Dose–response relationship between work-related cumulative postural exposure and low back pain: A systematic review

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Objectives: To assess the evidence for a dose–response relationship between ROM, duration, and frequency of trunk flexion, and risk of occupational LBP.

Methods: An electronic systematic search was conducted using Medline, Cumulative Index to Nursing and Allied Health Literature, EMBASE, and Scopus databases focusing on cohort and case–control studies. Studies were included if they focused on non-specific LBP and postural exposure, considering ROM, duration, or frequency of trunk flexion as independent variables. No language restriction was imposed. Included studies were assessed for risk of bias using the Newcastle-Ottawa Scale for observational studies and a summary of evidence is presented.

Results: Eight studies were included and all were methodologically rated as high quality. The included studies yielded a total of 7023 subjects who were considered for risk analysis. Different outcome measures for postural exposure were adopted making meta-analysis difficult to perform.

Conclusions: We could not find a clear dose–response relationship for work posture exposures and LBP. Limited evidence was found for ROM and duration of sustained flexed posture as risk factor for LBP. We found no evidence for frequency of trunk flexion as a risk factor for LBP.

Keywords: cumulative exposure; low back pain; posture; risk factor; systematic review

INTRODUCTION

Mechanical and non-mechanical factors can be associated with development of low back pain (LBP) (Vandergrift et al., 2011). Non-mechanical factors can be both personal and psychosocial (da Costa and Vieira, 2010; Vandergrift et al., 2011) and, while personal factors can explain up to 12% of first LBP occurrence (Adams et al., 1999), psychosocial factors seem to be more closely associated with the maintenance of the chronic stages of LBP (Ehrlich, 2003; Koes et al., 2006).

From a physical perspective, the association between cumulative trauma and LBP is thought to be linked to repetitive spinal loading (Ben-Masaud et al., 2009). Mechanical factors, such as high
physical demand, lifting tasks, and adoption of awk-
ward postures (da Costa and Vieira, 2010), are im-
portant biomechanical variables for assessing risk
during task assessment (Kumar, 1990; Norman
et al., 1998; Waters et al., 2006). A wide range of me-
chanical risk factors for LBP have been reported in the
literature, including peak lumbar shear force (Kerr
et al., 2001), frequency of repetitive loading (Le
et al., 2007), cumulative lumbar compression (Ku-
mar, 1990; Kerr et al., 2001), cumulative spinal loads
(Norman et al., 1998), cumulative lumbar extensor
moments (Norman et al., 1998), external forces
applied to the hand (Norman et al., 1998), peak
spinal flexion velocity (Norman et al., 1998), and
the amount of trunk flexion (e.g., greater than 20°)
(Punnett et al., 1991).

Subjects with LBP can also have increased co-
contraction of spinal muscles, which has been
linked to an increased risk of spinal tissue injury
(Marras et al., 2000). While laboratory studies have
clearly shown that repetition, sustained load, and/or
flexed posture can induce spinal neuromuscular dis-
orders (Parkinson et al., 2004; Ben-Masaud et al.,
2009), field studies have reported conflicting results
(Bakker et al., 2009). The role of work posture as
a risk factor for LBP is controversial and, while some
studies report increased risk for workers exposed to
flexed posture at work, current guidelines for LBP
prevention suggest that there is limited evidence for
posture as a risk factor for LBP (Burton et al.,
2006). Due to the likely cumulative effect, duration
(Parkinson et al., 2004; Milosavljevic et al., 2007),
trunk range of motion (ROM) (Hoogendoorn et al.,
2000a), and frequency of trunk flexion (Solomonow
et al., 1999) are considered to be the three main
domains that influence cumulative postural exposure
(Burdorf and van der Beek, 1999). The interaction
between these postural factors is complex and can lead
to a non-linear reduction of tissue load tolerance over
time (Waters et al., 2006), contributing toward
micro-rupture of lumbar soft tissues (Solomonow
et al., 2003a).

Although psychosocial factors are known to con-
tribute to LBP (Krause et al., 1998; Hoogendoorn
et al., 2000b), they do not appear to be predictors
of first time LBP, but instead with maintenance of
symptoms (Ehrlich, 2003; Koes et al., 2006). Psycho-
social risk factors reported in the literature include
stress, anxiety, negative emotions, and depression
(Nicholas et al., 2011). It has also been suggested that
work-related psychosocial factors such as high work
demands, poor peer support at work, and low job con-
trol may increase the risk of LBP (Kerr et al., 2001).
A recent study reported that these work-related psy-
chosocial factors (high work demand and low job
control) are associated with a new episode of LBP,
but only if workers were exposed to high physical
demands at work (Vandergrift et al., 2011). It is also
accepted that a previous history of LBP is the most
powerful predictor for a new episode of LBP (Burton
et al., 2006).

