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Associations of objectively measured sitting and standing with low-back pain intensity: a 6-month follow-up of construction and healthcare workers

by Lunde L-K, Koch M, Knardahl S, Veiersted KB

This study investigated associations between sitting and standing, respectively, and low-back pain with objectively measured exposures for several days and a prospective design. Sitting at work and during full-day is negatively associated with cross-sectional- and prospective low-back pain intensity. This association was seen for the healthcare sector, but not for the construction sector.

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Key terms: accelerometer; back pain; construction; construction work; construction worker; healthcare; healthcare work; healthcare worker; low-back pain; musculoskeletal disorder; objective measure; pain; physical work; physical work exposure; prospective design; sitting; standing

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Associations of objectively measured sitting and standing with low-back pain intensity: a 6-month follow-up of construction and healthcare workers

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Objectives This study aimed to determine the associations between objectively measured sitting and standing duration and intensity of low-back pain (LBP) among Norwegian construction and healthcare workers.

Methods One-hundred and twenty-four workers wore two accelerometers for 3-4 consecutive days, during work and leisure. Minutes of sitting and standing was calculated from accelerometer data. We obtained self-reported LBP intensity (0–3) at the time of objective measurement and after six months. We examined associations with linear mixed models and presented results per 100 minutes.

Results For healthcare workers, the duration of sitting during work [β= -0.33, 95% confidence interval (95% CI) -0.55– -0.10] and during full-day (work + leisure) (β= -0.21, 95% CI -0.38– -0.04) was associated with baseline LBP intensity. Furthermore, minutes of sitting at work (β=-0.35, 95% CI -0.57– -0.13) and during the full day (β=-0.20, 95% CI -0.37– -0.04) were significantly associated with LBP intensity at six months. Associations were attenuated when adjusting for work-related mechanical and psychosocial covariates and objectively measured exposure during leisure time. No significant associations between sitting and LBP intensity were found for construction workers. Standing at work was not consistently associated with LBP intensity at baseline or after six months for any work sector.

Conclusions This study suggests that a long duration of sitting at work is associated with lower levels of LBP intensity among healthcare workers. Standing duration had no consistent associations with LBP intensity.

Key terms accelerometer; construction work; healthcare work; musculoskeletal disorder; objective measure; physical work; physical work exposure; prospective design.

As one of the largest contributors to years lived with disability (1), low-back pain (LBP) is a major global public health problem (2). Construction and healthcare work are two sectors with a high prevalence of musculoskeletal disorders (3–6) and thus it is important to identify work-related risk factors. Previous research found that long durations of sitting and standing during work are positively linked to LBP (7, 8). However, reviews have concluded that there is no evidence for an association due to low quality studies and inconsistent results (9–12). A major reason for the discrepant findings may be bias due to self-reported exposure duration (13–15). Self-reports may have reduced validity because they depend on recall, individual interpretation of questions, and can be biased by pain levels and disability (16–18). Therefore, it has been recommended that activity exposures be measured using objective methods when investigating their associations to LBP (13). Moreover, objective measurements over several days are more reliable than single days of measurement (19). Thus, exposure measurements should be obtained on more than one day to better capture variations in exposure among work days. One of very few studies of objectively measured sitting for 1–4 working days found that longer sitting duration was associated with increased risk for high intensity LBP among blue-collar workers in cross-sectional data (20). Another cross-sectional study of objectively measured standing reported

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ambiguous associations between standing and LBP (21). Both studies emphasize that future studies should determine the association between sitting and standing duration at work and LBP by objectively measured exposures over several consecutive days using prospective designs. These criteria have also been requested by reviews on this topic (9, 10).

We currently do not understand the mechanisms surrounding why and how sitting and standing would cause pain. Intervertebral- and vertebral endplate compression and increases in inter-disc pressure (IDP) during sitting (22, 23) and standing activities (24) have been proposed as mechanisms. However, recent results consider increased IDP an unlikely cause of damage in non-degenerated discs (25). Prolonged flexion during sitting has been proposed to redistribute the nucleus within the annulus (26) or increase lumbar spine stiffness (27). Prolonged standing may also lead to pain from muscle fatigue (28). Further hypotheses imply reduced oxygenation in lumbar extensor musculature (29) and increased weight as result of inactivity in sitting (30, 31) as possible mechanisms.

