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Review Article

Causal assessment of occupational standing or walking and low back pain: results of a systematic review

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Abstract

BACKGROUND CONTEXT: Low back pain (LBP) is a widespread musculoskeletal condition that frequently occurs in the working-age population. Numerous occupational physical activities have been implicated in its etiology.

PURPOSE: To conduct a systematic review establishing a causal relationship between occupational standing or walking and LBP.

STUDY DESIGN: Systematic review of the literature.

SAMPLE: Studies reporting an association between occupational standing or walking and LBP.

OUTCOME MEASURES: Numerical association between exposure to standing or walking and the presence of LBP.

METHODS: A systematic review was performed to identify, evaluate, and summarize the literature related to establishing a causal relationship, according to Bradford-Hill criteria for causality, between occupational standing or walking and LBP. A search was conducted using MEDLINE, Embase, CINAHL, Cochrane Library, and Occupational Safety and Health database, gray literature, hand-searching occupational health journals, reference lists of included studies, and expert knowledge. Evaluation of methodological quality was performed using a modified Newcastle-Ottawa Scale.

RESULTS: This search yielded 2,766 citations. Eighteen studies met the inclusion criteria. Five were high-quality studies related to standing, and two were high-quality studies related to walking. For occupational standing and LBP, there was moderate to strong evidence against the association criterion, the only study examining dose response did not support this criterion, four studies examining temporality failed to support this criterion, and only one study discussed the biological plausibility criterion. For occupational walking and LBP, there was moderate evidence against a causal relationship with respect to the association, temporality, dose response, and biological plausibility criteria. No studies assessed the experiment criterion for these activities.

CONCLUSIONS: A summary of existing studies was not able to find any high-quality studies that satisfied more than two of the Bradford-Hill causation criteria for occupational standing or walking and LBP. Based on the evidence reviewed, it is unlikely that occupational standing or walking is

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independently causative of LBP in the populations of workers studied.

Keywords: Occupational health; Low back pain; Standing; Walking; Causality; Etiology; Systematic review

Introduction

Low back pain (LBP) is a potentially disabling condition with a complex etiology that may initially result from injury or irritation of the muscles, ligaments, intervertebral discs, facet joints, connective tissues, or spinal nerve roots but can then be compounded by various suspected psychosocial, occupational, and socioeconomic risk factors [1,2]. Low back pain is one of the most frequent musculoskeletal disorders and will affect 70% to 85% of the general population at some point in their lifetime [3,4]. In the working-age population, LBP is the most common cause of job-related disability and a leading contributor to absenteeism [5]. Health-care utilization is high, and LBP is the most frequent reason for visiting an occupational health physician in the United States [6]. To effectuate meaningful changes in the incidence of work-related LBP, it is necessary to improve our understanding of the etiology of LBP, as it relates to common specific occupational physical activities that may be implicated in its genesis.

Standing and walking are routine physical activities performed in many different occupations. Because of their ubiquity, numerous studies have sought to examine the association between standing or walking and LBP in the workplace [7,8]. Observational and biomechanical studies have shown that prolonged standing and excessive walking may result in significant intervertebral and vertebral endplate compression [9,10] and increased intradiscal pressure [11,12], both of which are potential predictors of disc degeneration. A biomechanical association, however, is not sufficient to establish a direct causal link. To further complicate the issue, other studies have reported a protective effect. Employers have reported reduced sick leave because of LBP after the implementation of low-impact exercise regimes involving daily bouts of physical activity that included standing and walking [13,14].

In an effort to resolve this conflicting information, a more thorough comprehension of the causal association between occupational standing or walking and LBP is required. This is difficult to achieve solely through primary scientific studies, especially when numerous studies have previously been conducted on this topic. A systematic review, however, can help to establish causation by summarizing all the available evidence in light of the many criteria that have been proposed to determine causation [15,16]. During this process, the methodological quality of the studies can also be assessed to establish the degree to which their results are subject to bias or confounding [15–17]. Recently, a systematic review by Bakker et al. [18] examined the association between biomechanical loading during standing or walking and LBP. As only two [19,20] out of the reported six studies highlighted a strong relationship, their conclusion was that the overall association was weak and inconsistent [18]. Unfortunately, the strength of this finding is undermined by the fact that the methodology for determining the degree of causation was not reported.

