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ORIGINAL ARTICLE

Association between objectively measured sitting time and neck–shoulder pain among blue-collar workers

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Abstract
Objectives Prolonged sitting has been suggested as a risk factor for neck–shoulder pain (NSP). Using a cross-sectional design, we investigated the extent to which objectively measured time sitting is associated with NSP among blue-collar workers.
Methods Sitting time was measured during multiple working days on male ($n = 118$) and female ($n = 84$) blue-collar workers ($n = 202$) using triaxial accelerometers (Actigraph) placed on the thigh and trunk. Workers were categorized into having, on average, a low, moderate or high sitting time, with mean values (SD between subjects) of 4.9 (1.0), 7.3 (0.5) and 9.6 (1.1) h in total per day. Workers rated their largest NSP intensity during the previous month on a numerical scale (0–9) and were subsequently dichotomized into a low and high NSP intensity group (ratings 0–4 and >4, respectively). Logistic regression analyses adjusted for several individual, and work-related factors were used to investigate the association between average sitting time per day (work, leisure and total) and NSP intensity.
Results For total sitting time, workers in the high sitting category were more likely (adjusted OR 2.97, CI 1.25–7.03) to report high NSP intensity than those who sat moderately (reference category). Low sitting during work was associated with a reduced NSP intensity, but only for males (adjusted OR 0.26 CI 0.07–0.96). No significant association was found between sitting during leisure and NSP intensity.
Conclusion These findings suggest an association between sitting time, in total per day and specifically during work, and NSP intensity among blue-collar workers. We encourage studying the structure and explanation of this association further in prospective studies on larger populations.

Keywords Daily sitting · Accelerometer · Occupational sitting · Sitting during leisure

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Introduction

Neck–shoulder pain (NSP) is prevalent in the working population (Côté et al. 2009) and imposes a massive economic burden on organizations and society due to sick leave and lost production (Hagberg et al. 2007; Hansson and Hansson 2005).

Commonly accepted biomechanical risk factors for NSP include high force demands, constrained working postures, working with arms raised and repetitive movements (Côté et al. 2009; Larsson et al. 2007; Palmer and Smedley 2007). In a recent prospective study, awkward lifting was found to be the most prominent biomechanical risk factor for reporting NSP during a 3-year follow-up (Sterud et al. 2014). In addition to biomechanical work exposures, several psychosocial risk factors (e.g., high quantitative demands, low social support, and low influence at work) have been identified (Bongers et al. 2006; Christensen and Knardahl 2014; Côté et al. 2009).

Epidemiological studies suggest that even prolonged sitting is an important risk factor for developing NSP (Ariëns et al. 2000, 2001; Cagnie et al. 2007; Côté et al. 2009; Hildebrandt et al. 2000; Skov et al. 1996). Many people spend a considerable proportion of their working day in a seated position (Miller and Brown 2004; Thorp et al. 2012; Toomingas et al. 2012). In addition to sitting at work, people irrespective of occupational group also sit for substantial proportions of their leisure time (Chau et al. 2012; Jans et al. 2007; Tudor-Locke et al. 2011). In Denmark, about 40 % of the Danish work force is considered to have a primarily sedentary job (e.g., sitting >75 %) (Overgaard et al. 2012), which is in line with findings from other European countries (Bennie et al. 2013). Skov et al. (1996) observed that self-reported sitting for more than 25 % of the work time was positively associated with neck pain, which is consistent with two cross-sectional studies by Yue et al. (2012) and Cagnie et al. (2007). Also, in a prospective study by Ariëns et al. (2001) using video recordings of sitting time at work, workers who sat for more than 95 % of their working time had a twofold risk of developing neck pain over a 3-year period, compared to those who hardly sat during work. In contrast, other authors did not find clear associations between sitting and NSP (Ariëns et al. 2002; Hallman et al. 2014; Hildebrandt et al. 2000), neither during work nor during leisure.

However, few studies have investigated the association between total sitting time per day and NSP. There is also a lack of studies assessing sitting time both at work and leisure, in order to investigate whether they are independently associated with neck–shoulder disorders.

A monotonically increasing relationship between sitting time and cardiovascular disease has been proposed by several studies (Owen et al. 2010). However, for musculoskeletal disorders (MSDs), both low and high levels of sitting might increase the risk of disorders compared to moderate sitting (Ariëns et al. 2001; Grooten et al. 2007). Thus, limited sitting may be a proxy of a larger exposure to other biomechanical risk factors, such as heavy physical work (da Costa and Vieira 2010; Larsson et al. 2007) or prolonged standing (Yue et al. 2012). Prolonged sitting, on the other hand, has been suggested to be associated with increased MSDs for several reasons. For instance, prolonged sitting may occur together with constrained postures requiring sustained muscle activation (Ariëns et al. 2001). Sustained activation of the neck–shoulder region, in turn, is a generally accepted risk factor for NSP (Visser and van Dieën 2006). Based on experimental and clinical studies, an alternative explanation would be that prolonged sitting affects pain processing through alterations in the central nervous system that result in increased pain sensitivity (Cheung et al. 2013; Ellingson et al. 2012; Sluka et al. 2013). Thus, it seems reasonable to hypothesize a U-shaped relationship between daily sitting time and NSP.

Previous studies have generally measured sitting time through self-reports, which are known to be imprecise and biased compared to estimates obtained by objective measurements, for instance using accelerometry (Celis-Morales et al. 2012). Also, subjects with muscle pain have been observed to overestimate exposure to physical activity more than pain-free subjects (Balogh et al. 2004; van Weering et al. 2011), which suggests that differential misclassification of exposure to sitting may occur when using self-reports. Therefore, objective data on sitting are needed for proper investigations of possible associations between sitting and health outcomes (Healy and Owen 2010).

