlane, G.J., 2003. Effects of psychosocial and individual psychological factors on the onset of musculoskeletal pain: common and site-specific effects. *Annals of the Rheumatic Diseases*, 62, 755–760.

National Research Council and the Institute of Medicine, 2001. *Musculoskeletal Disorders and the Workplace: Low back and Upper Extremities*. Panel on Musculoskeletal Disorders and the Workplace. Commission on Behavioral and Social Sciences and Education (Washington, DC: National Academy Press).

Nelson-Wong, E., Gregory, D.E., Winter, D.A., and Callaghan, J.P., 2008. Gluteus medius muscle activation patterns as a predictor of low back pain during standing. *Clinical Biomechanics*, 23, 545–553.

Palmer, K.T., Griffin, M.J., Syddall, H.E., Pannett, B., Cooper, C., and Coggon, D., 2003. The relative importance of whole body vibration and occupational lifting as risk factors for low-back pain. *Occupational and Environmental Medicine*, 60, 715–721.

Pietri, F., Leclerc, A., Boitel, L., Chastang, J.F., Morcet, J.F., and Blondet, M., 1992. Low-back pain in commercial travelers. *Scandinavian Journal of Work, Environment and Health*, 18, 52–58.

Punnett, L. and Wegman, D.H., 2004. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *Journal of Electromyography and Kinesiology*, 14, 13–23.

Radin, E.L., Parker, H.G., Pugh, J.W., Steinberg, R.S., Paul, I.L., and Rose, R.M., 1973. Response of joints to impact loading. 3. Relationship between trabecular microfractures and cartilage degeneration. *Journal of Biomechanics*, 6, 51–77.

Ratzon, N.Z., Yaros, T., Mizlik, A., and Kanner, T., 2000. Musculoskeletal symptoms among dentists in relation to work posture. *Work*, 15 (3), 153–158.

Redfern, M.S. and Chaffin, D.B., 1995. Influence of flooring on standing fatigue. *Human Factors*, 37 (3), 570–581.

RYS, M. and Konz, S., 1988. Standing work: carpet vs. concrete. *In*: *Proceedings of Human Factors Society 32nd annual meeting*, Santa Monica, California, 522–525.

RYS, M. and Konz, S., 1989. An evaluation on floor surfaces. *In*: *Proceedings of Human Factors Society 33rd annual meeting*, Denver, Colorado, 517–520.

Salmoni, A., 2002. Exposure to whole-body-vibration in transportation, mining, and construction. Final Report, WSIB Grant #00-031.

Schneider, S., Schmitt, H., Zoller, S., and Schiltenwolf, M., 2005. Workplace stress, lifestyle and social factors as correlates of back pain: a representative study of the German working population. *International Archives of Occupational and Environmental Health*, 78, 253–269.

Skov, T., Borg, V., and Orhede, E., 1996. Psychosocial and physical risk factors for musculoskeletal disorders of the neck, shoulders, and lower back in salespeople. *Occupational and Environmental Medicine*, 53, 351–356.

Stock, S.R., Fernandes, R., Delisle, A., and Vézina, N., 2005. Reproducibility and validity of workers' self-reports of physical work demands. *Scandinavian Journal of Work, Environment and Health*, 31, 409–437.

Stock, S., Vézina, N., Seifert, A.M., Tissot, F., and Messing, K., 2006. Les troubles musculo-squelettiques au Québec, la détresse psychologique et les conditions de travail : relations complexes dans un monde du travail en mutation. *Santé, Société et Solidarité de l'Observatoire franco-québécois de la santé et de la solidarité*, 2, 45–59.

Sun, G., Shook, T., and Kay, G.L., 1996. Inappropriate use of bivariate analysis to screen risk factors for use in multivariate analysis. *Journal of Clinical Epidemiology*, 49, 907–916.

Svensson, H.O. and Andersson, G.B., 1989. The relationship of low-back pain, work history, work environment, and stress. A retrospective cross-sectional study of 38- to 64-year-old women. *Spine*, 14, 517–522.

Thorbjörnsson, C.B., Alfredsson, L., Fredriksson, K., Michelsen, H., Punnett, L., Vingard, E., Torgen, M., and Kilbom, A., 2000. Physical and psychosocial factors related to low back pain during a 24-year period. A nested case-control analysis. *Spine*, 25, 369–374.

Thorslund, M., Wärneryd, B., and Östlin, P., 1992. The work-relatedness of disease: workers' own assessment. *Sociology of Health and Illness*, 14, 57–72.

Tiemessen, I.J., Hulshof, C.T., and Frings-Dresen, M.H., 2008. Low back pain in drivers exposed to whole body vibration: analysis of a dose-response pattern. *Occupational and Environmental Medicine*, 65, 667–675.