In order to develop better injury prevention pro-
grammes, it is important to establish and understand
the dose–response relationship between the effects
of cumulative flexed posture and the development of
LBP (Jansen et al., 2004; Vieira and Kumar, 2006).
A recent systematic review focusing on awkward
posture as a risk factor for LBP (Wai et al., 2010)
included both quantitative and qualitative postural
outcome measures. Although qualitative postural mea-
sures are commonly used, objective postural measure-
ments are likely to provide more accurate information
regarding work-related posture (Spielholz et al., 2001).
In order to assess the role of cumulative posture ex-
posure as a risk factor for LBP, we performed a systematic
review that aimed to assess the level of evidence for
ROM, duration, and frequency of trunk flexion as risk
factors for LBP.

MATERIALS AND METHODS

Eligibility criteria

To be eligible for inclusion, studies were required
to be a prospective cohort or case–control design; fo-
cus on non-specific LBP (defined as discomfort and
pain, with or without leg pain, above inferior gluteal
folds, and below the costal margin)(Waddell, 2004);
be available in full report in a peer-reviewed journal;
study a working age population (18–67 years); de-
scribe job activity; describe occupational exposure
to be a prospective cohort or case–control design; fo-
cuse on non-specific LBP (defined as discomfort and
pain, with or without leg pain, above inferior gluteal
folds, and below the costal margin)(Waddell, 2004);
be available in full report in a peer-reviewed journal;
study a working age population (18–67 years); de-
scribe job activity; describe occupational exposure
related to posture; focus on postural exposure; and
consider ROM, duration, or frequency of trunk flex-
ion as independent variables. We excluded studies of
cross-sectional, randomized controlled trial or litera-
ture review design; unrelated to occupational posture;
and that included patients with LBP during pregnancy
related to ‘red flag’ conditions (such as osteoporosis
and rheumatoid arthritis) (Bakker et al., 2009). No
language restriction was imposed.

Literature search

The guidelines from the Cochrane Back Review
Group (Furlan et al., 2009) were followed for the de-
velopment of the search strategy (Table 1). The key
terms included in the electronic searches of Medline
(1966 to December 2011), Cumulative Index to
Nursing and Allied Health Literature (1982 to
### Table 1. Search strategy and key terms used.

<table>
<thead>
<tr>
<th>Database</th>
<th>Keywords</th>
<th>Number of studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medline</td>
<td>(1) Posture; (2) movement; (3) sustained posture; (4) ‘Moving and Lifting Patients’/ or Lifting/ or Weight Lifting; (5) Mechanical stress; (6) stooped; (7) trunk flexion; (8) 1 or 2 or 3 or 4 or 5 or 6 or 7; (9) back pain; (10) low back pain; (11) back injuries; (12) spinal injuries; (13) cumulative trauma disorders; (14) 9 or 10 or 11 or 12 or 13; (15) Causality; (16) etiology; (17) aetiology; (18) precipitating factors; (19) odds ratio; (20) risk or risk factors; (21) 15 or 16 or 17 or 18 or 19 or 20; (22) Case–Control Studies; (23) Prospective Studies; (24) Longitudinal Studies; (25) Cohort Studies; (26) Retrospective Studies; (27) 22 or 23 or 24 or 25 or 26; (28) 8 and 14 and 21 and 27; (29) Osteoarthritis/ or Osteoarthrosis, Spine; (30) Arthritis; (31) Pregnancy; (32) Thoracic Vertebrae/ or Thoracic Injuries; (33) Cervical Vertebrae; (34) 29 or 30 or 31 or 32 or 33; (35) 28 not 34</td>
<td>66</td>
</tr>
<tr>
<td>EMBASE</td>
<td>(1) Body posture; (2) ‘movement (physiology)’; (3) lifting or biomechanics; (4) mechanical stress; (5) stooped; (6) lifting effort; (7) trunk flexion or kinematics; (8) 1 or 2 or 3 or 4 or 5 or 6 or 7; (9) backache; (10) low back pain; (11) repetitive strain injury or cumulative trauma disorder or occupational disease; (12) 9 or 10 or 11; (13) epidemiology; (14) aetiology; (15) risk; (16) risk factor; (17) 13 or 14 or 15 or 16; (18) case–control study; (19) prospective study; (20) longitudinal study; (21) cohort analysis; (22) retrospective study; (23) 18 or 19 or 20 or 21 or 22; (24) 8 and 12 and 17 and 23</td>
<td>47</td>
</tr>
<tr>
<td>Cumulative Index to Nursing and Allied Health Literature</td>
<td>(1) Case–Control Studies; (2) Prospective Studies; (3) Longitudinal Studies; (4) Cohort Studies; (5) Retrospective Studies; (6) 1 or 2 or 3 or 4 or 5; (7) causality; (8) etiology; (9) aetiology; (10) precipitating factors; (11) odds ratio; (12) risk; (13) risk factors; (14) 7 or 8 or 9 or 10 or 11 or 12 or 13; (15) back pain; (16) low back pain; (17) back injuries; (18) spinal injuries; (19) cumulative trauma disorder; (20) 15 or 16 or 17 or 18 or 19; (21) posture; (22) movement; (23) sustained posture; (24) lifting; (25) mechanical stress; (26) stooped; (27) trunk flexion; (28) 21 or 22 or 23 or 24 or 25 or 26 or 27; (29) 6 and 14 and 20 and 28</td>
<td>13</td>
</tr>
<tr>
<td>Scopus</td>
<td>(1) posture; (2) movement; (3) sustained posture; (4) lifting; (5) mechanical stress; (6) stooped; (7) trunk flexion; (8) 1 or 2 or 3 or 4 or 5 or 6 or 7; (9) back pain; (10) low back pain; (11) back injuries; (12) spinal injuries; (13) cumulative trauma disorder; (14) 9 or 10 or 11 or 12 or 13; (15) Causality; (16) etiology; (17) aetiology; (18) precipitating factors; (19) odds ratio; (20) risk; (21) risk factor; (22) 15 or 16 or 17 or 18 or 19 or 20 or 21; (23) case–control study; (24) prospective study; (25) longitudinal study; (26) cohort study; (27) retrospective study; (28) 23 or 24 or 25 or 26 or 27; (29) Osteoarthritis; (30) spine osteoarthritis; (31) arthritis; (32) pregnancy; (33) thoracic vertebrae; (34) thoracic injuries; (35) cervical vertebrae; (36) 29 or 30 or 31 or 32 or 33 or 34 or 35; (37) 8 and 14 and 22 and 28; (38) 37 not 29</td>
<td>168</td>
</tr>
</tbody>
</table>

