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Review

No consensus on causality of spine postures or physical exposure and low back pain: A systematic review of systematic reviews

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A B S T R A C T

Specific spinal postures and physical activities have been linked to low back pain (LBP) but previous reviews have produced contrasting outcomes. This umbrella review examined (1) what relationship, if any, is evident between specific spinal postures or physical activities and LBP; (2) the quality of existing systematic reviews in this area; and (3) the extent to which previous systematic reviews demonstrate causality.

Five electronic databases and reference lists of relevant articles were searched from January 1990 to June 2018. Systematic reviews and meta-analyses on spine posture or physical exposure and LBP symptoms (self-report) or outcomes (e.g. work absence, medical consultation) were included. The AMSTAR and the Bradford Hill Criteria were utilised to critically appraise the quality of included systematic reviews and to determine the extent to which these reviews demonstrated causality.

Two independent reviewers screened 4285 publications with 41 reviews included in the final review. Both positive and null associations between spine posture, prolonged standing, sitting, bending and twisting, awkward postures, whole body vibration, and components of heavy physical work were reported. Results from meta-analyses were more consistently in favour of an association, whereas systematic reviews that included only prospective studies were less able to provide consistent conclusions. Evidence that these factors precede first time LBP or have a dose response relationship with LBP outcomes was mixed.

Despite the availability of many reviews, there is no consensus regarding causality of physical exposure to LBP. Association has been documented but does not provide a causal explanation for LBP.

Contents

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1. Introduction

Early attempts at understanding low back pain (LBP) focussed largely on spine biomechanics. Studies on human cadaver spines and in vivo animal experiments demonstrated that repetitive movements, even small in magnitude, result in physical disruption to structures in and around the spine, preceding inflammation (Solomonow, 2012), injury (Adams and Hutton, 1985), and degeneration (Osti et al., 1990). As these findings aligned with observations from large epidemiological studies that documented a high prevalence of LBP in occupations that involved specific spine mechanical exposures (Marras et al., 1995), it was deduced that specific physical exposures represented important risk factors for LBP.

LBP is a multifactorial condition and evidence does not always support a clear relationship between physical exposure, spine injury, and LBP. For example, signs of mechanical damage do not always correlate with symptoms (Brinjikji et al., 2015), sedentary populations report a high prevalence of LBP (Heneweer et al., 2009), and depression and emotional distress can predict both the onset of first time LBP (Jarvik et al., 2005), as well as the consumption of health care services related to LBP (Traeger et al., 2016). While such findings do not dismiss a role of physical exposure in the aetiology of LBP in some populations, they do present questions regarding their collective importance.

Several systematic reviews and meta-analyses have been performed with the intent of objectively synthesising the evidence regarding physical exposures and LBP. However, these have produced conflicting, and at times, controversial findings. For example, while some systematic reviews support strong associations (Hoogendoorn et al., 1999), others, including a series of reviews summarised by Kwon et al. (2011), do not support a causal association between occupational exposures and LBP. Notably, these reviews received criticism for their scope and methods (Kuijer et al., 2011; McGill, 2011), as well as interpretation of individual (Andersen et al., 2011) and collective (Takala, 2010) findings. Therefore, to advance the understanding regarding specific physical exposures as risk factors for LBP, an umbrella review was considered. The aims of this review were to examine: (1) what relationship, if any, is evident between specific physical exposures and LBP; (2) what is the quality of existing systematic reviews in this area; and (3) to what extent do existing reviews demonstrate causality.

2. Methods

This review was conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009), and followed a methodology proposed by Smith et al. (2011) for conducting a systematic review of systematic reviews within the healthcare field. This review was prospectively registered on PROSPERO (CRD42018110739).

2.1. Search strategy

Using a combination of controlled MeSH and free-text terms (Appendix 1), relevant publications were identified through systematic searches of the following five electronic databases: MEDLINE, SportDiscuss, EMBASE, CINAHL, and the Cochrane Database of Systematic Reviews. In addition, reference lists of included systematic reviews were manually searched.