The purpose of this study was to identify, evaluate, and summarize the best available evidence regarding standing or walking and LBP in workers, using Bradford-Hill criteria for causality [21]. These criteria were developed by epidemiologists to provide a framework for evaluating a causal relationship between a particular exposure and outcome to minimize the possibility that important public health decisions are made on the basis of incomplete or flawed evidence [22,23]. This knowledge is needed to help establish safe parameters for exposure to standing or walking in occupational health guidelines and also to provide guidance to stakeholders involved in the adjudication of work-related LBP claims involving these activities.

Methods

An electronic search of MEDLINE (1966 to November 2007; updated in August 2008), EMBASE (1980 to November 2007) and CINAHL (1982 to November 2007) was conducted to identify articles using a comprehensive strategy combining indexed terms and free text with three main components: setting (ie, work-related), etiology (ie, standing or walking), and outcome (ie, LBP) (note: this search was part of a broader study on specific occupational physical activities and LBP; full search strategy details and results are available from the primary author on request). In addition, a hand search of the three occupational health journals with the highest impact factor ranking was performed for the period January 1997 to April 2008 (*Occupational and Environmental Medicine*; *Scandinavian Journal of Work Environment and Health*; and *Journal of Occupational and Environmental Medicine*).

The search was also expanded to include gray literature (ie, literature not published in peer-reviewed, indexed journals, such as conference abstracts or technical reports) by reviewing the following sources of information: 1) conference proceedings from the International Society for the Study of the Lumbar Spine; 2) conference proceedings from North American Spine Society; 3) Web sites of members of the International Network of Agencies for Health Technologies Assessment; 4) Occupational Safety and Health database and National Institute for Occupational Safety and Health database; and 5) a general Internet search for related materials. Electronic searching was complemented by reviewing references of included studies, reviewing references from previous systematic reviews on similar topics, and contacting experts in the field of occupational LBP.

Eligibility criteria

The inclusion criteria were as follows:

1. Published in English or French;
2. Related to occupational exposure;
3. Related to LBP;
4. Related to etiology or causation; and
5. Related to occupational standing or walking.

The exclusion criteria were as follows:

1. No specific population, exposure, and outcome (eg, too broad);
2. Nonscientific studies (eg, commentaries, letters to the editor);
3. Literature reviews;
4. Related only to treatment of LBP (eg, does not address a specific risk factor);
5. Health services research only (eg, costs of injuries);
6. Basic sciences, biomechanics studies, cadaver studies;
7. Less than 30 exposed subjects;
8. Whole-body vibration and psychosocial or environmental risk factors only; and
9. Neck pain, thoracic pain, whole-spine pain, or other nonspecific back pain.

Screening process

Search results were imported into Systematic Review Software, version 3.0 (TrialStat, Ottawa, Ontario, Canada) and screened independently by two reviewers after a calibration and training process. Disagreements between reviewers were resolved by discussion until consensus was reached. Level 1 screening consisted of evaluating all available information returned by the electronic search (eg, abstract, title, keywords). Level 2 screening consisted of evaluating full-text reports for studies deemed potentially eligible after level 1 screening.

Methodological quality assessment

The methodological quality of studies was assessed independently by two reviewers using a modified version of the Newcastle-Ottawa Scale (NOS) for observational studies (eg, case-control and cohort studies) [17]. Disagreements between reviewers were resolved by discussion until consensus was reached. The nine items assessed on the NOS were as follows:

1. Representativeness of the exposed cohort;
2. Selection of the nonexposed cohort;
3. Ascertainment of exposure (risk factor);
4. Demonstration that outcome of interest (ie, LBP) was not present at start of study;
5. Study controls for at least one non-work-related risk factor;
6. Study controls for two or more confounding factors;
7. Assessment of outcome (LBP);
8. Adequate length of follow-up; and
9. Adequacy of follow-up of cohorts/questionnaire response rate.

Only studies in which most of the nine items on the NOS were deemed satisfactory (ie, score of 5 or higher; maximum score=9) and in which appropriate statistical analysis was conducted were considered to be of high methodological quality. Given the numerous known or suspected confounders for LBP, appropriate statistical analysis required multivariate analysis or other acceptable methods of adjusting for multiple risk factors.