December 2011), EMBASE (1988 to December 2011), and Scopus (December 2011) are listed in Table 1. Furthermore, reference lists of all retrieved articles were hand searched for additional potentially eligible studies.

**Study selection**

Endnote software (v. 12) was used for electronic storage of all identified studies. Following exclusion of duplicates, the principal investigator (D.C.R.) screened all identified titles and article types for relevance. At this stage, only unrelated publications such as thesis dissertations and review articles were excluded. Two reviewers (D.C.R. and D.A.) then screened all search results for potentially relevant titles and abstracts. Potentially eligible articles were then accessed in full text format and fully screened by D.C.R. and D.A. against the inclusion and exclusion criteria. Disagreement between reviewers was resolved by discussion and arrival at a consensus. Where consensus could not be achieved, a third reviewer (G.S.) resolved the disagreement by forming a majority opinion. The reviewers were not blinded to journal titles, authors, and institutions, as blinding has been shown to not affect study selection and data extraction (Berlin, 1997).

**Data collection**

The methods used for data collection and analysis followed recommendations published by the Cochrane Back Review Group (Furlan et al., 2009), as well as the *Cochrane Handbook for Systematic Reviews for Interventions* (Higgins and Green, 2009). Data were extracted from all included studies by one reviewer (D.C.R.) and subsequently confirmed by a second reviewer (D.A.). These data included study design, study population, setting (occupation), job characteristics, response rates, type of LBP outcome (acute, chronic, or recurrent), measurement and control of LBP confounders (physical and psychosocial factors), association measurement for risk [relative risk (RR) or odds ratio (OR) and the confidence interval values] between posture (ROM, duration of sustained posture, or frequency of bending)
and LBP, and statistical information (statistical methods, significance values, and adjustment for confounders). Disagreement between reviewers was either resolved by discussion and agreement or resolved by consultation with a third review author (G.S.) if required.

Summary measures

The extracted summary measures refer to risk estimate (e.g. OR, RR) for three domains of flexed trunk posture: trunk ROM, duration of sustained posture, and frequency in which the flexed posture was adopted.

Assessment for risk of bias in included studies

Risk of bias in the included studies was assessed by D.C.R. and D.A., independently, using the Newcastle-Ottawa Scale (NOS) for observational studies (Wells et al., 2010). The criteria adopted for each item are described in Tables 4 and 5. Disagreement between reviewers was either resolved by discussion or by use of the third reviewer as previously described. For the purpose of this study, high-quality studies were considered as those with a summative quality score of at least 5 and where appropriate statistical analysis was used (e.g. risk adjustment) (Wai et al., 2010).

Additional analysis

Heterogeneity of outcome measures meant data were considered too disparate for further subgroup analysis between postural variables (trunk ROM, duration of sustained posture, and frequency in which the flexed posture was adopted) and LBP variables (acute, chronic, and recurrent LBP). SPSS version 16 (SPSS Inc., IL, USA) software was used for statistical analysis. Inter-rater reliability for assessment of risk of bias agreement between reviewers was measured by use of the Kappa statistic. Qualitative syntheses and analyses of data were primarily based on The Guidelines for Systematic Reviews in the Cochrane Back Review Group (Furlan et al., 2009). As the Cochrane Back Review Group recommends the use of five levels of evidence, the following descriptors were adopted: strong, moderate, limited, unclear, and no evidence (Table 2) (Furlan et al., 2009).