2.2. Inclusion and exclusion criteria

Only systematic reviews and meta-analyses published in peer-reviewed journals (i.e. grey literature excluded) in English between January 1990 and June 2018 were included. For a review to be considered systematic, the authors must have defined a strategy to: (a) search for studies, (b) appraise studies and (c) synthesise studies. Population groups of interest were adults (aged $\geq$ 18 yr). The exposure was restricted to postural curvature, static posture (sitting and standing) or dynamic/occupational movements (e.g., bending, twisting, lifting). To ensure consistency in the type of biomechanical exposure, general physical activity, activities in leisure time and sports, or other athletic activities were excluded. The primary outcomes included self-reported LBP symptoms or LBP-specific outcomes (e.g., activity limitation, work absence, care-seeking, medication use). Studies within these systematic reviews included cross-sectional analyses, prospective cohorts and randomised controlled trials.

2.3. Data extraction

Data of the publication (e.g. authors, title, year), protocol of the systematic review (e.g. population, exposure and outcomes), results of the systematic review (e.g. number of studies included, qualitative synthesis of findings, quantitative estimates [meta-analyses only], observed limitations, and suggestions for future research) were extracted by two independent assessors (CTVS and FP). In addition, to determine the extent to which existing reviews have demonstrated causality, summary findings pertinent to the Bradford Hill Criteria (including strength of association [i.e. effect size], consistency [i.e. the association is evident in multiple settings], temporality [i.e. evidence that the exposure precedes LBP], biological gradient [i.e. dose-response], as well as experiment [i.e. association is supported by experimental or intervention studies]) were extracted (Hill, 1965; Kwon et al., 2011). Any discrepancies were discussed between the two independent assessors, until consensus was reached. Prior to data extraction, the method was piloted and reviewed on five relevant systematic reviews.

2.4. Quality assessment of reviews

The second iteration of the assessment of multiple reviews (AMSTAR) tool (Shea et al., 2017) was utilised by two independent assessors (CTVS and FP) to critically appraise the quality of the

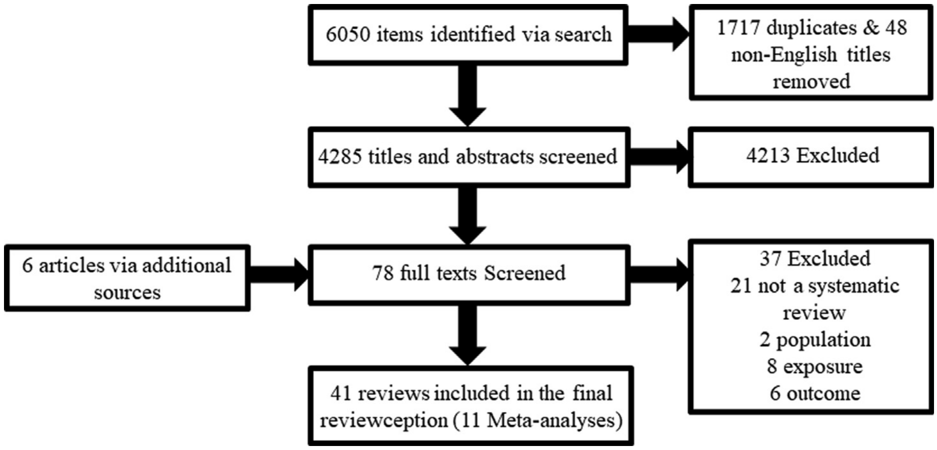

Fig. 1. PRISMA chart for eligible study selection process.

Table 1
Summary of review conclusions: physical exposures and LBP.

Exposure	Effect Estimates *Range of effect estimates from meta-analyses*	Association	Temporality	Dose – Response	AMSTAR *Range of Percentages* §
		Number of reviews in favour/ total number of reviews			
Spinal curvature	0.01(−0.00, 0.11)† to −0.66(−0.91, −0.40)†	3/5	2/2	Nil	62–92
Standing	1.31(1.10, 1.56)‡	4/8	2/3	1/3	54–92
Sitting	Nil	0/7	0/3	0/2	31–85
Bending and twisting	1.68(1.41, 2.01)‡	7/10	0/1	0/3	8–85
Awkward postures	1.14(1.08, 1.21)‡ to 2.03(1.26, 2.49)‡	4/5	0/1	0/1	15–75
Lifting, carrying, manual materials handling, and pushing or pulling	1.11(1.05, 1.18)‡ to 2.11(1.73, 2.57)‡	11/16	2/5	3/6	8–88
High physical workloads or occupational specific demands	1.31(0.96, 1.33)‡	10/12	1/1	1/1	8–85
Whole body vibration	1.39(1.24,1.55)‡ to 2.3(1.8,2.9) ‡	10/12	0/2	3/6	8–85

