Associations of objectively measured forward bending at work with low-back pain intensity: a 2-year follow-up of construction and healthcare workers

Lars-Kristian Lunde, Markus Koch, Suzanne Lerato Merkus, Stein Knardahl, Morten Wærsted, Kaj Bo Veiersted

ABSTRACT

Objectives This study aimed to determine possible associations between objectively measured forward bending at work (FBW) and low-back pain intensity (LBP) among Norwegian construction and healthcare workers.

Methods One-hundred and twenty-five workers wore two accelerometers for 3–4 consecutive days, during work and leisure to establish duration of ≥30° and ≥60° forward bending. The participating workers reported LBPi (0–3) at the time of objective measurements and after 6, 12, 18 and 24 months. We investigated associations using linear mixed models with significance level p≤0.05 and presented results per 100 min.

Results The duration of ≥30° and ≥60° FBW was not associated with average LBPi during follow-up, neither for the total sample nor stratified on work sector. Furthermore, analyses on all workers and on construction workers only found no significant association between ≥30° or ≥60° FBW and change in LBPi over the 2-year follow-up. For healthcare workers we found a consistent significant association between the duration of ≥30° FBW at baseline and the change in LBPi during follow-up, but this was not found for ≥60° FBW.

Conclusions This study suggests that objectively measured duration of FBW in minutes is not associated with average LBPi during follow-up, neither for the total sample nor stratified on work sector. Furthermore, analyses on all workers and on construction workers only found no significant association between ≥30° or ≥60° FBW and change in LBPi over the 2-year follow-up. For healthcare workers we found a consistent significant association between the duration of ≥30° FBW at baseline and the change in LBPi during follow-up, but this was not found for ≥60° FBW.

Key messages

What is already known about this subject?

► There is a high prevalence of musculoskeletal disorders in the construction and healthcare sectors.
► Long duration of forward bending of the upper body during work is suggested as a risk factor for developing low-back pain in physically demanding occupations.
► However, previous studies have largely relied on self-reported exposure duration, which provides inadequate evidence due to low methodological quality.
► The only published study using a prospective design and objective measures has investigated a mixed group of blue-collar workers and concluded there was no association.

What are the new findings?

► We investigated associations between objectively measured forward bending for 3–4 consecutive days and low-back pain in construction and healthcare workers, with a 2-year prospective design.
► Forward bending at work ≥30° was associated with a change in low-back pain intensity in healthcare, but not in construction; no associations were found for average pain.
► Results indicate that the associations between forward bending at work and low-back pain may vary depending on type of work tasks, gender or sector-specific factors.

INTRODUCTION

Low-back pain (LBP) is globally one of the largest contributors to years lived with disability and therefore a major public health problem. The high prevalence of musculoskeletal disorders in construction and healthcare sectors highlights the importance of identifying work-related risk factors. Laboratory studies suggest that load on the lumbar spine and muscle activity in the lower back increase in proportion to the degree of flexion of the upper body. Further, that regular biomechanical loading of the lower back from forward bending may lead to tissue damage of spine and back muscles, resulting in increased LBP. However, reviews on the association between forward bending at work (FBW) and LBP show conflicting results and highlight the methodological limitations pertaining to lack of objective measures. The discrepant findings may be a result of recall bias connected to self-reported exposure duration, differences in questionnaires, and lower back pain intensity.
interpretation or the effect of participants’ pain levels attenuating the validity of self-reported exposure.14–16 Thus, objective measurement methods are recommended in the investigation of physical exposures. Moreover, measurements over several days are preferable to single measurement days,14 15 because they capture variations in exposure between workdays. However, few studies have measured FBW objectively for consecutive working days when investigating its association to LBP. To our knowledge, only two cross-sectional studies and one prospective study in Danish blue-collar workers are available, which all reported no association.17–19 More studies with a prospective design and objective measures are needed to confirm these results.17–19 We are not aware of any studies that provide this knowledge for the construction and healthcare sectors.