RESULTS

Study selection

The search strategy resulted in 294 studies, of which 42 were included for full assessment. Thirty-four studies did not meet final selection criteria leaving eight studies for full review (Punnett et al., 1991; Josephson and Vingår, 1998; Hoogendoorn et al., 2000a; Miranda et al., 2002; Harkness et al., 2003; Jansen et al., 2004; Yip, 2004; Van Nieuwenhuyse et al., 2006). Of these, six were prospective cohort studies (Hoogendoorn et al., 2000a; Miranda et al., 2002; Harkness et al., 2003; Jansen et al., 2004; Yip, 2004; Van Nieuwenhuyse et al., 2006) and two were case–control (Punnett et al., 1991; Josephson and Vingår, 1998). As three studies (Hoogendoorn et al., 2000a; van den Heuvel et al., 2004; Hamberg-van Reenen et al., 2006) analyzed the same sample, we chose to review only the 2000 article by Hoogendoorn et al. (2000a). The included studies yielded a total of 7023 subjects who completed follow-up and were considered for risk analysis. The detailed stages through studies selection and reason for exclusion are described in Fig. 1.

Study characteristics

Study characteristics are presented in Table 3.

Risk of bias within studies

All included studies were rated as high quality with the scores presented in Tables 4 and 5 for cohort and case–control studies, respectively. Inter-rater reliability for assessment of risk of bias agreement between reviewers, measured by means of Kappa analysis, was found to be moderate (Cohen’s kappa: 0.60). Extracted data regarding changes in risk of LBP associated with posture exposure are presented in Table 6. The findings are presented in three categories of cumulative postural exposure: ROM, frequency, and duration of trunk flexion.

Results of individual studies

The risk of LBP associated with cumulative flexed posture categories (ROM and duration) for each
study is described in Table 6. All studies, with the exception of Harkness et al. (2003), identified increased risk for LBP when both duration and ROM increased (Table 6); however, confidence intervals for estimates of risk were wide. We identified no studies investigating frequency of trunk flexion as a risk factor for LBP.

Synthesis of results

Range of motion. Three studies reported different levels of exposure with respect to duration at differing ranges of trunk flexion motion as a risk factor for LBP (Punnett et al., 1991; Hoogendoorn et al., 2000a; Jansen et al., 2004). The other five studies focused on duration of trunk flexion alone as risk factor (Josephson and Vingård, 1998; Miranda et al., 2002; Harkness et al., 2003; Yip, 2004; Van Nieuwenhuyse et al., 2006). Hoogendoorn et al. (2000a) reported moderately increased risk for LBP for workers who sustained a work posture either (i) at a minimum of 30° of trunk flexion for more than 10% of work time or (ii) at a minimum of 60° for more than 5% of work time. Punnett et al. (1991) found increased risk for LBP when workers are exposed to either 20–45° or more than 45° of trunk flexion, despite duration of exposure (less or more than 10% of work time). Punnett et al. (1991) present an adjusted association for a combined postural variable (time in non-neutral), which reflects the sum of durations of mild and severe flexion and twisting (Table 6). Jansen et al. (2004) used the same cut-off ROM values and found trunk flexion between 20–45° and more than 45° were weak risk factor for LBP, regardless of the time spent in such postures (Table 6). Dependent on outcome measures, these authors found increasing strengths of association with LBP (with disability) when trunk flexion was held above 45° for longer than 45 min, with the strongest RR (3.18) demonstrated at 1.50 h/week (Jansen et al., 2004). This result is significant and the 95% confidence interval ranged from 1.13 to 9.00. There is a lack of similarity for ROM risk estimates between studies and divergent LBP definitions were adopted by all these studies. As a result, we conclude that there is only limited evidence for ROM as a risk factor for LBP.