Data abstraction

Data pertaining to the following elements were abstracted from all studies deemed relevant by one reviewer and verified independently by another reviewer; disagreements between reviewers were resolved by discussion until consensus was reached:

1. Study design (cross-sectional, case-control, prospective cohort);
2. Study population and setting (country, employer, industry, occupation);
3. Type of occupational standing or walking (definition, measurement, level of exposure);
4. Type of LBP outcome (definition, type, severity, assessment period, health-care use, sick leave);
5. Measurement and controlling for known LBP confounders (psychosocial work factors, other physical factors);
6. Type of analysis (statistical methods, univariate/multivariate, adjusting for confounders);
7. Measures of association (odds ratio, relative risk) with confidence interval or raw data necessary to calculate these measures of association; and
8. Study funding source and reported author conflicts of interest.

Subgroup analyses

Separate analyses were conducted for each category of outcome uncovered. Categories of outcomes consisted of specific categories of standing or walking and specific types of LBP.

The following categories of standing and walking were considered:

1. Standing (harmful);

Table 1
Statistical assessment of specific Bradford-Hill criteria for causation

Criteria	Statistical assessment	Qualification of strength of relationship*	Reference
Association and experiment	Odds ratio	Protective: <1.0 Weak: 1.0–2.4 Moderate: 2.5–3.9 Strong: >4.0	Rosenthal[31]
	Relative risk Hazard ratio Prevalence ratio Incidence rate ratio	Protective: <1.0 Weak: 1.0–1.9 Moderate: 2.0–2.9 Strong: >3.0	Milloy [32]
	t-Test	Clinically significant: >10% change in effect	Feinstein [33]
Consistency	Sackett's strength of evidence	Strong: >75% of studies (at least 2 high quality)	Sackett et al. [34]
Dose response	Pearson's correlation	Protective: <0.0 Weak: 0.1–0.29 Moderate: 0.3–0.49 Strong: >0.5	Cohen and Cohen [35]
	Logistical regression	Protective: <0.0 Weak: 0.1–0.29 Moderate: 0.3–0.49 Strong: >0.5	Cohen and Cohen [35]
	Confident intervals on estimates	Significant: nonoverlapping; trend: overlapping CI	

* Strength at the risk-estimate level refers to how strong a relationship is for the observed unique risk estimate or comparison. In contrast, strength at an evidence level (Table 2) refers to how strong the evidence supporting a conclusion is.

2. Standing (on slippery or uneven surfaces);
3. Standing (on elevated surfaces);
4. Standing (not reported [NR]); and
5. Walking (NR).

The following types of LBPs were considered:

1. Low back pain or injury (chronic);
2. Low back pain or injury (severe);
3. Low back pain or injury (any);
4. Low back pain or injury (seeking medical care); and
5. Low back pain or injury (mild/moderate).

A risk estimate was classified as ''any'' if the study used a minimal level of severity or duration or failed to define the level of severity or duration. Low back pain outcomes were defined as ''severe'' based on a functional rating index score of more than 30% [24], more severe LBP compared with no or minor LBP at baseline [25], or LBP lasting more than 2 weeks [26]. Low back pain outcomes were defined as ''chronic/recurrent'' according to the Dutch Musculoskeletal Questionnaire [27] and an unspecified physician-determined questionnaire [28]. One study classified LBP ''seeking medical care'' [20]. Low back pain outcomes were defined as ''mild/moderate'' based on results from the Nordic [29] or Karasek [30] Questionnaires.

Analysis

A number of the Bradford-Hill criteria are amendable to statistical analyses, whereas other criteria, such as specificity, are not appropriate for assessment of causality because of the high prevalence of LBP [16]. The following Bradford-Hill criteria for causation were evaluated for each category of outcome:

1. Association (including strength of significant associations);
2. Dose response;
3. Experiment;
4. Temporality;
5. Biological plausibility.

The criteria used to determine whether each criterion was met are summarized in Table 1. When studies reported multiple risk estimates, each risk estimate was analyzed to determine if it satisfied each of the Bradford-Hill criteria. If most of the risk estimates in a study satisfied the specific Bradford-Hill criteria, the results of the study were considered supportive.