Another limitation of several previous studies on associations between sitting and NSP is that the study population has been heterogeneous with respect to socioeconomic position (Andersen et al. 2007; Ariëns et al. 2001, 2002). This may result in socioeconomic confounding (Palmlöf et al. 2012). A further limitation has been the use of study populations with relatively small dispersions in sitting time, for instance office workers only (Cagnie et al. 2007). Thus, studies would be more effective if based on groups with a rather small dispersion in socioeconomic position, such as blue-collar workers, yet with a considerable dispersion in occupational sitting time.

In this study, we determined the association among blue-collar workers between NSP intensity and sitting time per day (in total, and specifically during work and leisure). Sitting time was measured using diurnal accelerometry, which has been shown to be valid for this purpose during free living conditions (Skotte et al. 2014).

Methods

Study population and design

The present study was based on data from the "New method for Objective Measurements of physical Activity in Daily living (NOMAD)" study in Denmark, with the primary aim to investigate the associations between self-reported and objectively measured physical activity. Data were collected from October 2011 to April 2012. The study was conducted on a cross-sectional sample of male ($n = 118$) and female ($n = 84$) blue-collar workers (e.g., construction workers, cleaners, garbage collectors, manufacturing workers, assembly workers, mobile plant operators and workers in the health service sector) recruited from seven workplaces located mainly in the Copenhagen area and the central/western part of Denmark. These workplaces were selected by convenience to have blue-collar workers employed with varying exposures to ergonomic risk factors such as heavy lifting and repetitive movements. The workplaces were recruited primarily through contact with trade unions or

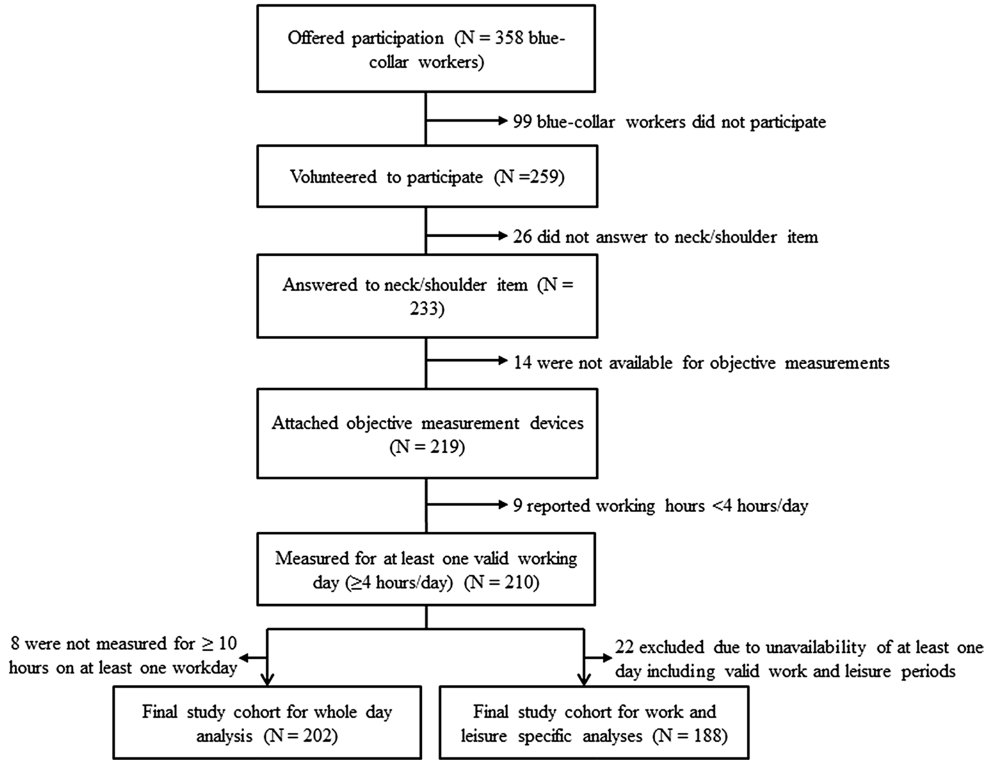

Fig. 1 Flowchart of the recruitment of participants

safety representatives at the individual workplaces. Workplaces were eligible if workers were allowed to participate in the study during paid working hours. Inclusion criteria for individuals to participate in the study were to perform blue-collar work as their primary work (main occupation) for at least 20 h per week, and being between 18 and 65 years of age. Exclusion criteria were declining to sign the informed consent, white-collar work, pregnancy and sickness absence on the day of testing. Furthermore, subjects were excluded if reporting skin allergy to adhesives. Recruitment flow of participants in the study is illustrated in Fig. 1.

The study was approved by the regional Ethics Committee in Copenhagen, Denmark (Journal Number H-2-2011-047), and conducted in accordance with the Helsinki declaration.

Procedure

All workers were invited to attend information meetings where the aim, contents, requirements and activities of the study were explained. All interested workers completed a screening questionnaire containing general information about demographic variables and provided their written informed consent to participate in the study. Data were collected for four consecutive days in each worker, with research staff visiting the worker at the workplace on days one and four. On the first day, workers (a) signed up for the study, (b) underwent anthropometric measurements, (c) were equipped with accelerometers for objective diurnal measurement of sitting time and (d) completed a computer-based questionnaire regarding neck and shoulder pain intensity. On day four, the workers returned the objective measurement devices, and the accelerometer data were downloaded to a computer by the research staff.