Tissot, F. and Messing, K., 1995. Perimenstrual symptoms and working conditions among hospital workers in Quebec. *American Journal of Industrial Medicine*, 27, 511–522.

Tissot, F., Messing, K., and Stock, S., 2005. Standing, sitting and associated working conditions in the Quebec population in 1998. *Ergonomics*, 48, 249–269.

Torgen, M., Winkel, J., Alfredsson, L., and Kilbom, A., 1999. Evaluation of questionnaire-based information on previous physical work loads. *Scandinavian Journal of Work, Environment and Health*, 25, 246–254.

Trinkoff, A.M., Lipscomb, J.A., Geiger-Brown, J., Storr, C.L., and Brady, B.A., 2003. Perceived physical demands and reported musculoskeletal problems in registered nurses. *American Journal of Preventive Medicine*, 24, 270–275.

Van Deursen, L.L., Patijn, J., Durinck, J.R., Brouwer, R., van Erven-Sommers, J.R., and Vortman, B.J., 1999. Sitting and low back pain: the positive effect of rotary dynamic stimuli during prolonged sitting. *European Spine Journal*, 8, 187–193.

Van Dieën, J.H., de Looze, M.P., and Hermans, V., 2001. Effects of dynamic office chairs on trunk kinematics, trunk extensor EMG and spinal shrinkage. *Ergonomics*, 44, 739–750.

Van Dieën, J.H. and Oude Vrielink, H.H., 1998. Evaluation of work-rest schedules with respect to the effects of postural workload in standing work. *Ergonomics*, 41, 1832–1844.

Van Nieuwenhuyse, A., Somville, P.R., Crombez, G., Burdorf, A., Verbeke, G., Johannik, K., Van den Bergh, O., Masschelein, R., Mairiaux, P., Moens, G.F. and BelCoBack Study Group, 2006. The role of physical workload and pain related fear in the development of low back pain in young workers: evidence from the BelCoBack Study; results after one year of follow up. *Occupational and Environmental Medicine*, 63, 45–52.

Viikari-Juntura, E., Rauas, S., Martikainen, R., Kuosma, E., Riihimäki, H., Takala, E.P., and Saarenmaa, K., 1996. Validity of self-reported physical work load in epidemiologic studies on musculoskeletal disorders. *Scandinavian Journal of Work, Environment and Health*, 22, 251–259.

Vingard, E., Alfredsson, L., Hagberg, M., Kilbom, A., Theorell, T., Waldenstrom, M., Hjelm, E.W., Wiktorin, C., and Hogstedt, C., 2000. To what extent do current and past physical and psychosocial occupational factors explain care-seeking for low back pain in a working population? Results from the Musculoskeletal Intervention Center-Norrtalje Study. *Spine*, 25, 493–500.

Voloshin, A. and Wosk, J., 1982. An in vivo study of low back pain and shock absorption in the human locomotor system. *Journal of Biomechanics*, 15, 21–27.

Walsh, K., Varnes, N., Osmond, C., Styles, R., and Coggin, D., 1989. Occupational causes of low back pain. *Scandinavian Journal of Work, Environment and Health*, 15, 54–59.

Whistance, R.S., Adams, L.P., Van Geems, B.A., and Bridger, R.S., 1995. Postural adaptations to workbench modifications in standing workers. *Ergonomics*, 38, 2485–2503.

Wiktorin, C., Karlqvist, L., and Winkel, J., 1993. Validity of self-reported exposures to work postures and manual materials handling. *Scandinavian Journal of Work, Environment and Health*, 19, 208–214.

Wiktorin, C., Vingård, E., Mortimer, M., Pernold, G., Wigaeus-Hjelm, E., Kilbom, A., and Alfredsson, L., 1999. Interview versus questionnaire for assessing physical loads in the population-based MUSIC–Norrt. *American journal of industrial medicine*, 35, 441–455.

Wilder, D.G. and Pope, M.H., 1996. Epidemiological and aetiological aspects of low back pain in vibration environments – an update. *Clinical Biomechanics*, 11, 61–73.

Wilke, H.J., Neef, P., Caimi, M., Hoogland, T., and Claes, L.E., 1999. New in vivo measurements of pressures in the intervertebral disc in daily life. *Spine*, 24, 755–762.

XU, Y., BACH, E., and ORHEDE, E., 1997. Work environment and low back pain: the influence of occupational activities. *Occupational and Environmental Medicine*, 54, 741–745.

Zhang, L., Drury, C.G., and Woolley, S.M., 1991. Constrained standing: Evaluating the foot/floor interface. *Ergonomics*, 34, 175–192.