Table 2
Requirements for levels of evidence relating to the Bradford-Hill criteria

Evidence	Requirements
Strong	2 or more high-quality studies with consistent multivariate results
Moderate	1 high-quality or 2 low-quality studies with consistent multivariate results
Limited	1 low-quality study or unadjusted results (note: these studies were not considered in the causation assessment)
Conflicting	Inconsistent studies of same quality (consistent high quality>inconsistent low quality)

Note: Strength at an evidence level refers to how strong the evidence supporting a conclusion is. In contrast, strength at the risk-estimate level (Table 1) refers to how strong a relationship is for the observed unique risk estimate or comparison.

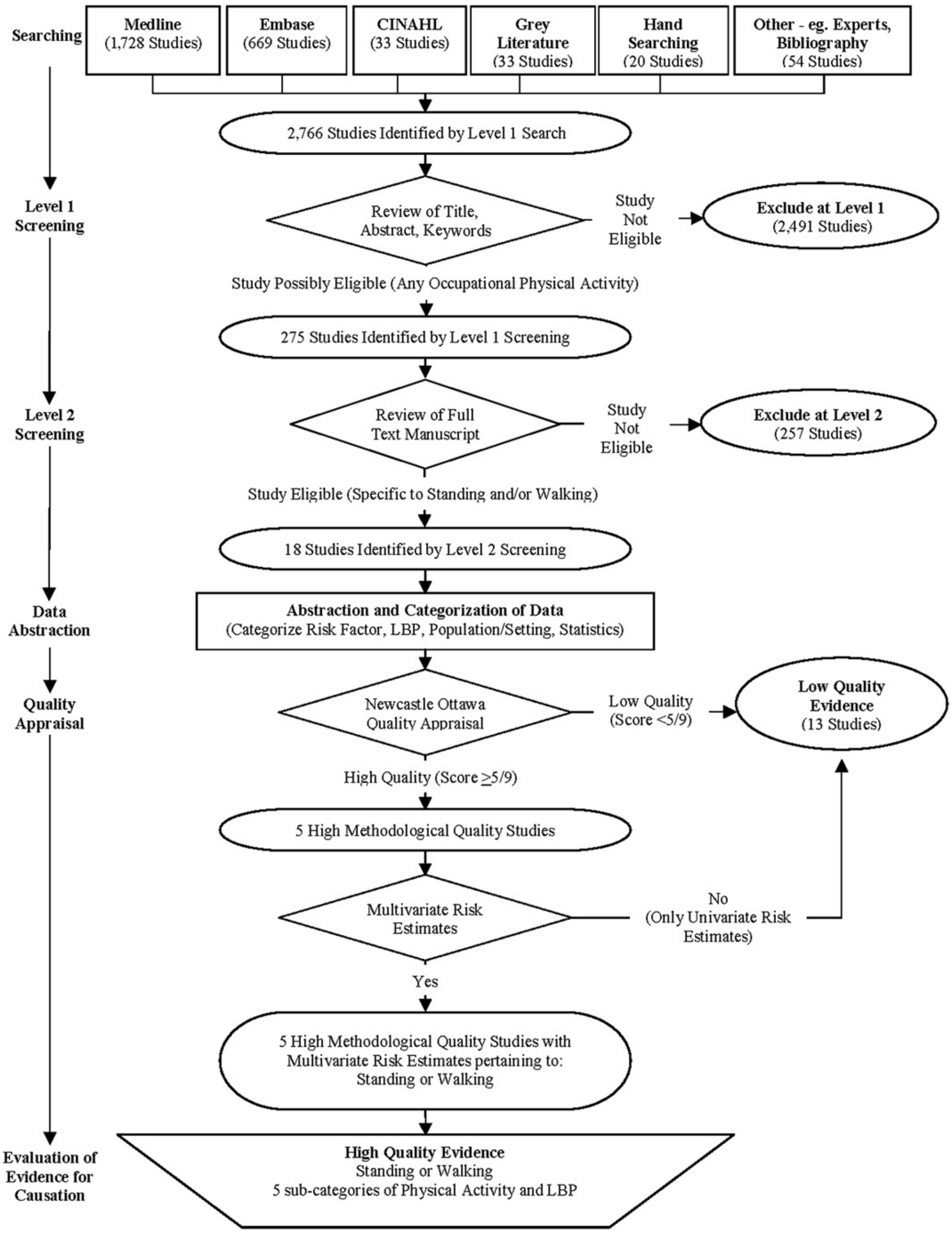

Figure. Study flow diagram.