Duration. Five articles reported different categories for quantifying the duration of trunk flexion (Table 6) (Josephson and Vingård, 1998; Miranda et al., 2002; Harkness et al., 2003; Yip, 2004; Van Nieuwenhuyse et al., 2006). Harkness et al. (2003) found a weak causation effect for trunk flexion
<table>
<thead>
<tr>
<th>Study et al.</th>
<th>Design</th>
<th>Participants</th>
<th>Type of LBP/LBP definition</th>
<th>Follow-up</th>
<th>Methods of investigation</th>
<th>Independent variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harkness et al. (2003)</td>
<td>PC</td>
<td>788 Workers from 12 diverse occupational groups. All participants were asymptomatic</td>
<td>New-onset LBP/pain localized between the 12th rib and gluteal folds lasting for more than 24 h in the last month</td>
<td>1 Year: 625 (79%); 2 years: 430 (86%)</td>
<td>LBP: self-report; physical exposure</td>
<td>Bending &lt; 15 or ≥ 15 min</td>
</tr>
<tr>
<td>Hoogendoorn et al. (2000a)</td>
<td>PC</td>
<td>861 Blue or white-collar jobs from 34 companies</td>
<td>LBP/regular or prolonged symptoms in the last 12 months</td>
<td>3 Years</td>
<td>1) Questionnaire, 2) physical examination, 3) workplace physical load assessment</td>
<td>Trunk flexion ≥ 30°, 5–10% work time; trunk flexion ≥ 30°, &gt;10% work time; trunk flexion ≥ 30°, &gt;10% work time or trunk flexion ≥ 60°, ≤5% work time; trunk flexion ≥ 60°, &gt;5% work time</td>
</tr>
<tr>
<td>Jansen et al. (2004)</td>
<td>PC</td>
<td>769 Workers from seven nursing homes</td>
<td>LBP and LBP with disability/ LBP: any episode of pain lasting for at least a few hours in the last 12 months. LBP with disability; LBP with a disability score &gt;50</td>
<td>12 months dropout: 32%</td>
<td>1) questionnaire, 2) observational multimoment method</td>
<td>Trunk flexion between 20 and 45°; trunk flexion ≥ 45°</td>
</tr>
<tr>
<td>Van Nieuwenhuyse et al. (2006)</td>
<td>PC</td>
<td>716 Health care or distribution workers</td>
<td>LBP/LBP with radiating below the knee for ≥7 days in the last 12 months</td>
<td>12 Months dropout: 16%</td>
<td>1) Questionnaire</td>
<td>≤2 h spent in bending and twisted posture; &gt;2 h spent in bending and twisted posture</td>
</tr>
<tr>
<td>Yip (2004)</td>
<td>PC</td>
<td>144 Nurses</td>
<td>LBP/discomfort between lower costal margins and gluteal folds, with or without radiation below the knee for at least 1 day in the last 12 months</td>
<td>12 Months dropout: 35.7%</td>
<td>Self-report</td>
<td>Bending to lift an item from the floor level (tertiles)</td>
</tr>
<tr>
<td>Miranda et al. (2002)</td>
<td>PC</td>
<td>327 Cases; 2077 controls from a forest industry company</td>
<td>Sciatic pain/LBP with radiating below the knee for ≥7 days in the last 12 months</td>
<td>36 months</td>
<td>Questionnaire</td>
<td>Working in forward flexed trunk</td>
</tr>
<tr>
<td>Punnett et al. (1991)</td>
<td>CC</td>
<td>95 Cases; 135 controls from an automobile assembly</td>
<td>LBP/at least three different episodes or one episode lasting for at least 1 week in the last 12 months</td>
<td>10 Months</td>
<td>Videotape</td>
<td>ROM; mild forward flexion (21–45° of trunk flexion) 0–10% of cycle time; mild forward flexion (21–45° of trunk flexion) ≥10% of cycle time; severe forward flexion (&gt;45° of trunk flexion) 0–10% of cycle time; severe forward flexion (&gt;45° of trunk flexion) ≥10% of cycle time</td>
</tr>
<tr>
<td>Josephson and Vingård (1998)</td>
<td>CC</td>
<td>694 Cases, 1423 controls, population based</td>
<td>LBP/definition unclear</td>
<td>36 Months</td>
<td>Interview</td>
<td>Working in forward bending position for (duration): &lt;60 min/day; &gt;60 min/day</td>
</tr>
</tbody>
</table>

PC, prospective cohort; CC, case–control.
Dose–response relationship between work-related cumulative postural exposure and LBP

Table 4. Risk of bias for cohort studies based on Newcastle-Ottawa Quality Assessment Scale.

<table>
<thead>
<tr>
<th>Study</th>
<th>Selection</th>
<th>Comparability</th>
<th>Outcome</th>
<th>Total score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoogendoorn et al. (2000a) (including van den Heuvel et al., 2004; Hamberg-van Reenen et al., 2006)</td>
<td>B*</td>
<td>A*</td>
<td>A*</td>
<td>8</td>
</tr>
</tbody>
</table>

*aCalculated by the sum of asterisks (*).

Selection
1) Representativeness of the exposed cohort,
   A) Truly representative of the average in the community (≥75%)*
   B) Somewhat representative of the average in the community (≥50 or <75%)*
   C) Selected group of users e.g. nurses, volunteers
   D) No description of the derivation of the cohort
2) Selection of the non-exposed cohort
   A) Drawn from the same community as the exposed cohort*
   B) Drawn from a different source
   C) No description of the derivation of the non-exposed cohort
3) Ascertainment of exposure
   A) Secure record (e.g. surgical records)*
   B) Structured interview*
   C) Written self-report
   D) No description
4) Demonstration that outcome of interest was not present at start of study
   A) Yes*
   B) No

Comparability
1) Comparability of cohorts on the basis of the design or analysis
   A) Study controls for personal factors*
   B) Study controls for any additional factor (psychosocial factors)*