Key:
† SMD (95% CI).
‡ OR (95% CI).
§ Number of items scored as 'partial' or 'yes'/total number of items.

systematic reviews included within this review. AMSTAR is a validated instrument that contains 16 items relating to the registration, design, methods, interpretation, and reporting standards of systematic reviews. Disagreements were resolved via discussion and a third reviewer (PJO) was available for adjudication if necessary.

3. Results

Search results are summarised in Fig. 1. The literature search returned a total of 6050 articles. Following duplication removal (n = 1717), removal of non-English publications (n = 48), a review of title and abstracts (n = 4285), 78 full texts were screened, with 41 publications included in the final review. A list of publications and reasons for exclusion following full text screening is included in Appendix 2.

3.1. Description of studies

Of the included reviews, 30 were systematic only, and 11 had a relevant meta-analysis component. The exposures examined included spinal curvature, standing, sitting, awkward spine postures, bending and twisting movement of the spine, heavy physical work and whole-body vibration. Characteristics and a summary of review findings are presented in Appendix 3. An overview of review conclusions is presented in Table 1.

3.2. Risk of bias

Risk of bias results are presented in Appendix 4. The systematic reviews partially or completely satisfied a median (range) 8(1–12) of 13 criteria and the meta-analyses satisfied a median (range) 13 (9–13) of 16 criteria. Higher scores were observed in more recent reviews. The individual items the reviews scored the worst on included the consideration of funding sources (0% of included reviews satisfied this criteria), explicitly stating a review was pre-registered (5%), performing data extraction in duplicate (49%), and providing a list of excluded studies with specific reasons for exclusion (49%). In addition, only four (36%) of the meta-analyses examined the extent of publication bias present, with some evidence of publication bias in favour of smaller studies with significant findings identified (Burstrom et al., 2015; Coenen et al., 2018). Of note, although not an item on the AMSTAR, one review included only primary studies that reported statistically significant outcomes (da Costa and Vieira, 2010). This review, as well as the three that scored the lowest on the AMSTAR (Burdorf and Sorock, 1997; Jansen and Burdorf, 2003; Jin et al., 2000), generally produced conclusions in favour of an association between physical exposures and LBP.

3.3. Physical exposures and LBP

3.3.1. Spinal curvature

Three meta-analyses (Chun et al., 2017; Laird et al., 2014; Sadler et al., 2017), as well as two systematic reviews (Christensen and

Hartvigsen, 2008; Coenen et al., 2017) included evidence regarding the association between spinal curves (i.e. sagittal lumbar spine curves when relaxed or standing) and LBP. Of these, two meta-analyses identified a significantly flatter lumbar spine in persons with LBP (standardised mean difference, SMD[95% confidence intervals, CI]: −0.66[−0.91, −0.40]) (Chun et al., 2017), or persons that went on to develop first time LBP (odds ratio, OR[95%CI]: 0.73 [0.55, 0.98]) (Sadler et al., 2017). Further, one review identified evidence that both increases in lumbar flexion as well as an increase in lumbar curvature were associated with symptom development following prolonged standing (Coenen et al., 2017). In contrast, one meta-analysis of studies using non-invasive assessment methods identified no difference in lumbar lordosis in persons with and without LBP (SMD[95% CI]: 0.01[−0.00, 0.11]) (Laird et al., 2014). The final systematic review concluded that as only 10/29 studies identified a positive association, there was insufficient evidence to support any interaction (Christensen and Hartvigsen, 2008). Based on these findings, there is support for an association and some support for temporality, but the findings are not consistent.