Neck–shoulder pain intensity

Self-reported information about neck and shoulder pain intensity was obtained by a modified version of the Standardized Nordic Questionnaire for the analysis of musculoskeletal symptoms (Kuorinka et al. 1987). Workers were asked to rate their worst pain intensity during the previous month for the neck and shoulder regions separately, on a numeric rating scale (NRS), ranging from 0 (no pain) to 9 (worst pain imaginable) (Andersen et al. 2012). The NRS is a valid instrument for the assessment of pain intensity (Ferreira-Valente et al. 2011), and it has been recommended as a "core outcome measure" by the "Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials," IMMPACT (Dworkin et al. 2005). The scale is horizontally oriented to resemble a visual analogue scale (Pincus et al. 2008). The rating from the primary pain region, i.e., the one with the highest intensity score, was used as the outcome in further statistical analyses. Since the scores of NSP intensity were not normally distributed, workers were categorized into a "low" (score 0–4) and a "high" (score >4) pain group prior to the statistical analyses. The cut point of 4 was chosen based on a previous prospective cohort study on musculoskeletal risk factors for sickness absence among healthcare workers which showed this cut point to be predictive for later long-term sick leave (Andersen et al. 2012).

Objectively measured sitting time

Sitting time was assessed using two accelerometers (Actigraph GT3X, ActiGraph LLC, Florida, USA) collecting data continuously for four consecutive days (i.e., 4 × 24 h). The Actigraph is a small, water-resistant device (19 × 34 × 45 mm, weight 19 g), which records, samples and stores triaxial acceleration data at a frequency of 30 Hz with a dynamic range of ±6G and a 12 bit precision. With very few exceptions, the 4-day period included waking hours during work as well as leisure for at least two working days.

One accelerometer was placed at the medial front of the right thigh, midway between the hip and knee joints, which is a recommended, standardized position (Skotte et al. 2014). The other accelerometer was placed at the trunk (spinous process at the level of T1–T2). The workers were instructed to (a) remove the accelerometers if they caused itching or any kind of discomfort such as disturbed sleep, (b) perform a reference measurement in upright standing for 15 s every day and (c) fill in a short diary every day concerning working hours, leisure time, sleep, non-wear time and time of reference measurement. Initialization of the Actigraph for recording and downloading of data was done using the manufacturer's software (Actilife software version 5.5, ActiGraph LLC, Pensacola, FL, USA).

The accelerometer data were processed and analyzed further using a customary MATLAB-based software, Acti4 (The National Research Centre for the Working Environment, Copenhagen, Denmark and BAuA, Berlin, Germany), determining the type and duration of different activities and body postures with a high sensitivity and specificity (Skotte et al. 2014). In this software, accelerometer data were low-pass filtered with a 5-Hz fourth-order Butterworth filter and then split up into 2-s sequences with 50 % overlap. Afterwards, using the individual's reference measurement, the occurrence of sitting postures was identified based on algorithms presented by Skotte et al. (2014). Sitting is registered when the inclination of the thigh is above 45° and the trunk inclination is below 45°.

Days were split into periods of "work," defined as self-reported time spent working, and periods of "leisure," identified as the waking hours on all working days that were not spent working. The following variables were then calculated: (a) "total sitting per day" (i.e., total sitting duration divided by the number of days), (b) "sitting per day at work" (i.e., total sitting duration during working periods divided by the number of days) and (c) "sitting per day during leisure" (i.e., total sitting duration during leisure periods divided by the number of days) (Lagersted-Olsen et al. 2013). All non-working days, sleep or bedtime periods during working days, and non-wear periods were excluded from the analysis. A non-wear period was identified when (a) the software detected a period longer than 60 min showing zero accelerometer counts per minute, (b) the participant reported non-wear time, or (c) artefacts or missing data were detected by visual inspection.

As this study was devoted to investigating working days only, days were only included if they contained objective measurements for at least 4 h of work. Further, only days comprising at least 10 h of total wear time were included in the analysis of total sitting per day. Separate analyses of sitting at work and leisure were performed only on days where the subject worked for at least 4 h, reported >75 % of the average (across days) working time, at least 4 h of leisure, and >75 % of the average reported leisure time. For each separate time stratum (day total, work and leisure), workers were categorized into tertiles according to their total sitting in that stratum, referred to as "low," "moderate" and "high" sitting.

Individual factors

Age was determined from the workers' Danish civil registration numbers, while smoking behavior was determined by the question *"Do you smoke?"* using four response categories summarized into two groups: yes ("yes daily," "yes sometimes") and no ("used to smoke," "I have never smoked"). The body mass index (BMI, kg m^{-2}) was calculated from objectively measured height (cm) and body weight (kg).

Work-related factors

Seniority in the job (months in total) was determined using the question: "*For how long have you had the kind of occupation that you have now?*"

Perceived influence at work (decision authority) was determined using four items (Cronbach's alpha 0.78) from the Copenhagen Psychosocial Questionnaire (Pejtersen et al. 2010): "*Do you have a large degree of influence concerning your work*?"; "*Can you influence the amount of work assigned to you*?"; "*Do you have a say in choosing who you work with*?"; and "*Do you have any influence on what you do at work*?". Responses were scored on a six-point Likert scale with categories from 0 ("never") to 5 ("always"). A composite scale measuring influence at work was constructed by calculating the mean rating of all

Table 1 Descriptive statistics of the workers stratified by total sitting time per day