The origin of LBP is multifactorial (32) and individual factors such as age and gender (33), smoking (30), and body mass index (BMI) (30, 34) are associated with LBP. Mechanical work factors such as awkward lifting, high muscular load, and stooped positions were found to be associated with LBP in a recent systematic review (35); accumulation of such exposures through high seniority may further increase the risk of LBP (36, 37). Psychosocial factors including decision control, type of leadership, and the social climate at work sites are also associated with LBP (33, 38, 39). Accordingly, both individual and work-related factors must be controlled for when studying the association between sitting and standing at work and LBP. Additionally, non-work activities may produce pain conditions (9, 40) and therefore exposures during leisure time should also be accounted for.

We aimed to determine whether objectively measured time spent sitting and standing was associated with intensity of LBP among construction and healthcare workers at baseline and after six months.

Methods

Study population and design

This study was designed as a part of a larger prospective cohort study among construction and healthcare workers (41). Four construction companies (N=580 workers) and two local healthcare distributors (N=585 workers) in the Oslo area agreed to participate. The purpose, format and methods of the study were presented to the workers at informational meetings located at their work site. Of the 1165 workers, 594 participants (construction workers: N=293; healthcare workers: N=301) agreed to complete a questionnaire at baseline and six months later. Of these, 178 construction workers and 193 healthcare workers additionally agreed to participate in technical measurements at baseline, which included clinical examination and measurements using accelerometers for 3–4 days while maintaining a short diary. Exclusion criteria were: inadequate skills in reading and writing Norwegian, known allergic reaction to plaster, tape, or bandages, or being pregnant. Subjects diagnosed with severe or insufficiently treated cardiovascular disease or musculoskeletal disorders were not subjected to tests they could not perform. We performed technical measurements on 62 construction workers and 63 healthcare workers selected to best fit logistics (availability, work schedules and profession). We have previously provided a full description of job titles (19).

All subjects signed a written informed consent form. This study was conducted in accordance with the Helsinki Declaration and approved by the Regional Committee for Medical and Health Research Ethics in Norway (2014/138/REK south east D).

Instrumentation for technical measurements

We used ActiGraph GT3X+ sensors (ActiGraph LLC, Pensacola, FL, USA) to measure the acceleration, position and angle of body segments with a sampling frequency of 30 Hz. The accelerometers were placed at the participant's right thigh (medially between the iliac crest and the upper crest of the patella) and right side of the hip (just below iliac crest) (42, 43). The accelerometers are lightweight (19 grams) and were fixed on the skin using double-sided tape (Fixomull, BSN Medical, Hamburg, Germany) and covered with transparent film (Tegaderm, 3 M, St. Paul, MN, USA).

Sitting and standing activities

From raw data measured by accelerometers for 3–4 days, minutes spent in sitting and standing positions were determined by a custom-made MATLAB-based program, Acti4 (National Research Center for the Working Environment, Denmark and Federal Institute for Occupational Safety and Health, Germany). Based on acceleration and the calculated angles of the thigh and hip, Acti4 algorithms discriminate between different types of activities and estimate the time spent in activity periods. Studies have found the Actigraph GT3X+ sensors setup at hip and thigh to be valid for detecting different physical activities (42, 43). In standardized trials, both the sensitivity and specificity for detecting sitting and standing are higher than 99% (43). From the participants' diary, we categorized each day into periods of work, periods of leisure, and periods of sleep. We excluded periods of sleep, periods during which the accelerometers were not worn, and when data did not fulfill the measurement criteria (<4 hours or 75% of the mean length of all respective periods) (20).

Low-back pain intensity

Subjects were asked to rate their LBP intensity for the preceding four weeks. They rated LBP intensity on a 4-point scale (not troubled=0, a little troubled=1, rather intensely troubled=2 and very intensely troubled=3) (44). A drawing adapted from the "Nordic questionnaire on musculoskeletal symptoms" was used to facilitate localization of body regions (45).

Covariates

Individual factors. Information on all individual factors were collected by self-report. Age, gender, seniority in profession, BMI (kg/m^2), and smoking status were established by general questions. We classified participants as smokers if they smoked daily or occasionally.