Outcome
1) Assessment of outcome
   A) Independent blind assessment*
   B) Record linkage (validated questionnaire, e.g. Nordic questionnaire)*
   C) Self-report
   D) No description
2) Was follow-up long enough for outcomes to occur
   A) Yes (at least one year)*
   B) No
3) Adequacy of follow-up of cohorts
   A) Complete follow-up—all subjects accounted for*
   B) Subjects lost to follow-up unlikely to introduce bias—small number lost—>80%*
   C) Follow-up rate <75% (select an adequate percentage) and no description of those lost
   D) No statement

sustained for more than 15 min. Josephson and Vingård (1998) found increased risk for LBP when a flexed posture was adopted for longer than 60 min/working day. Miranda et al. (2002) found the risk (OR = 2.1) for sciatic pain was significant when the time spent in a flexed posture was greater than 2 h (Miranda et al., 2002). The OR for this model was adjusted for sex and age (Table 6). Van Nieuwenhuyse et al. (2006) identified increased RR for LBP (RR = 2.21) when more than 2 h/day was spent in bent and twisted postures. These authors have not attempted to independently analyze the flexed and twisted components of this posture. The results from Yip (2004) also suggest an increased risk for LBP when bending to lift an item from the floor during a work shift. This study does not present RR estimates but describes the association, measured by the chi-square test, between posture and new LBP symptoms (Yip, 2004). As presented in Table 6, confidence interval values are wide for all duration risk estimates. Furthermore, there is a lack of similarity for duration risk estimates between studies as well as for LBP.
As a result, we conclude that there is only limited evidence for duration as a risk factor for LBP.

**DISCUSSION**

**Summary of evidence**

This study has explored for dose–response relationships between work-related posture and LBP. Limited evidence has been found for relationships between work-related ROM, duration of postures, and risk of LBP. Due to considerable heterogeneity in categories for ROM and duration of exposure, LBP definition, and adjustment for risk estimates, meta-analysis was precluded and a qualitative synthesis was alternatively described. Despite this heterogeneity, the use of the NOS quality assessment tool rated the eight included studies as high quality.