	Sitting categories			p
	Low ($n = 67$)	Moderate ($n = 68$)	High ($n = 67$)	
Age, years (SD)	43.7 (9.6)	45.6 (10.7)	45.0 (8.8)	.52
Gender				
Males, *n* (%)	36 (30.5)	41 (34.7)	41 (34.7)	.63
Females, *n* (%)	31 (36.9)	27 (32.1)	26 (31.0)	
Body mass index, kg/m^2 (SD)	25.7 (4.2)	26.1 (4.9)	27.5 (5.8)	.09
Smoking, *n* (%)				
Sometimes or daily	26 (31.7)	27 (32.9)	29 (35.4)	.82
Non-smoker	38 (34.9)	37 (33.9)	34 (31.2)	
Seniority, months (SD)	145 (138)	165 (125)	172 (143)	.54
Time measured, h/day (SD)	16.0 (1.5)	16.6 (1.3)	17.1 (1.7)	<.001
Influence at work, scale 0–100 (SD)	38.8 (22.5)	43.7 (22.4)	49.1 (24.6)	.04
Lifting and carrying, h/day (SD)	3.7 (1.3)	3.5 (1.4)	3.7 (1.3)	.62
Neck–shoulder pain intensity, scale 0–9 (SD)	3.1 (2.4)	2.3 (2.2)	3.4 (2.7)	.01
Neck–shoulder pain, *n* (%)				
Low intensity (0–4)	45 (31.7)	55 (38.7)	42 (29.6)	.05
High intensity (>4)	22 (36.7)	13 (21.7)	25 (41.7)	

Data are given as mean (SD) or *n* (%); percentages are obtained for each row

four items and transforming the result onto a scale ranging from 0 to 100 (corresponding to mean ratings of 0–5), with increasing numbers representing more influence at work.

Self-reported information about duration of biomechanical exposures at work was obtained using three questions from the Danish Work Environment Cohort Survey (DWECS): *How much of your working time do you carry or lift?*; *Does your work involve raising your arms at or above shoulder level?*; and *Does your work involve repeating the same movements with your arms many times per minute?*. The responses were scored on a six-point scale ranging from 1 (“almost all the time”) to 6 (“never”) (Tüchsen et al. 2006).

The variables age, BMI, seniority, time spent carrying/lifting at work, working with arms raised, working with repetitive arm movements and influence at work were treated as continuous variables, while gender and smoking were entered as categorical variables in the statistical analyses.

Statistical analyses

All statistical analyses were performed using SPSS version 20 (IBM). Descriptive data are given as means and standard deviations (SD) or *n* (%). One-way ANOVAs or Chi-square tests, as appropriate, were applied to test differences between the sitting groups (low, moderate and high total sitting per day) in individual factors (age, gender, BMI, smoking), work-related factors (seniority, influence at work, lifting carrying), total recording time, sitting time and self-reported pain intensity. One-way ANOVAs were used to test for differences in NSP intensity and sitting time at work between the seven occupational groups. Pearson correlation coefficients were used to test the dependency between pairs of the three sitting time variables, i.e., daily total, work and leisure, which were all normally distributed.

The association between sitting time (tertile categories low, moderate and high) and NSP intensity (dichotomized as low or high) was determined using logistic regression models. In the primary model, sitting time per day was used as the primary independent variable, with moderate sitting as the reference category. NSP intensity was used as the dependent variable, while adjusting for age and gender (model 1). A second, extended model (model 2) included adjustments for additional individual factors (i.e., BMI and smoking), while a third and further extended model (model 3) included even work-related factors (i.e., seniority, influence at work and lifting/carrying). Two sensitivity analyses (models 4 and 5) were performed with a basis in model 3 by additional adjustment for either (model 4) total measured time (since it was significantly larger in the high sitting category, Table 1) or (model 5) additional biomechanical exposures at work (working with arms raised above shoulder level and working with repetitive arm movements). These in total five models were resolved for the total sample as well as separately for males and females. Corresponding logistic regression analyses were also conducted using sitting time at work and leisure as independent variables. The sensitivity analysis adjusting for total measured time as described above (model 4) was performed

Table 2 Gender distribution and mean (SD between subjects) sitting time (hours per day) in total ($n = 201$), during work ($n = 187$) and during leisure time ($n = 187$) among different occupations

	Males/females	Total	Work	Leisure
	n[a]	Mean (SD)	Mean (SD)	Mean (SD)
Health service	0/14	7.4 (1.6)	2.7 (0.9)	5.1 (1.3)
Assembly	4/28	8.2 (2.0)	3.7 (1.7)	4.8 (1.5)
Cleaning	5/26	7.1 (1.5)	2.9 (1.5)	4.4 (1.7)
Construction	38/0	8.3 (1.6)	3.5 (1.1)	5.2 (1.4)
Manufacturing	41/16	5.5 (1.6)	2.3 (1.0)	3.7 (1.6)
Garbage collectors	19/0	7.7 (1.9)	2.0 (1.0)	6.0 (1.1)
Mobile plant operators	10/0	10.1 (1.8)	4.5 (0.9)	6.9 (2.5)

[a] One male worker was classified as having another occupation and is not included in the table

using either sitting during leisure or at work as the additional factor, depending on the independent variable.

For each model, odds ratios (OR) with 95 % confidence intervals (CI) were derived. p values <.05 were taken to show significant associations, while p values between .05 and .10 were considered to indicate trends.

Multicollinearity among the independent variables was tested by collinearity diagnostics. Neither condition indices (all <30) nor VIF values (all <10) indicated that multicollinearity was an issue in the present material.