Self-reported mechanical exposures. Participants reported time spent sitting and standing during work with five response categories (never=0, sometimes=1, approximately 25% of the time=2, approximately 50% of the time=3, approximately 75% of the time=4 or almost all the time=5). To assess heavy lifting, they were asked if they normally lifted something weighing more than 20 kg during work, with three response alternatives (no=0, 1–4 times=1, 5–19 times=2, and ≥20 times per day=3) (46).

Psychosocial factors. We assessed decision control, fair- and empowering leadership and social climate in the organization using items adapted from the General Nordic Questionnaire for Psychological and Social Factors at work (QPS_{Nordic}) (47, 48). A full description of these questions is available online as supplementary material (www.sjweh.fi/index.php?page=data-repository).

Objectively measured forward bending. Forward bending during work was measured objectively by two accelerometers placed at the spinous processes at the level of T1–T2 and the halfway mark on the vertical line between the anterior superior iliac spine and the patella (43). We used minutes with ≥60° deviation from the upraised position as a measure for forward bending. Flexion ≥60° has previously been categorized as extreme flexion to very extreme flexion (49).

Statistical analysis

We tested associations between exposure and LBP intensity with linear mixed models fitted by restricted maximum likelihood with a random intercept added for subject. We did not adjust for baseline pain response, but we retained the baseline value as part of the outcome vector with no assumptions on its mean response at baseline, as recommended for observational data (50). Sitting or standing duration (in minutes) was entered as the main exposure variable and LBP intensity was entered as a dependent outcome variable. Analyses were carried out in two designs: (i) association between absolute work exposure duration (minutes) and LBP intensity; and (ii) association between absolute full-day (work + leisure) exposure duration (minutes) and LBP intensity. Analyses were performed stratified by work sector (construction and healthcare). Design 1 consisted of 5 models: model 1 – crude association between exposure and LBP; model 2 – as model 1 + adjustments for age, gender, smoking and BMI; model 3 – as model 2 + adjustments for objectively measured forward bending during work and heavy lifting; model 4 – as model 3 + adjustments for social climate, decision control, fair leadership, and empowering leadership; and model 5 – as model 4 + adjustment for objectively measured sitting or standing (minutes) during leisure. For Design 2, model 5 was not implemented. The mixed model may be expressed mathematically as where is the LBP intensity of worker *i* at time *t* and is a vector of regressors (sitting at work, age, …) linking the observations to the fixed effects β. Furthermore, represents independent and identically distributed normal random effects, with a mean 0 and variance, while are independent and identically distributed normal random residuals with a mean 0 and variance. All variables were selected prior to analyses and examined for collinearity. Seniority was excluded due to its high correlation with age. We performed sensitivity analyses to test the robustness of the main analyses: having or not having LBP (0 versus 1, 2, 3) and having low or moderate/high levels of LBP (0, 1 versus 2, 3) by multilevel mixed-effects logistic regression. Additionally, we performed non-responder analysis and performed analyses with the duration of sitting/standing as percentage of the individual's work- and full-day periods, instead of absolute values (minutes). As an indicator of change in job characteristics, we tested possible changes in self-reported sitting or standing duration and social climate between baseline and six months with Wilcoxon rank tests.

Associations were calculated by β coefficients (per 100 minutes) with 95% confidence intervals (95% CI). Statistical analyses were conducted in STATA, version 13.0 (StataCorp, College Station, TX, USA).

Results

There were no differences in self-reported sitting or standing time or social climate in the organization between baseline and six months follow-up, so we assumed these exposures to be unchanged.

Distribution of low-back pain intensity

At baseline, 41% of healthcare workers reported being untroubled by LBP, while 23% and 33% reported being a little or rather intensely troubled, respectively. Three percent reported being very intensely troubled. For construction, the corresponding percentages were 48, 25, 27 and 0%. At six months' follow-up, 45% of healthcare workers were not troubled by LBP; 14% reported being a little troubled, while 37% and 4% reported to be rather intensely troubled or very intensely troubled, respectively. The corresponding percentages for construction at six months were 51, 26, 19 and 4%.