3.3.2. Standing

Eight reviews examined the interaction between standing exposure and LBP outcomes (Bakker et al., 2009; Burdorf and Sorock, 1997; Coenen et al., 2017; Coenen et al., 2018; Heneweer et al., 2011; Hoogendoorn et al., 1999; Roffey et al., 2010d; Taylor et al., 2014). In favour of a relationship, one meta-analysis identified substantial (>4h/d) occupational standing was associated with LBP symptoms (OR[95%CI]: 1.31[1.10, 1.56]) (Coenen et al., 2018). The OR were higher in high-quality studies (1.38[1.16, 1.64]), but no dose response relationship was identified. In a review of laboratory based studies, 19/19 studies identified an association between standing and low back symptom development in at least a subgroup of participants (Coenen et al., 2017). In this review, data pooling did identify a dose response relationship, with symptom development after 71 min of standing in general populations, and after 42 min in subgroups of individuals classified as pain developers. Evidence for temporality was demonstrated by one review that found standing for more than two hours preceded first time LBP in women and recurrent LBP in both men and women (Taylor et al., 2014). In contrast, four reviews concluded that evidence did not support an association (Bakker et al., 2009; Burdorf and Sorock, 1997; Hoogendoorn et al., 1999; Roffey et al., 2010d). Of these, one review highlighted limited evidence for a dose response relationship (Roffey et al., 2010d), and two contained contrasting evidence that standing precedes LBP development (Bakker et al., 2009; Roffey et al., 2010d). In summary, there was evidence in support of, as well as in opposition to, an association, dose-response, or temporal relationship between standing and LBP.

3.3.3. Sitting

Seven reviews provided information regarding the relationship between sitting and LBP (Bakker et al., 2009; Chen et al., 2009; Hartvigsen et al., 2000; Hoogendoorn et al., 1999; Lis et al., 2007; Roffey et al., 2010c; Taylor et al., 2014). All concluded that there was either no, or limited evidence, for an association, a dose-response relationship, or temporality. Among the primary studies included in the reviews, one identified a negative (protective) effect of prolonged sitting (Taylor et al., 2014). Reviews do not support sitting on its own as a factor related to LBP.

3.3.4. Bending and twisting

One meta-analysis (Lotters et al., 2003) and nine systematic reviews, provided information regarding bending and twisting movements or flexed postures as risk factors for LBP (Bakker et al., 2009; Burdorf and Sorock, 1997; Coenen et al., 2017; Heneweer et al., 2011; Hoogendoorn et al., 1999; Jansen and Burdorf, 2003; Jin et al., 2000; Ribeiro et al., 2012; Wai et al., 2010a). In the meta-analysis, the OR(95% CI) for bending and twisting and LBP was 1.68(1.41, 2.01) (Lotters et al., 2003). Individuals with high exposure 1.31(0.92, 1.87) had slightly higher odds than individuals with low exposure 1.14(0.85, 1.52), however, neither of these were statistically significant on their own. In the eight remaining systematic reviews, five identified strong or mostly positive evidence for an association (Burdorf and Sorock, 1997; Heneweer et al., 2011; Hoogendoorn et al., 1999; Jansen and Burdorf, 2003; Jin et al., 2000), one identified evidence that axial rotation increases symptoms following prolonged standing (Coenen et al., 2017), one identified conflicting evidence (Bakker et al., 2009), and two did not identify convincing evidence (Ribeiro et al., 2012; Wai et al., 2010a). Two systematic reviews commented on dose response, stating that there was either limited or no clear evidence in support of a relationship (Ribeiro et al., 2012; Wai et al., 2010a). One of these also stated that there was strong evidence against temporality (Wai et al., 2010a), although, a review that included only prospective cohort studies with people free of LBP at baseline did identify conflicting evidence (Bakker et al., 2009). Collectively, while there is evidence from a meta-analysis of a relationship, the findings from systematic reviews were inconsistent, the evidence for a dose response relationship is limited, and temporality is conflicting.