The literature describes three cumulative domains associated with working in a flexed posture (ROM, duration, and frequency) (Milosavljevic et al., 2007; Parkinson and Callaghan, 2009). These can interact and lead to non-linear reduction of tissue load tolerance with time (Waters et al., 2006). The interplay between cumulative postural exposure and cumulative load exposure can lead to different types of structural injury (Parkinson and Callaghan, 2009). Repetitive trunk flexion associated with high load magnitude can lead to vertebral end plate fracture, while repetitive trunk flexion with low load magnitude can also cause intervertebral disc injury (Parkinson and Callaghan, 2009). While end plate fractures have been shown to occur with high spinal compression, the load required for mechanical failure decreases as spinal flexion increases (Gunning et al., 2001). During work-related tasks, workers are likely to adopt risk postures while handling...
<table>
<thead>
<tr>
<th>Authors</th>
<th>Crude association (95% CI)</th>
<th>Adjusted association (95% CI)</th>
<th>Adjusted for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harkness et al. (2003)</td>
<td>OR bending &lt; 15 min: 1.6 (1.1–2.3); OR bending ≥ 15 min: 1.3 (0.8–1.9) #</td>
<td>OR bending &lt; 15 min: 1.6 (0.9–2.0); OR bending ≥ 15 min: 1.0 (0.6–1.5) §</td>
<td>‘#’ Adjusted for gender, age group, and occupation; ‘§’ Adjusted for gender, age group, occupation, and all other postures</td>
</tr>
<tr>
<td>Hoogendoorn et al. (2000a)</td>
<td>Trunk flexion ≥ 30°, 5–10% work time: RR = 0.98 (0.68–1.41); trunk flexion ≥ 30°, &gt;10% work time: RR = 1.17 (0.86–1.59); trunk flexion ≥ 30°, &gt;10% work time or trunk flexion ≥ 60°, &lt;5% work time: RR = 1.08 (0.77–1.53); trunk flexion ≥ 60°, &gt;5% work time: RR = 1.42 (0.88–2.30)</td>
<td>Trunk flexion ≥ 30°, 5–10% work time: RR = 1.04 (0.70–1.54); trunk flexion ≥ 30°, &gt;10% work time or trunk flexion ≥ 60°, &gt;5% work time or trunk flexion ≥ 60°, &lt;5% work time: RR = 1.09 (0.76–1.58); trunk flexion ≥ 60°, &gt;5% work time: RR = 1.48 (0.90–2.42)</td>
<td>Gender, age, exercise behavior during leisure time, quantitative job, demands, decision authority, skill discretion, supervisor support, coworker support, moving of heavy loads during leisure time, flexion and/or rotation of the upper part of the body during leisure time, driving a vehicle during leisure time, and driving a vehicle at work</td>
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<td>Jansen et al. (2004)</td>
<td>Trunk flexion between 20 and 45°:</td>
<td>Trunk flexion between 20 and 45°:</td>
<td>Lifting and carrying loads over 10 kg, decision authority, skill discretion, psychosocial demands, year of employment in the facility, and age at baseline</td>
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<td>2 h/week (reference)</td>
<td>2 h/week (reference)</td>
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<td>3 h/week: RR = 1.25 (0.66–2.37)</td>
<td>3 h/week: RR = 1.12 (0.71–1.77)</td>
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<td>4 h/week: RR = 1.55 (0.44–5.37)</td>
<td>4 h/week: RR = 1.25 (0.51–3.07)</td>
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<td>5 h/week: RR = 1.55 (0.42–5.66)</td>
<td>5 h/week: RR = 1.21 (0.44–3.30)</td>
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<td>6 h/week: RR = 1.13 (0.30–4.22)</td>
<td>6 h/week: RR = 0.91 (0.34–2.47)</td>
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<td>Trunk flexion &gt; 45°:</td>
<td>Trunk flexion &gt; 45°:</td>
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<td>30 min/week (reference)</td>
<td>30 min/week (reference)</td>
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<td></td>
<td>45 min/week: RR = 0.99 (0.66–2.37 1.49)</td>
<td>45 min/week: RR = 1.08 (0.90–1.30)</td>
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<td>1 h/week: RR = 0.98 (0.43–2.23)</td>
<td>1 h/week: RR = 1.16 (0.80–1.68)</td>
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<td>1 h 30 min/week: RR = 1.31 (0.42–4.11)</td>
<td>1 h 30 min/week: RR = 1.34 (0.66–2.74)</td>
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<td>1 h 45 min/week: RR = 2.02 (0.60–6.83)</td>
<td>1 h 45 min/week: RR = 1.40 (0.61–3.22)</td>
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<tr>
<td>Van Nieuwenhuyse et al. (2006)</td>
<td>≤2 h spent in bent and twisted posture: RR = 1.44 (0.86–2.42)</td>
<td>≤2 h spent in bent and twisted posture: RR = 1.30 (0.77–2.20)</td>
<td>Age, sex, inability to change posture regularly, regular recreational sport, pushing or pulling heavy loads, standing for long periods, possibilities to develop skills, job satisfaction, psychological job demands, previous LBP, perceived general health, previous upper limb pain, pain-related fear, family situation, language, BMI, pain catastrophizing, and previous lower limb pain</td>
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<td></td>
<td>&gt;2 h spent in bent and twisted posture: RR = 2.35 (1.28–4.31)</td>
<td>&gt;2 h spent in bent and twisted posture: RR = 2.21 (1.20–4.07)</td>
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<td>Yip (2004)</td>
<td>Bending to lift an item from the floor level—middle tertile ( P \leq 0.01 )</td>
<td>Bending to lift an item from the floor level—middle tertile: RR = 0.66 (0.25–1.75); highest tertile: RR = 2.76 (1.06–7.22)</td>
<td>Age</td>
</tr>
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<td>Miranda et al. (2002)</td>
<td>Working in forward flexed trunk (€): &lt;30 min/day, OR = 1.0; 30–60 min/day, OR = 1.2 (0.8–1.8); 1–2 h/day, OR = 1.3 (0.8–2.3); &gt;2 h/day, OR = 2.1 (1.4–3.2); € = values adjusted for age and sex</td>
<td>Working in forward bending position for &lt;60 min/day, OR = 2.2 (0.7–10); &gt;60 min/day, OR = 8.7 (2.1–46)</td>
<td>Sex, age, smoking, mental stress, walking, twisting movements of the trunk, working in kneeling or squatting position, and working with the hand above shoulder level</td>
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external loads and are likely to expose spinal tissues to creep deformation and stress relaxation (Parkinson et al., 2004). The main challenge seems to precisely quantify such load and postural exposures during observational studies (Vieira and Kumar, 2004). We have focused our review on postural exposure and have identified a number of different and divergent measures of postural exposure.

These divergent postural measures ruled out the use of meta-analysis and we have thus presented these results and arguments by descriptive comparison. Consensus on postural measurement is therefore needed for comparative assessment of work-related posture in observational studies. These uncertain relationships suggest that the three domains (ROM, duration of sustained posture, and frequency of trunk flexion in a work day) are underestimated as mechanical risk factors for LBP. Different definitions for LBP were also used by the various authors. For example, Hoogendoorn et al. (2000a) examined regular or prolonged LBP in the last 12 months while Miranda et al. (2002) examined sciatic pain for at least 7 days in the past 12 months (Table 3). Additionally, estimates of risk were adjusted for different variables (Table 6). As an example, Yip (2004) adjusted estimates of risk for age, while Hoogendoorn et al. (2000a) adjusted for numerous variables including gender, age, exercise behavior during leisure time, quantitative job demands, decision authority, and skill discretion. We suggest that an initiative such as the Outcome Measures in Rheumatology (Tugwell et al., 2007), introduced by a group of rheumatology researchers to improve outcome measurements related to their field, should be developed for this field of research. Ideally, consensus for outcome measures for ROM, duration, and frequency of trunk flexion should be established. These guidelines could also be expanded for trunk rotation and lateral bending. It is likely that, after establishing such guidelines, future research will help to improve current knowledge regarding posture as a risk factor for LBP. Researchers, ergonomists, and health professionals should work together toward the development of consensus for measures of postural exposure and LBP definition for future studies assessing posture as a risk factor for LBP.