Generally, the development of LBP is of multifactorial origin with suggested individual risk factors being age and gender,20 body mass index (BMI) and smoking.21 22 Mechanical exposures at work, such as heavy lifting and overall heavy physical work, are also linked to LBP.12 High seniority in professions with heavy work may further increase the risk of LBP due to accumulation of such exposures.23 24 For the population presented in this study, we have previously found sitting at work to be associated with lower LBP levels in healthcare workers.25 LBP is also linked to LBP.12 High seniority in professions with heavy work may further increase the risk of LBP due to accumulation of such exposures.23 24 For the population presented in this study, we have previously found sitting at work to be associated with lower LBP levels in healthcare workers.25 LBP is also linked to LBP.12 High seniority in professions with heavy work may further increase the risk of LBP due to accumulation of such exposures.23 24 For the population presented in this study, we have previously found sitting at work to be associated with lower LBP levels in healthcare workers.25 LBP is also linked to LBP.12

Forward bending during work
From raw data provided by the 3–4 days of accelerometer assessments at baseline, minutes spent in forward bent position 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). Studies have found the ActiGraph GT3X+ sensors’ set-up to be valid for detecting durations of different upper body inclinations.26–31 From the participants’ diary, we categorised 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 fulfil the measurement criteria (shorter than 4 hours or 75% of the mean length of all respective periods).32 We present data on forward bending as the average daily duration in minutes with trunk flexion $\geq 30^\circ$ and $\geq 60^\circ$ from the individuals’ neutral standing position. Flexion of $\geq 30^\circ$ and $\geq 60^\circ$ has previously been categorised as respectively mild and extreme flexions.17 19

Self-reported FBW
Participants reported the fraction of their daily work performed with forward bended trunk, with the response alternatives (0) Never, (1) Very small part of the time, (2) Approximately 25% of the time, (3) Approximately 50% of the time, (4) Approximately 75% of the time, and (5) Almost all the time.33 This question was used as a proxy for change in exposure to FBW during the 2-year follow-up.
Low-back pain intensity
Subjects were asked to rate their LBPi during the preceding 4 weeks. They rated LBPi on a 4-point scale (not troubled = 0, a little troubled = 1, rather intensely troubled = 2 and very intensely troubled = 3).34 A manikin drawing facilitated localisation of different body regions.

Covariates
Individual factors
Information of age, gender, seniority in profession, BMI (kg/m²) and smoking status was collected by self-reports. We classified participants as smokers if they smoked daily or occasionally.

Self-reported manual handling
Participants reported if they, during regular workdays, lifted something weighing more than 20 kg, with response alternatives (0) No, (1) Yes, 1–4 times, (2) Yes, 5–19 times and (3) Yes, at least 20 times a day.33

Psychosocial factors
We assessed decision control, fair and empowering leadership, and social climate in the organisation by items from the General Nordic Questionnaire for Psychological and Social Factors at work.35 36 A full description of these questions is available in online supplementary material text A.

Automatically measured sitting
Simultaneously as measuring forward bending, we measured sitting duration for 3–4 days using two ActiGraph GT3X sensors placed at the hip and the thigh, a set-up valid for sitting duration for 3–4 days using two ActiGraph GT3X sensors placed at the hip and the thigh, a set-up valid for detecting sitting activities.29 30

Statistical analyses
To test the associations between FBW and LBPi, we used linear mixed models fitted by restricted maximum likelihood with a random intercept added for subject. We treated FBW duration in minutes as the main exposure variable and LBPi as the dependent variable. To test the preset hypotheses, we implemented analyses with two different designs: (1) the association between exposure to FBW in minutes and the average LBPi over the 2-year follow-up (ie, including FBW duration as main effect in the model); and (2) the association between exposure to FBW in minutes and the change in LBPi (ΔLBPi) between baseline and the four time points during the 2-year follow-up (ie, including FBW duration as main effect, time as categorical variable and an interaction between FBW duration*time). In order to remove a reversed causal effect between pain and exposure at baseline, we additionally performed analyses with duration of FBW as percentage of work period. To detect potential differences between responders and non-responders, and the technical measurements group and the group only answering questionnaires, we compared group variables by independent sample t-test and Wilcoxon rank-sum test. Finally, as an indicator of change in job characteristics, we tested possible changes in self-reported FBW and social climate between baseline, 6, 12, 18 and 24 months with Friedman’s analysis of variance.