3.3.5. Awkward postures

One meta-analysis (Griffith et al., 2012) and four systematic reviews examined the association between awkward, flexed, or non-neutral postures and LBP (da Costa and Vieira, 2010; Lis et al., 2007; Nelson and Hughes, 2009; Roffey et al., 2010a). In the meta-analysis, the effects (OR[95% CI]) ranged from 1.14 (1.08, 1.21) to 2.03(1.26, 2.49) (Griffith et al., 2012). Three systematic reviews concluded that there was reasonable evidence for awkward postures and LBP (da Costa and Vieira, 2010), that sitting combined with awkward postures increased risk for LBP (Lis et al., 2007), or that non-neutral postures combined with lifting increased LBP risk (Nelson and Hughes, 2009). In contrast, one review concluded there was strong evidence against an association or temporality (Roffey et al., 2010a).

3.3.6. Heavy physical work

There were 22 reviews that examined exposures including heavy physical work, lifting, manual materials handling, carrying, pushing or pulling, and specific occupational demands. Of these, three of three meta-analyses identified significant positive associations between these exposures and LBP. Specifically, Coenen et al. (2014) identified an OR(95% CI) of 1.11(1.05, 1.18) per 10 kg lifted and 1.09(1.03, 1.15) per 10 lifts/d. Griffith et al. (2012) identified OR (95%CI) ranging from 1.40(1.30, 1.62) to 2.11(1.73, 2.57) for lifting or heavy physical work forces. Lotters et al. (2003) identified increased OR(95%CI) for manual materials handling: 1.51(1.31, 1.74), including higher odds for individuals with high exposure (1.61[1.26, 2.05]) compared to low exposure (1.27[1.00, 1.62]); however, the odds for heavy physical work were not significant 1.31(0.96, 1.33). In addition, eight systematic reviews concluded evidence in favour of an association between these components of heavy physical work and LBP was strong (Heneweer et al., 2011), reasonable (da Costa and Vieira, 2010), consistent (Burdorf and Sorock, 1997; Ferreira et al., 2013; Nelson and Hughes, 2009), or present (Jansen and Burdorf, 2003; Janwantanakul et al., 2012; Kuiper et al., 1999). Of note, heavy physical work was associated with LBP when controlling for heritability (Ferreira et al., 2013), and lifting as a risk factor may be more important in men than women (Hooftman et al., 2004). Three further reviews that examined occupational specific demands (e.g. related to nursing) provided conclusions in favour of these associations (Lagerstrom et al., 1998; Sherehiy et al., 2004; Yassi and Lockhart, 2013).

In contrast, the conclusions of five systematic reviews did not support an association, describing the evidence as conflicting (Bakker et al., 2009; Roffey et al., 2010b; Wai et al., 2010c), or strongly against (Roffey et al., 2010e; Wai et al., 2010b). Similarly, some reviews identified evidence for a dose response relationship (Burdorf and Sorock, 1997; Ferreira et al., 2013) although others described this as minimal and mostly non-significant (Roffey et al., 2010b, e; Wai et al., 2010b, c). Three reviews identified evidence that lifting (Bakker et al., 2009; Taylor et al., 2014) and high job strain (Janwantanakul et al., 2012) can precede episodes of LBP, whereas four reviews interpreted the evidence regarding temporality as less convincing (Roffey et al., 2010b, e; Wai et al., 2010b, c). On balance, evidence was in favour of an association between parameters related to heavy physical work and LBP, and, at times, did support dose-response and temporality. A consensus was not achieved.

3.3.7. Whole body vibration

Twelve reviews (Bakker et al., 2009; Bovenzi and Hulshof, 1999; Burdorf and Sorock, 1997; Burstrom et al., 2015; Hoogendoorn et al., 1999; Jansen and Burdorf, 2003; Jin et al., 2000; Lings and Leboeuf-Yde, 2000; Lis et al., 2007; Lotters et al., 2003; Taylor et al., 2014; Waters et al., 2008) examined whole body vibration as a risk factor for LBP. Of these, four meta-analyses documented a positive association, with OR(95%CI) of 1.39(1.24,1.55) (Lotters et al., 2003), 2.2(1.6,2.9) (Burstrom et al., 2015), 2.2 (1.8, 3.0) (Waters et al., 2008) and 2.3(1.8,2.9) (Bovenzi and Hulshof, 1999). A dose response relationship was also identified: Lotters et al. (2003) observed persons with high exposure had higher odds (2.63[1.69, 4.10]) than those with low exposure (2.25[2.01, 2.52]) and Burstrom et al. (2015) identified higher odds in persons with higher compared to lower exposure (OR[95% CI]: 1.5[1.3,1.8]); although, it was noted that the type of evidence available was predominantly (23/27 studies) cross-sectional. In addition to these, six reviews found strong or consistent evidence that vibration was associated with LBP (Burdorf and Sorock, 1997; Hoogendoorn et al., 1999; Jansen and Burdorf, 2003; Jin et al., 2000; Lings and Leboeuf-Yde, 2000; Lis et al., 2007). However, in reviews that included only prospective studies of pain free individuals, there was inconsistent and conflicting evidence for an association (Bakker et al., 2009), with weak or no evidence that vibration is a risk factor for first time LBP (Taylor et al., 2014). Overall, meta-analyses demonstrated association, with evidence for a dose response relationship. However, prospective studies were less clear and did not strongly support temporality.