Potential confounders were selected a priori based on previous studies of risk factors for NSP. Specifically, gender, age, BMI and smoking have been identified as potential individual risk factors or effect modifiers for NSP, while seniority, perceived influence at work, lifting and carrying at work, working with arms raised above shoulder level and working with repetitive arm movements were included to represent occupational risk factors that might act as confounders.

Results

In total, 502 days of measurement from 202 workers were available for further data analysis (3 workers had five days, 37 four, 56 three, 65 two and 41 one day); 369 days were included in the separate analyses of sitting at work and leisure. Subjects spent on average 7.3 (between subjects SD 2.1, range 2.5–13.5) hours sitting per day, with mean sitting times at work and leisure of 3.0 (SD 1.4, range 0.3–6.6) and 4.8 (SD 1.7, range 0.8–10.3) h, respectively. Sitting times at work and leisure were not correlated ($r = -.01$, $p = .87$), but both were correlated with total sitting time (work: $r = .61$, $p < .001$; leisure: $r = .73$, $p < .001$).

Out of the 202 workers, 50 (24.8 %) reported no pain during the previous month, and the average pain intensity across all workers was 2.9 (SD 2.5).

Health service, assembly and cleaning were clearly dominated by female workers, while construction work, garbage collecting and manufacturing occurred mainly among males (Table 2). Occupations differed (ANOVA, $p < .001$) in mean sitting time during work (Table 2). “Low sitting” occurred mainly among manufacturing workers ($n = 41$) and cleaners ($n = 11$); “moderate sitting” occurred to a similar extent in several trades (health service ($n = 6$), assembly ($n = 11$), cleaning ($n = 14$), construction ($n = 14$) manufacturing ($n = 12$) and garbage collectors ($n = 9$)); and “high sitting” was mainly represented among assembly ($n = 17$) and construction ($n = 20$) workers, garbage collectors ($n = 7$) and mobile plant operators ($n = 6$). There were no significant differences between these occupations in NSP intensity (ANOVA, $p = .91$).

Figure 2 shows the cumulative probability distribution of sitting time in each of the three sitting categories. There were no significant gender differences in total sitting per day (Fig. 2a), sitting at work (Fig. 2b) or sitting during leisure (Fig. 2c).

Table 1 shows descriptive statistics of all workers ($n = 202$) stratified by total sitting duration per day. There were no marked differences between sitting categories in the number of males/females or smokers/non-smokers. No significant differences between sitting time categories were found for age, BMI, seniority or lifting/carrying. Pain intensity was higher in the low and high sitting categories compared with the moderate sitting category, suggesting a U-shaped relationship between sitting and NSP intensity. Time measured per day was significantly higher for the low sitting category, and perceived influence at work was lower in that group of workers than in the high sitting group.

Association between total sitting time and neck–shoulder pain intensity

The results from the primary regression analyses (models 1–3) are shown in Tables 3, 4 and 5, while the sensitivity analyses (models 4–5) are only reported in the text below. Table 3 shows the results of the logistic regression modeling of the association between total sitting time per day and NSP intensity, using moderate sitting as the reference category. We found a U-shaped association between sitting time and pain intensity; workers in the low and high sitting categories were more likely to report high pain intensity than those in the moderate sitting category, even if the effect was not significant for low sitting. When adjusting for smoking and BMI (model 2), a significant association between high sitting and pain intensity was still present, while the effect of low sitting

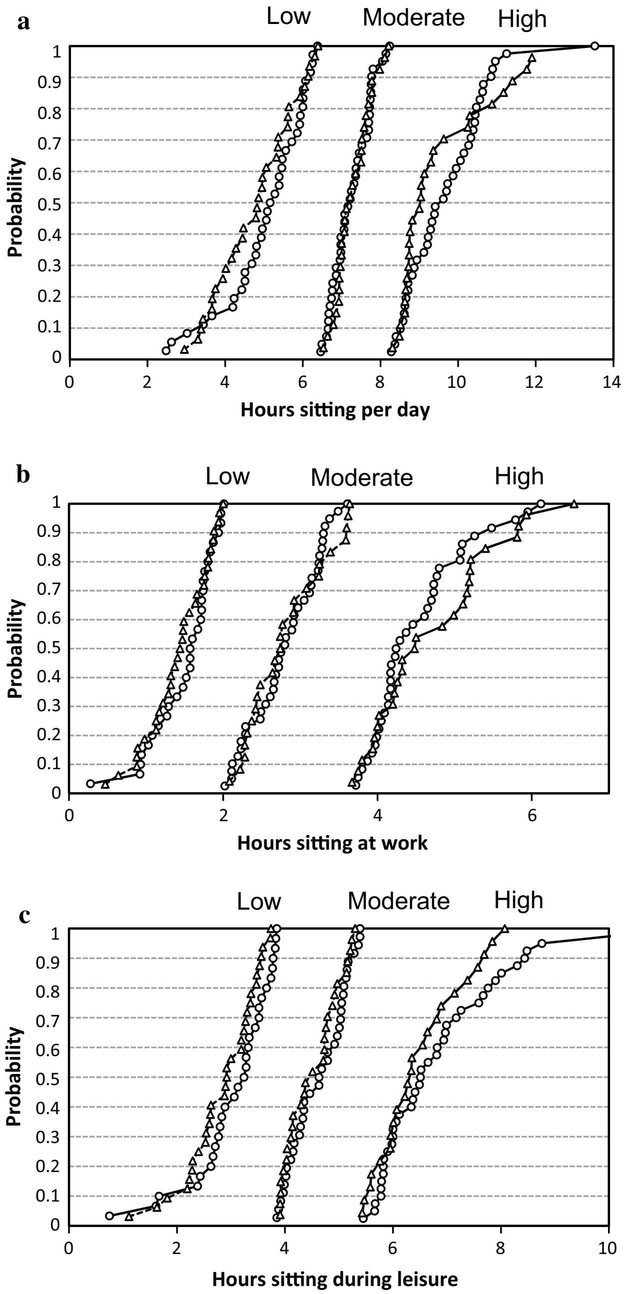

Fig. 2 Cumulative probability distributions of sitting time in total (**a**), during work (**b**), and during leisure (**c**), for males (*circles*) and females (*triangles*) in each of the three sitting categories "low," "moderate" and "high"