RESULTS
Twelve of the 138 selected employees were unable to participate due to various practical reasons (no show, acute illness, change in work location). One person was removed from analysis after reporting having Bechterew’s disease. This led to a final study sample of 125 employees (construction n=61; healthcare n=64). See table 1 for subject characteristics, and figure 1 for distributions of LBPi for the full study period. There was no difference in self-reported forward bending at baseline between those undergoing technical measures and the group only answering questionnaires (p=0.164). Additionally, we found no differences in self-reported FBW (construction p=0.273; healthcare p=0.442) and reported social climate (construction p=0.304; healthcare p=0.318) between baseline, 6, 12, 18 and 24 months.

Total measurement time and missing data
We measured a total of 946 hours of work with an average of 7.6 work hours per day. From the 125 individuals in the study sample, accelerometer data were available for 95% (n=119) of the participants. Two per cent of the subjects did not answer the LBPi question at baseline. Twenty-two %, 42%, 42% and 47% missed the LBPi question or did not respond to the questionnaire at 6, 12, 18 and 24 months. Fifty-four subjects responded to all questionnaires, while 71 failed to respond on one or more follow-ups. Analyses on the construction workers showed no statistically significant differences between responders and non-responders concerning age, gender, objectively measured FBW and baseline LBPi. For healthcare, the non-responders were statistically significantly younger, had shorter duration of objectively measured forward bending and consisted of more males.

FBW and average LBPi
For all workers, analyses on the duration of ≥30° and ≥60° forward bending in minutes at work showed no significant associations with the average reported LBPi from the 2 years of follow-up (table 2). Similarly, we found no associations in the analyses stratified on construction or healthcare workers.

FBW and change in LBPi
Forward bending at ≥30°
Analyses of all workers and construction workers only showed no statistically significant associations between duration of ≥30° FBW and change in LBPi during follow-up (table 3). For healthcare workers, the analyses showed a trend of statistically
Table 1  Descriptive characteristics of the study participants at baseline (n=125)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Total (n=125)</th>
<th>Construction (n=61)</th>
<th>Healthcare (n=64)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age (years)</td>
<td>42.0</td>
<td>11.9</td>
<td></td>
</tr>
<tr>
<td>Gender (male)</td>
<td>59.2</td>
<td>98.4</td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>25.3</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Smokers</td>
<td>28.8</td>
<td>31.1</td>
<td></td>
</tr>
<tr>
<td>Seniority in profession</td>
<td>16.4</td>
<td>11.2</td>
<td></td>
</tr>
<tr>
<td>Normal work hours per week</td>
<td>36.7</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>Work hours measured per day</td>
<td>7.6</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Bending ≥30° at work (min)</td>
<td>86.4</td>
<td>46.2</td>
<td></td>
</tr>
<tr>
<td>Bending ≥60° at work (min)</td>
<td>21.5</td>
<td>19.7</td>
<td></td>
</tr>
<tr>
<td>LBPI at baseline (0–3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not troubled</td>
<td>44.3</td>
<td>48.3</td>
<td></td>
</tr>
<tr>
<td>A little troubled</td>
<td>25.4</td>
<td>26.7</td>
<td></td>
</tr>
<tr>
<td>Rather intensely troubled</td>
<td>28.7</td>
<td>25.0</td>
<td></td>
</tr>
<tr>
<td>Very intensely troubled</td>
<td>1.6</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Sitting duration at work (min)</td>
<td>165.0</td>
<td>104.3</td>
<td></td>
</tr>
<tr>
<td>Heavy lifting at work (0–3)*</td>
<td>0.9</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Social climate at work (1–5)†</td>
<td>4.0</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Decision control at work (1–5)‡</td>
<td>3.1</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Fair leadership (1–5)‡</td>
<td>4.0</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>Empowering leadership (1–5)‡</td>
<td>3.1</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

*Response alternatives: (0) No, (1) Yes, 1–4 times, (2) Yes, 5–19 times, (3) Yes, at least 20 times a day.
†Response alternatives for supportive, trustful and comfortable climate: (1) Very little or not at all, (2) Rather little, (3) Somewhat, (4) Rather much, (5) Very much.
‡Response alternatives: (1) Very seldom or never, (2) Rather seldom, (3) Sometimes, (4) Rather often, (5) Very often or always.
LBPI, low-back pain intensity.

Significant associations between forward bending and positive change in LBPI for all models at follow-up times T2, T3 and T4, but not T5 (table 3).