Level of evidence

The results from each study were then summarized to determine the overall level of evidence supporting each criterion for causality for each category of outcome. The levels of evidence were developed based on previous methodologies to combine results from different study designs (eg, Agency for Health Care Policy and Research [36], Oxford Center for Evidence Based Medicine [34]) (Table 2).

Results

The electronic and manual search strategies yielded a total of 2,766 citations, of which 275 were deemed potentially relevant at the first level of screening. After the review of the full-text articles, 18 studies satisfied the inclusion/exclusion criteria. Thirteen studies were of low methodological quality, and five studies were of high methodological quality. Two of the five high-methodological-quality studies reported on more than one risk factor and,

Table 3
Characteristics of high-quality studies

Author, year [reference]	Country	Study design (FU)	Occupation(s) studied (industry)	Mean age (years)	N	NOS score
Andersen et al., 2007 [25]	Denmark	Pros. cohort (2 y)	Administrators, general laborers, technicians, nurses, auxiliary personnel (hospital)	43.9	3,276	6
Engels et al., 1996 [28]	The Netherlands	Case-control	Nurses (nursing homes [4 homes])	29.0	846	7
Harkness et al., 2003 [37]	United Kingdom	Pros. cohort (2 y)	Retail salespersons, general laborers, childcare providers, administrators, firefighters, police officers, military personnel, shipbuilders, nurses, podiatrists, forestry workers, postal workers (multiple [12 occupation groups])	23	625	6
Yip et al., 2004 [38]	China	Case-control	Nurses (district hospitals [6 hospitals])	31.1	144	6
Yip et al., 2004 [26]	China	Case-control	Multiple (general population and patients from family practice unit)	NR	418	5

N, number analyzed; NOS, Newcastle-Ottawa Scale; NR, not reported; Pros., prospective; FU, follow up.

therefore, were included in both physical activity categories (producing a combined total of seven high-methodological-quality studies for standing and walking combined). The mean NOS score was 3.9, with a standard deviation (SD) of 1.5. The Figure summarizes the retrieval, screening, abstraction, and analysis process. Tables 3 and 4 summarize the characteristics of the high- and low-quality studies, respectively.

The total number of participants enrolled across all 18 studies was 31,810 (mean: 1,767; SD: 2,047). The mean prevalence of LBP was 43.2% (SD: 19.7%). These studies were conducted in 10 countries, most commonly in the United Kingdom (n=4) and Denmark (n=3). Twenty different occupations were assessed in these studies, with multiple occupations (n=13) and nursing (n=7) being represented most often. There were 11 cross-sectional studies, 6 prospective-cohort studies, and 5 case-control studies. Most of the studies (13 out of 18) reported performing statistical analysis, in which results were adjusted for known confounders in LBP.

Overall association of standing or walking with low back pain

Across all 18 studies, a total of 84 estimates were assessed for their association with the specific categories of standing or walking and specific types of LBP outcomes. Out of the 84 estimates, 21 (25%) were found to be

Table 4
Characteristics of low-quality studies

Author, year [reference]	Country	Study design (FU)	Occupation(s) studied (industry)	Mean age (years)	N	NOS score
Ben Lellahom et al., 1990 [39]	Tunisia	Cross-sectional	Administrators, general laborers, technicians, nurses, auxiliary personnel (hospital)	NR	573	4
Bos et al., 2007 [27]	The Netherlands	Cross-sectional	Nurses (university hospital)	38	3,169	3
Gheldof et al., 2007 [30]	Belgium	Pros. cohort (1.5 y)	Multiple (multiple [10 companies—metallurgical or steel])	39.4	812	4
Juul-Kristensen and Jensen 2005 [29]	Denmark	Pros. cohort (1 y)	Administration (office)	NR	2,576	3
Macfarlane et al., 1997 [20]	United Kingdom	Pros. cohort (1 y)	Multiple (patients from family unit)	38	847	3
Magora, 1972 [40]	United States	Case-control	Multiple (multiple [8 occupations—sales and service])	NR	3,316	3
Nahit et al., 2001 [41]	United Kingdom	Cross-sectional	Firefighters, retail salespersons, shipbuilders, dentists, army infantry/officers, nurses, podiatrists, postal workers, administrators, police officers, forestry workers (multiple [12 occupation groups])	23	1,081	2
Svensson and Andersson, 1983 [8]	Sweden	Cross-sectional	Multiple (general population)	44	714	3
Svensson and Andersson, 1989 [42]	Sweden	Cross-sectional	Multiple (general population)	NR	1,410	4
van Vuuren et al., 2005 [24]	South Africa	Cross-sectional	Laborers (metal fabrication) (steel plant)	31.8	366	3
Walsh et al., 1991 [43]	United Kingdom	Cross-sectional	Multiple (multiple [patients from family unit])	NR	2,667	3
Wickstrom and Pentti, 1998 [44]	Finland	Pros. cohort (2 y)	Administration (multiple [shipyard and ventilation])	39	306	2
Xu et al, 1997 [45]	Denmark	Cross-sectional	Multiple (general population)	NR	8,664	4