was borderline significant. For high sitting, this association remained significant after further adjustment for factors at work (model 3). Similar results (not shown in table) were obtained when also adjusting for total measured time in the sensitivity analysis (OR 3.01; 95 % CI 1.26–7.13), and associations remained significant even when adjusting for additional biomechanical factors at work, i.e., working with arms above shoulder level and working with repetitive arm movements (OR 3.32; 95 % CI 1.28–8.62).

In the gender-stratified analysis, the U-shaped association between sitting time and NSP intensity was still present among males, but not among females.

Association between sitting at work and leisure and neck–shoulder pain intensity

While total sitting time showed a U-shaped association with NSP, an *inverse* U-shaped relationship was found between sitting time at work and pain among males (Table 4, models 1–3). Male workers in the low sitting category were less likely to report high pain intensity compared to those sitting moderately, in both the crude and the adjusted models. This relationship persisted even after additional adjustment for total measured time, and leisure time sitting in the sensitivity analysis (OR 0.20; 95 % CI 0.05–0.81), and when adjusting for additional biomechanical factors at work (OR 0.23; 95 % CI 0.06–0.90).

For sitting in leisure, a trend was observed for males in the high sitting category reporting higher NSP intensity after adjustment for individual and work-related factors (Table 5, models 2 and 3). When also adjusting for sitting time at work, the association among males between high sitting during leisure and NSP became almost significant at the $p < .05$ level (OR 3.50; 95 % CI 0.98–12.54) and remained so after including additional biomechanical factors in the model (OR 3.74; 95 % CI 1.00–14.05).

Discussion

Our study aimed to investigate the association between sitting time measured using validated diurnal accelerometry and NSP intensity in a population of blue-collar workers. We found a U-shaped association between total sitting time per day and NSP, where moderate sitting time was associated with less pain intensity than both less and more sitting. When stratifying by gender, we found that this association was, however, present only for males. We found a nonsignificant trend among males for a similar U-shaped association between sitting during leisure and NSP, while the opposite association, i.e., less sitting being associated with *less* pain intensity than moderate sitting, was observed for sitting during work.

In being based on a group with a pronounced average exposure to sitting yet also with a considerable dispersion between workers (Fig. 2), we claim that our study design is adequate for investigating possible associations between sitting and, in the present case, NSP. The strengths of the associations between sitting and NSP suggest that total sitting time per day may be a more important determinant of risk for pain among blue-collar workers than sitting at either work or leisure alone.

Table 3 Associations between total sitting time per day and high NSP intensity (>4 on scale 0–9) according to models with different levels of adjustment

Logistic regression	Total sample				Males				Females			
	N	OR	CI	*p*	*N*	OR	CI	*p*	*N*	OR	CI	*p*
Model 1 (adjusted for age and gender)												
Low sitting	202	2.06	0.93–4.57	.07	118	2.91	0.96–8.84	.06	84	1.36	0.53–4.35	.61
Moderate sitting		1				1				1		
High sitting		**2.53**	**1.16–5.52**	**.02**		**3.74**	**1.28–10.92**	**.02**		1.51	0.46–5.02	.50
Model 2[a]												
Low sitting	191	**2.32**	**1.0–5.39**	**.05**	113	**4.22**	**1.20–14.93**	**.03**	78	1.20	0.36–4.02	.77
Moderate sitting		1				1				1		
High sitting		**3.15**	**1.36–7.29**	**.007**		**5.97**	**1.7–20.78**	**.005**		1.42	0.40–5.05	.59
Model 3[b]												
Low sitting	186	2.0	0.84–4.74	.12	110	**3.40**	**1.09–14.6**	**.04**	76	0.80	0.21–2.99	.80
Moderate sitting		1				1				1		
High sitting		**2.97**	**1.25–7.03**	**.01**		**6.44**	**1.76–23.56**	**.005**		1.19	0.31–4.51	.44

Table shows odds ratios (OR) with 95 % confidence intervals (CI) and the corresponding *p* values. Moderate sitting was used as the reference category

Significant ($p < .05$) associations are bold faced

[a] Adjusted for age, gender, BMI, smoking

[b] Adjusted for age, gender, BMI, smoking, seniority, influence at work and lifting and carrying at work

Table 4 Association between sitting time during work and high NSP intensity (>4 on scale 0–9), with *p* values, odds ratios (OR) and 95 % confidence intervals (CI)

Logistic regression	Total sample				Males				Females			
	N	OR	CI	*p*	*N*	OR	CI	*p*	*N*	OR	CI	*p*
Model 1 (adjusted for age and gender)												
Low sitting	188	0.49	0.22–1.09	.08	106	**0.25**	**0.07–0.85**	**.03**	82	0.92	0.29–2.91	.89
Moderate sitting		1				1				1		
High sitting		0.74	0.35–1.57	.44		0.68	0.26–1.76	.43		0.88	0.27–2.91	.84
Model 2[a]												
Low sitting	177	0.56	0.25–0.27	.17	101	**0.28**	**0.08–0.98**	**.05**	76	1.04	0.31–3.50	.95
Moderate sitting		1				1				1		
High sitting		0.78	0.36–1.72	.54		0.74	0.26–2.10	.57		1.02	0.29–3.58	.98
Model 3[b]												
Low sitting	173	0.54	0.23–1.25	.15	99	**0.26**	**0.07–0.96**	**.04**	74	1.01	0.28–3.59	.99
Moderate sitting		1				1				1		
High sitting		0.92	0.41–2.06	.83		0.94	0.31–2.85	.92		1.17	0.32–4.33	.82