4. Discussion

The purpose of this umbrella review was to examine what relationship, if any, is evident between specific physical exposures and LBP, and whether previous systematic reviews provide evidence that supports causality. This review also assessed the quality of existing systematic reviews in this area. Among the included reviews, consensus was found for the *absence* of an association between exposure to prolonged or occupational sitting and LBP. With respect to the other physical exposures examined, including sagittal spine curvatures, prolonged or occupational standing, awkward postures, bending and twisting movements of the spine, components of heavy physical work, and whole-body vibration, the evidence was conflicting.

When considering meta-analyses alone, consistent, significant, and positive associations were demonstrated for prolonged standing (Coenen et al., 2018), lifting (Coenen et al., 2014), manual materials handling (Lotters et al., 2003), operating heavy equipment (Waters et al., 2008), whole body vibration (Bovenzi and Hulshof, 1999; Burstrom et al., 2015), as well as bending and twisting (Lotters et al., 2003) or maintaining flexed and non-neutral postures (Griffith et al., 2012) and LBP. These include some evidence for dose response. In addition, two of three meta-analyses provided evidence that persons with LBP possess a reduced lumbar lordosis, or that a reduced lordosis precedes first time LBP (Chun et al., 2017; Laird et al., 2014; Sadler et al., 2017).

The level of evidence appeared to impact review conclusions. For example, reviews that included only prospective studies identified inconsistent as well as null results (Bakker et al., 2009). Moreover, in meta-analyses, there was some suggestion of publication bias in favour of studies with statistically significant and positive associations (Burstrom et al., 2015; Coenen et al., 2018). Further, reviews did comment that the evidence in favour of an association was stronger in studies that were classified as lower quality following appraisal (Kuiper et al., 1999), and that evidence from studies classified as higher quality did not provide strong evidence in favour of association or causation (Roffey et al., 2010a, b, c, d, e; Wai et al., 2010a, b, c). Importantly, this was not always a consistent finding. For example, one meta-analysis documented stronger associations between lifting and LBP in higher rated studies (Coenen et al., 2018).

There is no simple explanation for why similar reviews produced contrasting findings. Quality may be an issue, as the lower AMSTAR scores did belong to reviews that ruled in favour of associations. However, as meta-analyses typically scored well on the AMSTAR, and ruled in favour of an association, quality provides only a partial explanation. Heterogeneity in reviews may have contributed to conflict. For example, in two meta-analyses that assessed the relationship between spine curvature and LBP, a clear association was identified when the exposure was narrowly defined and assessed radiologically (Chun et al., 2017), while no association was identified when it was assessed using a range of non-invasive measurement techniques (Laird et al., 2014). Ultimately, although systematic reviews are designed to ensure objectivity, authors are still required to interpret the evidence and provide a judgement.

The included reviews identified several challenges to obtaining true effect estimates. These predominantly focussed on study design as well as the assessment of exposure and outcomes. First, it is true that cross sectional studies, from which most estimates are sourced, do not provide a high level of evidence and are less able to establish causation than prospective studies. However, given lifetime prevalence of LBP reaches adult levels by late adolescence (Hoy et al., 2012), even well-designed prospective studies may be limited in their ability to detect first time LBP in an adult (e.g. occupational) populations.