N, number analyzed; NOS, Newcastle-Ottawa scale; NR, not reported; Pros., prospective; FU, follow up.

statistically significant. Of those statistically significant estimates, 11 (52%) were classified as weak, 5 (24%) were classified as moderate, 2 (10%) were classified as protective, and 3 (14%) did not provide a quantitative estimate of the strength of the association. None of the estimates reported a strong association. A difference was noted between the numbers of statistically significant estimates that came from high-quality (4 out of 21) versus low-quality (17 out of 21) studies.

Subgroup analyses—standing

A total of five high-quality studies (score 5–7) reported an association between occupational standing and LBP [25,26,28,37,38]. Three were case-control studies [26,28, 38], and two were prospective cohort studies [25,37]. Two studies were of nurses [28,38], and three studies were of workers in multiple occupations [25,26,37]. A total of 5,309 participants were analyzed in these five studies.

One multivariate risk estimate for occupational standing and LBP was statistically significant. The association reported by this statistically significant estimate was weak and conflicting, whereas there was no association for occupational standing and LBP reported across all the remaining studies. Only one out of five studies (20%) assessed multiple doses of occupational standing, with results indicating a nonsignificant dose-response trend [37]. Three studies (60%) were able to assess temporality, and two of them reported no evidence. The search results did not identify any study that satisfied the experiment criterion. Only one study (20%) reported on the presence of a biologically plausible causality link between occupational standing and LBP [25].

Based on the aforementioned classifications, there were three multivariate subgroup analyses in the five high-quality studies. A weak, conflicting association and evidence of temporality were reported for standing (NR) and LBP or injury (severe). Otherwise, none of these categories of occupational standing had any high-quality evidence to satisfy any other criterion for LBP causation (Table 5).

Subgroup analyses—walking

A total of two high-quality studies (score 6–7) reported on an association between occupational walking and LBP [28,38]. Both the studies were case-control studies conducted on nurses [28,38]. A total of 990 participants were analyzed.

In these two high-quality studies, none of the multivariate risk estimates for walking were statistically significant. As such, there was a consistent and moderate level of evidence to indicate no association across the studies. Both studies failed to assess dose response, and only one study reported no evidence for temporality. There was no available evidence to assess the experiment criterion. As there were no statistically significant associations reported, there was no discussion of biological plausibility.

Table 5
Results in high-quality studies for standing

Categories of standing and LBP	Author, year [reference]	Estimates per study	Association	Strength of association	Dose response	Experiment	Temporality	Biological plausibility
Standing (NR)—LBP or injury (any or NR)	Yip et al., 2004 [38]	1	No	NS	NA	NA	No	NA
	Harkness et al., 2003 [37]	3	No	NS	Trend	NA	No	NA
	Yip et al., 2004 [26]	1	No	NS	NA	NA	NA	NA
Level of evidence across studies			No (strong)		No (moderate)	NA	No (strong)	NA
Standing (NR)—LBP or injury (chronic, subacute, or recurrent)	Engels et al., 1996 [28]	1	No	NS	NA	NA	NA	NA
Level of evidence across studies			No (moderate)		NA	NA	NA	NA
Standing (NR)—LBP or injury (severe)	Yip et al., 2004 [26]	1	No	NS	NA	NA	NA	NA
	Andersen et al, 2007 [25]	1	Yes	Weak	NA	NA	Yes	No
Level of evidence across studies			Conflicting		NA	NA	Yes (moderate)	No (moderate)

LBP, low back pain; NA, not available; NS, not significant; NR, not reported.
Note: strength at an evidence level refers to how strong the evidence supporting a conclusion is. In contrast, strength at the risk-estimate level (Table 2) refers to how strong a relationship is for the observed unique risk estimate or comparison.