Forward bending at ≥60°
For all workers, and for construction workers only, analyses on ≥60° forward bending in minutes at work showed no statistically significant associations with the change in LBPI between baseline and any of the time points during follow-up (table 4). Analyses of healthcare workers showed statistically significant positive associations only at T3 for models 3 and 4 (table 4).

Additional analyses
Additional analyses on duration of ≥30° and ≥60° FBW as percentage of the work period consistently supported the results based on duration in minutes, both for average pain and change in pain. Analyses of ≥30° FBW as percentage on average pain in construction workers showed a statistically significant negative association (online supplementary tables A–C).

DISCUSSION
We did not find any association between duration of ≥30° or ≥60° FBW and the average level of LBPI during the 2-year follow-up in construction or healthcare workers. Similarly, no significant associations were found between ≥30° or ≥60° FBW and change in pain when analysing all workers or construction workers only. For healthcare workers there was a consistent significant association between the duration of ≥30° FBW and the change in LBPI between baseline and follow-up, but not for ≥60° FBW, where only T3 in adjusted models reflected significant results.

There are very few studies investigating the association between objectively measured FBW and LBPI. A cross-sectional
Table 2  Linear mixed model with exposure to ≥30° and ≥60° forward bending at work (per 100 min) and average low-back pain during follow-up (design 1)

<table>
<thead>
<tr>
<th>Model</th>
<th>Coefficient</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>≥30°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All workers</td>
<td>−0.08</td>
<td>−0.50 to 0.24</td>
<td>0.625</td>
</tr>
<tr>
<td>Construction</td>
<td>−0.25</td>
<td>−0.64 to 0.14</td>
<td>0.204</td>
</tr>
<tr>
<td>Healthcare</td>
<td>0.26</td>
<td>−0.33 to 0.84</td>
<td>0.385</td>
</tr>
<tr>
<td>Model 2</td>
<td>≥30°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All workers</td>
<td>−0.13</td>
<td>−0.47 to 0.21</td>
<td>0.453</td>
</tr>
<tr>
<td>Construction</td>
<td>−0.32</td>
<td>−0.72 to 0.08</td>
<td>0.113</td>
</tr>
<tr>
<td>Healthcare</td>
<td>0.24</td>
<td>−0.38 to 0.86</td>
<td>0.448</td>
</tr>
<tr>
<td>Model 3</td>
<td>≥30°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All workers</td>
<td>−0.13</td>
<td>−0.46 to 0.21</td>
<td>0.467</td>
</tr>
<tr>
<td>Construction</td>
<td>−0.32</td>
<td>−0.72 to 0.08</td>
<td>0.121</td>
</tr>
<tr>
<td>Healthcare</td>
<td>0.24</td>
<td>−0.37 to 0.86</td>
<td>0.439</td>
</tr>
<tr>
<td>Model 4</td>
<td>≥30°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All workers</td>
<td>−0.12</td>
<td>−0.45 to 0.21</td>
<td>0.480</td>
</tr>
<tr>
<td>Construction</td>
<td>−0.33</td>
<td>−0.71 to 0.05</td>
<td>0.089</td>
</tr>
<tr>
<td>Healthcare</td>
<td>0.29</td>
<td>−0.35 to 0.92</td>
<td>0.377</td>
</tr>
<tr>
<td>Model 5</td>
<td>≥30°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All workers</td>
<td>−0.11</td>
<td>−0.44 to 0.21</td>
<td>0.486</td>
</tr>
<tr>
<td>Construction</td>
<td>−0.32</td>
<td>−0.71 to 0.06</td>
<td>0.100</td>
</tr>
<tr>
<td>Healthcare</td>
<td>0.15</td>
<td>−0.45 to 0.76</td>
<td>0.623</td>
</tr>
</tbody>
</table>

Table 3  Linear mixed model with exposure to forward bending ≥30° at work (per 100 min) and change in low-back pain during follow-up (design 2)