Moderate sitting was used as the reference category

Significant ($p < .05$) associations are bold faced

[a] Adjusted for age, gender, BMI, smoking

[b] Adjusted for age, gender, BMI, smoking, seniority, influence at work and lifting and carrying at work

Total sitting time per day and neck–shoulder pain intensity

Most studies on the relationship between sitting time and NSP have addressed sitting at work (Ariëns et al. 2001; Cagnie et al. 2007; Skov et al. 1996; Yue et al. 2012), while studies based on total sitting time per day are rare. Thus, we are not aware of any study that has investigated NSP among blue-collar workers using objective, reliable methods for continuous registration of sitting time.

We found that blue-collar workers with high total sitting time per day (i.e., at least 8.3 h, Fig. 2a) were more likely to report high NSP intensity compared to those sitting

Table 5 Association between sitting time during leisure and high NSP intensity (>4 on scale 0–9), with *p* values, odds ratios (OR) and 95 % confidence intervals (CI)

Logistic regression	Total sample				Males				Females			
	N	OR	CI	*p*	*N*	OR	CI	*p*	*N*	OR	CI	*p*
Model 1 (adjusted for age and gender)												
Low sitting	188	1.18	0.54–2.61	.68	106	1.78	0.57–5.55	.32	82	0.78	0.26–2.38	.67
Moderate sitting		1				1				1		
High sitting		1.68	0.76–3.71	.20		2.39	0.81–7.06	.12		1.10	0.33–3.66	.88
Model 2[a]												
Low sitting	177	1.02	0.45–2.35	.96	101	1.79	0.53–6.05	.35	76	0.68	0.21–2.22	.52
Moderate sitting		1				1				1		
High sitting		1.59	0.70–3.62	.27		2.83	0.88–9.07	.08		0.94	0.27–3.22	.93
Model 3[b]												
Low sitting	173	1.14	0.48–2.69	.77	99	1.74	0.50–6.04	.38	74	0.86	0.25–3.02	.82
Moderate sitting		1				1				1		
High sitting		1.60	0.68–3.74	.28		2.76	0.83–9.18	.097		1.02	0.28–3.74	.97

Moderate sitting was used as the reference category

[a] Adjusted for age, gender, BMI, smoking

[b] Adjusted for age, gender, BMI, smoking, seniority, influence at work and lifting and carrying at work

moderately (i.e., between 6.5 and 8.2 h per day). This finding corroborates some previous studies (Ariëns et al. 2001; Cagnie et al. 2007; Skov et al. 1996; Yue et al. 2012), while being in contrast to other cross-sectional (Hildebrandt et al. 2000; Linton 1990) and prospective (Andersen et al. 2007; Ariëns et al. 2002) studies. However, all of these previous studies estimated occupational sitting time using self-report or observation, which is not directly comparable to our approach of using accelerometers for estimating daily sitting time.

Grooten et al. (2007) reported that in workers with neck pain, more sedentary work increased the probability of being free from symptoms 5 to 6 years later. This suggests that some extent of daily sitting might be protective against neck pain. In support of this, we found that male workers with low occurrence of sitting per day were more likely to report high NSP intensity than those sitting moderately, although this relationship was absent for females. If further research confirms that it is, indeed, better to sit for "moderate" durations per day than sitting "much" or only "little," interventions should be devoted to optimizing daily sitting time, rather than, for instance, eliminating it.

As noted above, an interesting, yet unexpected, finding in the gender-stratified analyses was that the U-shaped association between total sitting time per day and NSP intensity was observed among males only; effect sizes differed substantially between males and females, and none of the associations were significant for females (Tables 3, 4, 5). While this may, indeed, suggest a gender-specific relationship between NSP and sitting, we would also point to the risk of insufficient statistical power in the female group, which was somewhat smaller than the male group (Table 1). Also, the observed differences in the gender distribution between the seven occupational groups (Table 2) may, to some extent, have influenced the results, even though pain intensities were comparable among the occupations, and the exposure distribution (Fig. 2) for the three sitting categories did not differ between genders. In any case, the difference between males and females observed in our study strongly suggests that gender-specific analyses should be considered in future studies of sitting.

We used dichotomized pain intensity as an outcome, categorized on the basis of ratings on a ten-point numerical scale, while several studies have assessed the occurrence of NSP, e.g., during the previous 12 months (Ariëns et al. 2001; Cagnie et al. 2007; Skov et al. 1996) without consideration to intensity. Our discrimination level between "low" and "high" pain intensity was based on a prospective study (Andersen et al. 2012), showing that a NSP intensity level larger than 4 markedly increased the risk of the worker eventually being on sick leave. Therefore, we believe that our discrimination level is of clinical relevance.