Second, few primary studies were able to directly quantify exposure or to isolate different types of physical exposure, which resulted in broad categorical headings (e.g. ‘bending *and* twisting’). Currently, there is no gold standard for quantifying spinal loads that result from different postures and spine movements. Notably, a review that included only studies that used objective assessment (e.g. direct observation, instrumentation) and standard biomechanical techniques (e.g. 2 or 3-dimensional biomechanical modelling systems, or lifting equations) to estimate load did identify consistent, positive associations between occupational stresses and LBP outcomes (Nelson and Hughes, 2009). This suggests that improving assessment of exposure will provide greater insight into exposure – outcome estimates.

Third, LBP case definitions were rarely consistent. Using appropriate definitions for LBP is particularly important as pain cannot be objectively identified (Merskey and Bogduk, 1994), and the decision to report an episode is influenced by several personal

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and contextual factors (Edwards et al., 2017; Tabor et al., 2017). Using objective measures such as medical records also presents limitation, as only around half of the people that experience LBP will seek treatment for it (Ferreira et al., 2010). To address the limitations identified by these reviews, future studies should consider using consensus definitions of LBP (Dionne et al., 2008), which suggests using a standardised description of the low back region, accompanied by a diagram, and a minimum severity criterion.

The complexity of LBP must also be acknowledged. LBP is a heterogeneous condition. It is not considered, on its own, a single disease state, rather a symptom whose presence does not necessarily reveal anything about the underlying factors that cause it (Adams et al., 2013). Further, the factors that cause it are truly multidimensional and vary within and between individuals. As delays between cause and effect, nonlinear relationships between variables, and unanticipated system behaviour are common hallmarks of complexity (Burke et al., 2015), a simple interpretation of epidemiology studies best designed to assess association can only provide limited insight into whether an exposure causes LBP.

For future reviews, given the challenges in assessing exposures to the spine as well as LBP outcomes, strategies to limit these challenges could include more precise classification of exposure. An example may be to subclassify non-neutral postures into more flexed or more extended categories to avoid washing out differences when pooling (Dankaerts et al., 2006). Further, determining whether the evidence allows insight into causation must be addressed before causative conclusions can be made. Approaches such as the Grading of Recommendations Assessment, Development and Evaluation (GRADE) (Guyatt et al., 2008) would be suitable. Two stage reviews, which assess the relationship between exposure, biological intermediates, and outcomes, are currently being used in fields such as cancer research, and these may provide appraisal of biological plausibility (Robles et al., 2019), which epidemiology studies have yet not done on their own for LBP.

The primary strength of this review is that it provides a synthesis of the highest level of evidence concerning spinal curvature, physical exposures, and LBP available, namely other systematic reviews and meta-analyses. Nonetheless, there are several methodological limitations that should be acknowledged. First, unlike meta-analyses that generate summary statistics, systematic reviews provide a qualitative synthesis of research findings. Given this, it is possible that some insight and detail of interpretation is lost when providing a summary of review conclusions. Second, it was not within the scope of this review to re-examine the knowledge base at the primary research level, and therefore it cannot identify the factors differentiating primary studies that did and did not identify positive associations. Nor can it comment whether the interpretation of primary research findings contained with systematic reviews was accurate and correct, which some editorial correspondence has previously questioned (Andersen et al., 2011; Kuijer et al., 2011). Third, there was overlap in the physical exposures examined. For example, some reviews considered lifting distinct from manual materials handling or heavy physical work, while others did not. Several reviews did comment that it was not always possible to consider these exposures separately. Fourth, only systematic reviews and meta-analyses published in peer reviewed journals were eligible for inclusion. While this is a strength, it does mean that industry reports and other relevant sources of literature were not eligible for inclusion. Finally, as our study selection was limited by the search strategy and English language restrictions, it is possible that some reviews have been overlooked.

Systematic reviews and meta-analyses aim to provide objective and reliable sources of evidence to inform clinical practice, policy, and future research. Therefore, it seems helpful to no one that a simple consensus is not available in these reviews. However, it may be that these findings do provide an accurate description of the current knowledge regarding physical exposure and LBP. That is, while specific physical exposures do seem to increase risk for either recurrent or first time LBP, and this risk may increase with greater exposure, there is no simple, clear, link to LBP.

Declaration of Competing Interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbiomech.2019.08.006.

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