Although this review has not shown strong relationships between posture and LBP, the comparative methodological limitations of the included studies preclude an interpretation of no relationship between these variables. Repetitive or sustained trunk flexion has been found to reduce tension in lumbar spine viscoelastic tissues and increase spinal muscle activity (Solomonow et al., 2003a; Olson et al., 2009).
and to induce ligament injury and muscle spasm (Solomonow et al., 2003b) as well as changes in spinal ligament–muscle reflex thresholds (Olson et al., 2009). Such ligament and neuromuscular changes are considered to be related to LBP (Panjabi, 2006). Posture is also closely related to spinal tissue loads that occur dependent on how workers perform a task (McGill et al., 2003). The relationship between spinal tissue load and spinal injury is considered to be ‘U’ shaped where very low or very high spinal tissue loads are likely to lead to spinal tissue injury (McGill, 2009). A similar relationship has been reported for physical activity levels and LBP (Heneweer et al., 2009). The challenge is to identify the ideal amount of spinal tissue load relative to the many postures undertaken in daily living activities and workplace demands. When attempting to minimize for low back injury, not only external load magnitude but also posture, neuromuscular patterns, and spinal kinematics can modulate how spinal tissues will adapt or fail (Callaghan and McGill, 2001; Gunning et al., 2001; McGill et al., 2003; McGill, 2009). A further challenge for reducing risk of low back injury is that the ideal spinal tissue load is likely to vary among individuals. Some workers may thus tolerate certain levels of postural exposure while others may develop LBP at similar levels, particularly when compounded by psychosocial factors (Vandergrift et al., 2011). Further research is necessary to identify postural ranges that consistently lead to increased risk for developing LBP. The use of portable and reliable postural monitor devices, such as inclinometers, may provide objective and valuable information regarding this topic (Trask et al., 2007; Teschke et al. 2009; Ribeiro et al. 2011). Consensus on postural outcome measures will enhance future epidemiological investigations regarding the role of posture as a risk factor for occupational LBP.

**Strengths and limitations**

This review focused only on studies reporting qualitative exposure. We excluded studies that reported qualitative exposure for trunk posture (e.g. Likert scales such as not often, often, and very often). We found no evidence relating to frequency of trunk flexion as a risk factor for LBP. However, we did find studies that have assessed frequency of trunk flexion qualitatively (Gheldof et al., 2007; Plouvier et al., 2008). When attempting to establish a dose–response relationship between cumulative trunk flexion exposure and LBP, qualitative categories of exposure might not provide sufficient information.

The quantification of exposure in the included studies was done by means of different techniques (e.g. interview, self-report, validated questionnaire, and videotape) that are likely to have varying degrees of validity. Considering our findings, we support what has been previously suggested by other researchers: there is a need to improve quantitative measurements for postural exposure at the workplace (Vieira and Kumar, 2004). Currently, it seems that the risk of cumulative postural exposure has been underestimated due to poor kinematic measurement (Straker et al., 2010).

**Previous systematic review**

We could identify one published systematic review related to trunk flexion as a risk factor for occupational LBP (Wai et al., 2010). That review included studies where no clear or quantitative definitions were described for ‘awkward’ posture. In contrast, we have included only studies with quantitative outcomes for posture as a risk factor for LBP. A further difference was the methods used to grade the quality of evidence. While we have adopted the suggested criteria by the Cochrane Back Review Group, Wai et al. (2010) have adopted combined results from the Agency for Health Care Policy and Research and Oxford Centre for Evidence-Based Medicine. Those authors found conflicting evidence for trunk flexion and twisting as risk factors for LBP (Wai et al., 2010) while we found limited evidence for ROM, duration, and frequency of trunk flexion as risk factors for LBP. These methodological differences are probably the reason for the disparity in the comparative summary of evidence findings between the current investigation and that of Wai et al. (2010).

**CONCLUSION**

We consider there is limited evidence for any association between quantity (ROM) or duration of trunk flexion and occupational LBP. We found no studies and thus no evidence for frequency of trunk flexion as a risk factor for LBP. In addition, we suggest that a consensus for measures of postural exposure is needed to clarify its role as a risk factor for LBP.

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REFERENCES


Dose–response relationship between work-related cumulative postural exposure and LBP