The observed association between total sitting per day and NSP remained consistent when adjusting for several individual and work-related risk factors as potential confounders of NSP (Table 3). Total recording time per day was higher in the high sitting group than in the low and moderate sitting groups (Table 1). However, adjusting for this difference in measured time between groups did not affect the association with NSP. We accounted for several important biomechanical risk factors for NSP and therefore expect any residual confounding by biomechanical exposures to be small. Still, it is possible that other factors at work (Sterud et al. 2014) or during leisure (Hildebrandt et al. 2000) not adjusted for in our statistical models could have influenced the association between sitting and NSP. Furthermore, only blue-collar workers were included in the study because they were expected to be reasonably homogeneous with respect to socioeconomic position, while at the same time—as confirmed by our data—showing a large dispersion in exposure to sitting at work.

We cannot answer from our findings whether sitting per se is a risk factor for NSP, or whether sitting is a proxy for other risk factors not addressed in our models. A recent systematic review (Mayer et al. 2012) based on longitudinal studies on occupational risk factors for neck–shoulder complaints found a strong evidence for a causal relationship between awkward postures and NSP, while the evidence for sitting as a risk factor was considered insufficient. Ariëns et al. (2001) suggested that prolonged sitting may result in neck pain due to an increased muscle tension, as induced by constrained postures, thus suggesting that sitting is a proxy for other etiological factors. Another plausible explanation that prolonged sitting may cause NSP is that inactivity associated with prolonged sitting may lead to altered pain processing in the central nervous system (Ellingson et al. 2012; Ferretti et al. 2009; Sluka et al. 2013). Since we did not assess muscle activation, pain sensitivity or central processing, these mechanistic hypotheses could not be tested in the current study. As for the association between prolonged sitting and NSP possibly being influenced by the occurrence of awkward upper extremity postures, an appealing idea would be to record both sitting and arm postures and enter both in a model aiming at explaining NSP, including a possible interaction between the two.

Sitting time at work and leisure and neck–shoulder pain

In the current study, sitting time was recorded and analyzed for the entire day, as well as during work and leisure separately. This allowed us to analyze separate exposure associations with NSP, while previous studies have mainly assessed occupational sitting only. As opposed to high total sitting time per day, high sitting time at work was not associated with NSP in the present study. This finding may be explained by a healthy worker effect, i.e., workers with severe pain may have changed to work tasks involving prolonged sitting to a lesser extent. However, we also found that male workers with low occupational sitting time were less likely to report high NSP intensity than those with moderate sitting (Table 4). This supports some previous studies of occupational sitting and NSP [e.g., (Cagnie et al. 2007; Skov et al. 1996; Yue et al. 2012)], but the results are in contrast to the idea of a U-shaped association between occupational sitting and NSP.

The association between sitting during leisure and pain intensity was not significant, although we found a nonsignificant trend that males with high sitting time at leisure were more likely to report high NSP than those sitting moderately. There was no significant correlation between sitting time at work and leisure ($r = -.01$), so the apparently different relationships with NSP for sitting at work and sitting during leisure can, indeed, be viewed as statistically independent findings. A possible differential effect of sitting at work and during leisure was also suggested in a recent cross-sectional study of associations between self-reported sitting and cardiovascular and muscular fitness (Saidj et al. 2014). However, we cannot, on the basis of the present data, examine the nature of this difference, let alone why sitting at work and sitting in leisure would show inverse associations with NSP.

Study strengths and limitations

The major strength of the present study is its use of valid objective measurements of sitting time, with extensive data collected from 202 individuals. Even though sitting was measured for several working days in each individual, inference about a causal relationship between sitting and pain is, however, not possible due to the cross-sectional study design. Therefore, the current results should be interpreted with caution. Still, it is worth noting that previous case–control studies have failed to detect significant differences in objectively measured sitting time between workers with and without chronic NSP (Hallman et al. 2014; Hallman and Lyskov 2012). This finding suggests that chronic pain from the neck–shoulder region does not result in increased sitting time, i.e., that reversed causality seems unlikely in the present material. However, a thorough understanding of the causal relationships needs a basis in prospective studies of objectively measured sitting and NSP.

It has been argued that transforming continuous data into categories should be avoided as it results in loss of information and reduces the precision of the individual exposure estimates [e.g., (Royston et al. 2006)]. Nevertheless, we decided to create three categories of sitting to match our study hypothesis of a U-shaped relationship between sitting and NSP. The three categories were determined from tertiles in the exposure distribution in order to get a balanced dataset and, thus, increase statistical power. At the same time, this may be considered as a potential limitation of the study, since it resulted in categories of different width (Fig. 2) for which the effect sizes (Table 3) may be difficult to interpret.

A further potential limitation is the lack of analyses on temporal sitting patterns in the current study, which could be important to both metabolic (Healy et al. 2008) and musculoskeletal health outcomes (Mathiassen 2006). This might have provided additional information on why the effect of sitting appears to be different between work and leisure, and between males and females (Toomingas et al. 2012). Also, adding measurements of neck and arm postures could have revealed whether sitting is merely a proxy for constrained postures and thus whether sitting per se appears to be a risk factor for NSP or not.

Conclusion

In conclusion, we found in this cross-sectional study that high total sitting time per day in blue-collar workers, recorded using diurnal accelerometry, was associated with increased NSP intensity compared to moderate sitting, while a U-shaped association favoring moderate sitting was found only among males. Low occupational sitting was associated with reduced NSP among males, while no significant association was found for sitting during leisure time for either males or females. The association between sitting and NSP should be further investigated in gender-stratified studies using larger sample sizes and prospective designs, while still applying objective measures of sitting behavior. Moreover, the mechanisms underlying possible relationships between sitting and pain need further investigation; in particular whether sitting is a proxy of other biological risk factors for pain or whether it can be considered a risk factor in its own right.

Conflict of interest The authors have no conflict of interest to declare.

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