Total measurement time and missing data

We measured a total of 944 hours of work and 971 hours of leisure with an average of 7.6 hours of work and 8.8 hours of leisure per day. From the 125 individuals initially measured, 1 subject did not have valid sit or stand exposure data for work and was therefore excluded. The characteristics of the subjects are provided in table 1: 15 did not have valid sit or stand exposure data for leisure, 3 did not answer the LBP intensity question at baseline, 1 did not answer the LBP intensity question at six months, and 27 did not respond to the six months questionnaire. The tested variables of age, gender, objectively measured sitting at work, objectively measured standing at work, and LBP intensity did not differ significantly between responders (N=97) and non-responders (N=27) (data not shown). The 124 participants reported lower perceived sitting time and higher perceived standing time at baseline compared to the 469 who completed questionnaire only (data not shown).

Sitting and low-back pain intensity at baseline

Healthcare sector. Duration of sitting at work was associated with baseline LBP intensity for the crude model (β=-0.33, 95% CI -0.55– -0.10) and models adjusted for individual and work related factors (models 2–4; table 2). For full-day data, significant associations with LBP intensity were found for the crude model (β=-0.21, 95% CI -0.38– -0.04) and the model adjusted for individual factors (model 2; table 4).

Table 1. Descriptive characteristics of study participants (N=124). [SD=standard deviation; LBP=low-back pain.]

Variables	Construction (N=61)			Healthcare (N=63)		
	%	Mean	SD	%	Mean	SD
Age (years)		39.9	13.6		44.5	9.6
Gender (male)	98.4			22.2		
Body mass index (kg/m²)		25.7	3.3		25.1	3.8
Smokers	31.1			27.0		
Normal work hours per week		37.8	4.0		35.7	4.2
Work hours measured per day		8.2	1.8		7.1	0.8
Sitting at work (minutes)		156.8	114.2		171.6	93.8
Sitting in leisure (minutes)		282.0	78.4		274.0	94.3
Standing at work (minutes)		156.8	69.4		123.1	58.9
Standing in leisure (minutes)		88.3	45.9		100.8	46.1
Forward bending at work (minutes)		27.4	24.9		15.8	10.3
Heavy lifting at work (0–3) [a]		1.5	1.2		0.4	0.6
Social climate at work (1–5) [b]		3.2	0.5		3.2	0.6
Decision control at work (1–5) [c]		3.2	0.7		2.9	0.8
Fair leadership (1–5) [c]		3.3	0.5		3.3	0.7
Empowering leadership (1–5) [c]		3.1	0.9		3.9	1.0
LBP intensity at baseline (0–3)		0.5	0.5		0.6	0.5
LBP intensity at 6 months (0–3) [d]		0.7	0.9		1.0	1.0

[a] Response alternatives: (0) No, (1) Yes, 1–4 times, (2) yes, 5–19 times and (3) yes, ≥20 times a day.
[b] Response alternatives: (1) very little or not at all, (2) rather little, (3) somewhat, (4) rather much and (5) very much;
[c] Response alternatives: (1) very seldom or never, (2) rather seldom, (3) sometimes, (4) rather often, and (5) very often or always
[d] 71% of workers reporting pain at baseline had pain at follow up.

Construction sector. Sitting duration had no significant associations with LBP intensity at baseline, either for work- or full-day exposure (table 2 and 4).

Sitting at baseline and low-back pain intensity after six months

Healthcare sector. Sitting duration (minutes) at work was associated with 6-month LBP intensity in the crude (β=-0.35, 95% CI -0.57– -0.13) and all adjusted models (table 2). For full-day data, significant associations were also shown for the crude model (β=-0.20, 95% CI -0.37– -0.04) and the model adjusted for individual factors (model 2; table 4).

Construction sector. Sitting duration (minutes) had no significant associations with LBP intensity at six months for construction workers, either for exposure at work- or full-day (table 2 and 4).

Standing and low-back pain intensity at baseline

Healthcare sector. There was a significant association between standing duration at work and baseline LBP intensity in the fully adjusted model (β=0.54, 95% CI 0.01– 1.07; table 3). No associations were found in full-day data (table 5).

Table 2. Linear mixed model with sitting exposure at work per 100 minutes and low-back pain intensity (Design 1). **Bold denotes P<0.05**.