<table>
<thead>
<tr>
<th>Model</th>
<th>Coefficient</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>0.12</td>
<td>−0.26 to 0.50</td>
<td>0.528</td>
</tr>
<tr>
<td>T3</td>
<td>0.05</td>
<td>−0.34 to 0.45</td>
<td>0.799</td>
</tr>
<tr>
<td>T4</td>
<td>0.25</td>
<td>−0.14 to 0.63</td>
<td>0.214</td>
</tr>
<tr>
<td>T5</td>
<td>0.19</td>
<td>−0.28 to 0.66</td>
<td>0.422</td>
</tr>
<tr>
<td>Model 2</td>
<td>Construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>−0.23</td>
<td>−0.70 to 0.24</td>
<td>0.342</td>
</tr>
<tr>
<td>T3</td>
<td>−0.33</td>
<td>−0.82 to 0.15</td>
<td>0.180</td>
</tr>
<tr>
<td>T4</td>
<td>−0.05</td>
<td>−0.52 to 0.42</td>
<td>0.828</td>
</tr>
<tr>
<td>T5</td>
<td>0.23</td>
<td>−0.40 to 0.85</td>
<td>0.478</td>
</tr>
<tr>
<td>Model 3</td>
<td>Healthcare</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>0.84</td>
<td>0.20 to 1.48</td>
<td>0.010</td>
</tr>
<tr>
<td>T3</td>
<td>0.81</td>
<td>0.14 to 1.49</td>
<td>0.018</td>
</tr>
<tr>
<td>T4</td>
<td>0.85</td>
<td>0.17 to 1.52</td>
<td>0.014</td>
</tr>
<tr>
<td>T5</td>
<td>0.42</td>
<td>−0.29 to 1.12</td>
<td>0.251</td>
</tr>
</tbody>
</table>

Observations: total observations included in linear mixed models for all workers/construction/healthcare. Independent variables: Model 1: forward bending at work (min/workday). Model 2: as model 1+age, gender, smoking, body mass index (BMI). Model 3: as model 2+heavy lifting. Model 4: as model 3+social climate, decision control, fair leadership, empowering leadership. Model 5: as model 4+objectively measured sitting at work (min/workday).
study on 198 Danish blue-collar workers reported no significant association of objectively measured duration of ≥30°, ≥60° and ≥90° FBW with LBP. With a similar set of objective measures at baseline, Lagersted-Olsen et al collected LBP reports for 1 year prospectively in a group of mixed blue-collar professions and concluded there was no association between ≥60° FBW and the development or aggravation of LBP. Our data from construction workers may be the most relatable to the study populations of mixed blue-collar workers in these two studies, and did support their findings of no association. We were not able to find studies with objective measures on workers in healthcare professions.

Lagersted-Olsen et al suggested three possible explanations for their findings of no association: (1) there is no association between forward bending and LBP; (2) there is an association, but limitations in design or methods preclude the detection of effect; and (3) the association is valid, but only when a third factor is present, under specific circumstances or in specific populations.

Our study partly supported the third explanation: a significant association for healthcare workers, but not for construction workers. This may indicate that gender differences and/or differences in work characteristics influence pathogenic mechanisms differentially, leading to diverging results between the sectors. Therefore, large unspacific groups labelled as ‘blue-collar’ workers may hide possible associations in subgroups. For our study population in particular, differences in biomechanical exposure and attitude towards pain may explain some of the differences in findings between the sectors. Variation in work tasks over time could also influence associations in our study. We did not find any change in the mean self-reported duration of exposure to FBW for either group throughout the follow-up. However, self-reported exposures have weaknesses and other circumstances than merely the exposure itself that may influence how workers respond. Overall, it is likely that construction workers had more variation in physical work exposures throughout the 2 years of follow-up than the healthcare workers, mainly due to project building cycles. The healthcare workers are probably less exposed to large variations in work tasks, thus the 4-day recording of FBW may be a better representation of their regular job exposures over the years. Hence, baseline exposure may be a better predictor for future pain in healthcare workers than in the construction workers.

We consider the size of the coefficients of the association between ≥30° FBW and LBP change in healthcare workers to be relatively large. Our results indicate a change in pain of around 0.8–0.9 units per 100 min spent in ≥30° FBW (table 3, healthcare T2–T4). In our sample, approximately 80 min per workday is on average spent in ≥30° forward bending positions, and around 28% of the healthcare workers have a daily exposure above 100 min (data not shown). Depending on pain scale and chronicity, 20%–30% improvement in a pain variable may be considered as a minimally clinically important change. Thus, a group of mixed blue-collar professions and concluded there was no association between ≥60° FBW and the development or aggravation of LBP. Our data from construction workers may be the most relatable to the study populations of mixed blue-collar workers in these two studies, and did support their findings of no association. We were not able to find studies with objective measures on workers in healthcare professions.