	Model 1 [a]			Model 2 [b]			Model 3 [c]			Model 4 [d]			Model 5 [e]		
	Observations [f]=107/110			Observations [f]=107/106			Observations [f]=101/104			Observations [f]=101/100			Observations [f]=88/95		
	Coef.	95% CI	P-value	Coef.	95% CI	P-value	Coef.	95% CI	P-value	Coef.	95% CI	P-value	Coef.	95% CI	P-value
Construction															
T1 [g]	-0.01	-0.19–0.17	0.914	-0.02	-0.22–0.19	0.863	-0.009	-0.28–0.29	0.950	-0.005	-0.34–0.32	0.977	-0.00001	-0.35–0.35	1.00
T2 [h]	-0.02	-0.20–0.16	0.836	-0.03	-0.24–0.18	0.795	-0.0007	-0.29– 0.29	0.996	-0.014	-0.35–0.32	0.936	-0.003	-0.36–0.35	0.986
Healthcare															
T1 [g]	-0.33	-0.55– -0.10	**0.004**	-0.31	-0.06– -0.08	**0.009**	-0.32	-0.58– -0.05	**0.018**	-0.28	-0.56–-0.003	**0.047**	-0.31	-0.63– 0.01	**0.058**
T2 [h]	-0.35	-0.57– -0.13	**0.002**	-0.34	-0.58– -0.10	**0.005**	-0.35	-0.61– -0.08	**0.012**	-0.31	-0.60–-0.03	**0.029**	-0.34	-0.66– -0.02	**0.040**

[a] Sitting at work (per 100 minutes). Dependent variable: Pain (T1, T2).
[b] As model 1 + age, gender, smoking, body mass index.
[c] As model 2 + heavy lifting, forward bending at work.
[d] As model 3 + social climate, decision control, fair leadership, empowering leadership.
[e] As model 4 + sitting (minutes) during leisure time.
[f] Total observations included in linear mixed models for construction/healthcare.
[g] T1: baseline.
[h] T2: 6 month.

Table 3. Linear mixed model with standing exposure at work per 100 minutes and low-back pain intensity (Design 1). **Bold denotes P<0.05**.

	Model 1 [a]			Model 2 [b]			Model 3 [c]			Model 4 [d]			Model 5 [e]		
	Observations [f]=107/110			Observations [f]=107/106			Observations [f]=101/104			Observations [f]=101/100			Observations [f]=88/95		
	Coef.	95% CI	P-value	Coef.	95% CI	P-value	Coef.	95% CI	P-value	Coef.	95% CI	P-value	Coef.	95% CI	P-value
Construction															
T1 [g]	0.21	-0.08–0.50	0.152	0.22	-0.09–0.53	0.168	0.29	-0.11–0.70	0.156	0.29	-0.13–0.72	0.179	0.02	-0.51–0.55	0.940
T2 [h]	0.22	-0.07–0.52	0.135	0.23	-0.09–0.56	0.153	0.31	-0.11–0.72	0.144	0.31	-0.13–0.75	0.167	0.04	-0.50–0.58	0.873
Health care															
T1 [g]	0.29	-0.08–0.66	0.124	0.24	-0.14–0.63	0.220	0.29	-0.12–0.70	0.167	0.39	-0.07–0.85	0.095	0.54	0.01–1.07	**0.045**
T2 [h]	0.34	-0.05–0.72	0.084	0.29	-0.58–0.68	0.159	0.35	-0.07–0.77	0.106	0.42	-0.05–0.89	0.079	0.58	0.04–1.11	**0.035**

[a] Standing at work (per 100 minutes). Dependent variable: Pain (T1, T2).
[b] As model 1 + age, gender, smoking, body mass index.
[c] As model 2 + heavy lifting, forward bending at work.
[d] As model 3 + social climate, decision control, fair leadership, empowering leadership.
[e] As model 4 + sitting (minutes) during leisure time.
[f] Total observations included in linear mixed models for construction/healthcare.
[g] T1: baseline.
[h] T2: 6 month.

Construction sector. No significant associations were found (table 3 and 5).

Standing at baseline and low-back pain after six months

Healthcare sector. A significant association between standing at work and LBP intensity at baseline was found in the fully adjusted model only (β=0.58, 95% CI 0.04–1.11; table 3). Full-day data showed no significant associations (table 5).

Construction sector. No significant associations were found (table 3 and 5).

Additional analysis

The sensitivity analyses on dichotomized LBP variables supported the main analysis (data not shown). Furthermore, the analyses on the percentage of work or full-day spent sitting/standing showed similar, but somewhat weaker, associations as in the analyses with duration in minutes (data not shown).

Discussion

For healthcare workers, this study showed a negative association between the duration of sitting at work and LBP intensity at baseline and at six months' follow-up. The duration of standing at work was positively associated with LBP intensity, but only in the fully adjusted models. For construction workers, no associations were found between sitting and standing, and LBP intensity.

Very few studies have investigated the association between objectively measured sitting and/or standing exposure and LBP. However, two cross-sectional studies based on similar objective measures as the present

Table 4. Linear mixed model on full-day sitting exposure per 100 minutes and low-back pain intensity (Design 2). **Bold denotes P<0.05**.

	Model 1 [a]			Model 2 [a]			Model 3 [c]			Model 4 [d]		
	Observations [e]=90/101			Observations [e]=90/99			Observations [e]=88/99			Observations [e]=88/95		
	Coef.	95% CI	P-value	Coef.	95% CI	P-value	Coef.	95% CI	P-value	Coef.	95% CI	P-value
Construction												
T1 [f]	-0.05	-0.20–0.11	0.555	-0.06	-0.22–0.11	0.511	-0.07	-0.29–0.16	0.515	-0.07	-0.31–0.18	0.596
T2 [g]	-0.05	-0.20–0.10	0.477	-0.07	-0.23–0.10	0.441	-0.08	-0.30–0.14	0.460	-0.08	-0.31–0.17	0.541
Health care												
T1 [f]	-0.21	-0.38– -0.04	**0.016**	-0.21	-0.39– -0.02	**0.027**	-0.18	-0.40–0.04	0.118	-0.16	-0.40–0.08	0.183
T2 [g]	-0.20	-0.37– -0.04	**0.017**	-0.20	-0.39– -0.02	**0.028**	-0.17	-0.40–0.05	0.125	-0.17	-0.40–0.07	0.168

[a] Sitting full-day (per 100 minutes). Dependent variable: Pain (T1, T2).
[b] As model 1 + age, gender, smoking, body mass index.
[c] As model 2 + heavy lifting, forward bending at work.
[d] As model 3 + social climate, decision control, fair leadership, empowering leadership.
[e] Total observations included in linear mixed models for construction/healthcare.
[f] T1: baseline.
[g] T2: 6 month.

Table 5. Linear mixed model with full-day standing exposure per 100 minutes and low-back pain intensity (Design 2).

	Model 1 [a]			Model 2 [b]			Model 3 [c]			Model 4 [d]		
	Observations [e]=90/101			Observations [e]=90/99			Observations [e]=88/99			Observations [e]=88/95		
	Coef.	95% CI	P-value	Coef.	95% CI	P-value	Coef.	95% CI	P-value	Coef.	95% CI	P-value
Construction												
T1 [f]	-0.005	-0.29–0.28	0.975	0.0005	-0.31–0.32	0.998	-0.033	-0.40–0.33	0.857	-0.06	-0.46– 0.34	0.759
T2 [g]	-0.0004	-0.29–0.29	0.998	0.004	-0.32–0.33	0.983	-0.030	-0.40–0.34	0.876	-0.06	-0.46– 0.35	0.776
Health care												
T1 [f]	0.11	-0.16–0.39	0.419	0.07	-0.21–0.36	0.626	0.10	-0.20–0.39	0.521	0.11	-0.21– 0.44	0.495
T2 [g]	0.14	-0.15–0.42	0.350	0.09	-0.20–0.38	0.548	0.12	-0.18–0.42	0.422	0.12	-0.20– 0.45	0.466

[a] Standing at work (per 100 minutes). Dependent variable: Pain (T1, T2).
[b] As model 1 + age, gender, smoking, body mass index.
[c] As model 2 + heavy lifting, forward bending at work.
[d] As model 3 + social climate, decision control, fair leadership, empowering leadership.
[e] Total observations included in linear mixed models for construction/healthcare.
[f] T1: baseline.
[g] T2: 6 month.

study have recently been published. Gupta et al's cross-sectional study of 201 blue-collar workers reported that an increase in total hours of objectively measured sitting duration at work and throughout the day (work + leisure) was significantly associated with a higher LBP intensity (20). In contrast to those findings, the present study found an association between long sitting duration and lower LBP intensity. Our results agreed with the reviews of Hartvigsen (11) and Roffey (10).