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Our study partly supported the third explanation: a significant association for healthcare workers, but not for construction workers. This may indicate that gender differences and/or differences in work characteristics influence pathogenic mechanisms differentially, leading to diverging results between the sectors. Therefore, large unspacific groups labelled as ‘blue-collar’ workers may hide possible associations in subgroups. For our study population in particular, differences in biomechanical exposure and attitude towards pain may explain some of the differences in findings between the sectors. Variation in work tasks over time could also influence associations in our study. We did not find any change in the mean self-reported duration of exposure to FBW for either group throughout the follow-up. However, self-reported exposures have weaknesses and other circumstances than merely the exposure itself that may influence how workers respond. Overall, it is likely that construction workers had more variation in physical work exposures throughout the 2 years of follow-up than the healthcare workers, mainly due to project building cycles. The healthcare workers are probably less exposed to large variations in work tasks, thus the 4-day recording of FBW may be a better representation of their regular job exposures over the years. Hence, baseline exposure may be a better predictor for future pain in healthcare workers than in the construction workers.

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and season. Account for possible changes in exposure due to project cycles. Exposure assessments would also provide additional precision to exposure assessments would be crucial methods for untangling such dynamics in the relationship between FBW and LBP.

**Strengths and limitations**

A major strength of this study was the use of validated objectively measured FBW for several consecutive days, providing a precise measure of exposure and avoiding biases related to self-reported exposure assessment. Another strength was the 2-year follow-up of the pain outcome. The study was restricted to include only healthcare and construction workers, which attenuate confounding effects from large variations in work characteristics and socioeconomic factors. To our knowledge, no previous studies on construction and healthcare workers have provided the kind of information presented here.

We only measured duration spent in different angles of FBW, which is only one of several aspects of the work pattern. Thus, we did not consider posture variation, load, twisting or trunk rotation, which could show independent associations to LBP or provide additional information in FBW’s relation to LBP. Objective measures increased resources used per participant as well as the extra burden put on participating individuals. This could lead to a possible selection of workers consenting to participate in the technical measurement group. However, we found no difference in age, seniority in profession, gender, LBP at baseline or the mean self-reported FBW between the 125 participants with objective measures and the group only answering questionnaires. Something that indicates a certain level of representativeness. That means that something indicates a certain level of representativeness. The sample size was relatively small, and we cannot rule out that a larger sample size could reflect findings for smaller effect sizes and provide more solid data for investigating ≥60° FBW.

Even though very few participants reported any serious spine-related injuries in the 12 months prior to baseline, we did not have information on long-term history of LBPs. Compared with a commonly used 0–10 measure, a pain scale of 0–3 will not have information on long-term history of LBP. Compared with a commonly used 0–10 measure, a pain scale of 0–3 will not have information on long-term history of LBP. Compared with a commonly used 0–10 measure, a pain scale of 0–3 will not have information on long-term history of LBP. Compared with a commonly used 0–10 measure, a pain scale of 0–3 will not have information on long-term history of LBP.

Multiple exposure assessments would also provide additional precision to prediction of pain during the follow-up and make it feasible to account for possible changes in exposure due to project cycles and season.

**Concluding remarks**

Objectively measured duration of FBW was not associated with average levels of, or change in LBP over a 2-year period in construction workers. In healthcare workers, exposure to ≥30° FBW was associated with change in LBP, while we did not find this for ≥60° FBW. Results may indicate that the associations between FBW and LBP vary depending on type of work tasks, gender or sector-specific factors.

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**Contributors**

All authors contributed to form the study design. LKL and MK collected the data. LKL drafted the paper and was responsible for statistical analysis and interpreting the data. MK, SLM, SK, MW and KBV assisted with data interpretation and reviewed, edited and approved the final version of the manuscript.

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**Competing interests**

None declared.

**Patient consent for publication**

Not required.

**Ethics approval**

The study was approved by the Regional Committee for Medical and Health Research Ethics in Norway (2014/138/REK south-east D).

**Provenance and peer review**

Not commissioned; externally peer reviewed.

**Data availability statement**

Data are available upon reasonable request.

**Open access**

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