There are several possible explanations for the mixed findings regarding sitting at work and LBP intensity. Sitting may be associated with jobs with higher levels of control and autonomy and more engaging tasks, reducing reported LBP intensity (38). Longer durations of sitting may also by exclusion be associated with lower exposures to other physical factors such as manual-materials handling (51). Models in the present study including self-reported physical and psychosocial exposures showed attenuated sitting associations (tables 2–5).

Munch Nielsen et al's cross-sectional study of 187 Danish workers based on objective measures of standing duration at work reported a non-significant association between the time standing and level of LBP intensity (21). An association between prolonged standing at work and LBP intensity was only found in fully adjusted analysis among healthcare workers in our study. Thus, the present study does not permit the conclusion that the duration of standing during work or during the full-day is a risk factor for LBP. As discussed above for jobs involving sitting, there may be characteristics connected to jobs involving standing that affects pain reporting, creating the opposite scenario with increased reporting of LBP. It is also possible that subjects with LBP avoid activities causing pain or perform tasks differently (52, 53), obscuring cross-sectional results.

Our data indicated that the association between sitting, standing, and LBP intensity varied between work sectors and that the often used blue-collar classification may obscure possible sub-group associations. Moreover, the difference in gender composition between the two sectors involved in our study (healthcare=78% female, construction=98% male) is characteristic for these sectors and suggests that disentangling work sector and gender in such cases is difficult.

Strengths and limitations

A major strength of the present study was the use of objectively measured sitting and standing for several consecutive days, both during work and leisure time, in combination with the prospective outcome. To our knowledge, this is the first study providing this kind of information. This gives a precise measure of exposure, and we avoid depending on self-reported exposures that may lead to biased estimations on association between exposure and LBP intensity (12).

By restricting the study to healthcare and construction workers, we attenuated confounding effects of large variations in work content and socioeconomic gradients. Furthermore, the analyses were adjusted for several potential confounders, including mechanical and psychosocial work-related factors. The confounders of forward bending at work and the respective exposure during leisure were also measured objectively.

The use of mixed models provides flexible variance structures, robustness against dropouts and full utilization of all available observations. We retained the baseline pain response as part of the outcome variable, and did not use it as an adjustment variable. This enabled us to study the change in pain response in a manner that did not make any assumptions that the baseline pain response is associated with other covariates (eg, sitting minutes) being studied. Adjusting for the baseline pain response requires that there is no association between baseline outcome and the covariates being studied (54).

An important issue is that the coefficients found for significant associations are small and therefore differences in exposure durations needs to be large for the changes in LBP to be of any clinical relevance. Depending on whether the pain is acute or chronic and the type of scoring, previous studies on various pain intensity scales suggests levels of 20–30% improvement in a variable as a minimally clinically important change (55, 56). In our case, a clinically relevant change in LBP corresponds to a change in sitting duration from the lowest measured values to the highest, a total change in sitting characteristics during work.

Our use of technical measurements does limit the size of the study population, which was a small fraction (11%) of those initially invited for participation. The 124 participants included in this study reported lower perceived sitting time and higher perceived standing time at baseline compared to the 469 who only completed questionnaires. This may be due to an overrepresentation of manual workers in our study (most represented professions: carpenter, concrete worker, nurse, and personal care workers). Furthermore, data visualization indicates that results may be somewhat driven by few observations with high exposure values. Thus, larger groups and a longer follow-up with more measurements may provide a more accurate representation. Multiple follow-ups would also capture possible fluctuations in time observed with pain variables (57), thereby enhancing the reliability of outcome measurements.

We did not consider any possible seasonal changes, and although exposure was measured for several days it was only measured on one occasion. We did not collect specific information on long-term LBP history at baseline. However, very few participants reported serious spine related injuries in the previous 12 months. We cannot exclude the presence of a healthy-worker effect, due to unhealthy workers being on sick leave or outside the work force, or possible differences between individuals with a long or short history of LBP.

Concluding remarks

For healthcare workers, this study showed a negative association between the duration of sitting at work and LBP intensity at baseline and at 6-month follow-up. The duration of standing at work was positively associated with LBP intensity only in the fully adjusted models. For construction workers, we found no associations between sitting and standing, and LBP intensity.

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