Based on the aforementioned classifications, there were two multivariate subgroup analyses in the two high-quality studies. None of these categories of occupational walking had any high-quality evidence to satisfy any of the criteria for causation (Table 6).

Discussion

Standing and walking are physical activities commonly performed in many different occupations. Previous studies have identified that prolonged bouts of standing or walking could be associated with LBP [19,20,42]. However, results from the current systematic review indicate that occupational standing or walking did not meet any of the accepted criteria required to establish causation for LBP. According to our assessment of the Bradford-Hill criteria [21], there was moderate to strong evidence against the association and dose-response criteria for occupational standing or walking and LBP and conflicting evidence concerning the temporality criterion. No studies evaluating the experiment criterion were identified. Among the subgroups of occupational standing and walking, none had any evidence to satisfy more than three of these criteria for causation. Standing (NR) and LBP (severe) had a conflicting level of evidence for a weak association and a moderate level of evidence for a positive temporality result, but there was no evidence of a dose-response trend. Thus, it is unlikely that this subgroup category of occupational standing is causative of LBP. Based on the evidence summarized in this systematic review, an independent causal relationship between occupational standing or walking and LBP is not currently supported by the Bradford-Hill criteria evaluated.

A small number of studies have previously examined the biomechanical load placed on the spine and lower back during periods of extended standing and walking [9–11]. A common issue arising from these studies is the inadequacy with which the true nature of the load that could be potentially exposing the individual to develop LBP is characterized. Factors, such as the time spent doing the activity, where the activity was being undertaken and under what conditions, and any confounding postural/body-weight issues, are likely to play a significant role and should be described as accurately as possible. In addition, exposure to activities, such as standing or walking, routinely occurs outside workplace settings. To truly measure the association between occupational exposure to walking and standing and LBP, one should control for exposure to those activities in nonoccupational settings. However, this aspect was largely overlooked by the studies reviewed, which attributed results to occupational exposure. Similarly, the control groups chosen in the studies reviewed were not selected on the basis of observed differences in exposure to occupational standing or walking. Rather, the control groups were chosen on the basis of assumed differences in exposure based largely on job title rather than any

Table 6
Results in high-quality studies for walking

Categories of standing and LBP	Author, year [reference]	Estimates per study	Association	Strength of association	Dose response	Experiment	Temporality	Biological plausibility
Walking (NR)—LBP or injury (any or NR)	Yip et al., 2004 [38]	1	No	NS	NA	NA	No	NA
Level of evidence across studies			No (moderate)		NA	NA	No (moderate)	NA
Walking (NR)—LBP or injury (chronic, subacute, or recurrent)	Engels et al., 1996 [28]	1	No	NS	NA	NA	NA	NA
Level of evidence across studies			No (moderate)		NA	NA	NA	NA

LBP, low back pain; NA, not available; NS, not significant; NR, not reported.

Note: strength at an evidence level refers to how strong the evidence supporting a conclusion is. In contrast, strength at the risk-estimate level (Table 2) refers to how strong a relationship is for the observed unique risk estimate or comparison.

supporting data. It is, therefore, possible that the results observed may be attributed to differences in nonoccupational exposure to standing or walking or unexpected differences in actual rather than perceived exposure to those activities between study groups and control groups.

In the present review, the type of occupational standing and walking reported in the five high-quality studies were categorized as ''NR,'' making it difficult to accurately assess the constituents of the physical activity risk factor. For this reason, future studies should attempt to specify the type of occupational standing and walking (eg, standing on ladders or on uneven surfaces, walking on uneven terrain or outside on slippery surfaces) to attain a more detailed description to enable a more thorough explanation of any association with LBP.

Although biomechanical and physiological studies have evaluated possible mechanisms by which occupational standing or walking could theoretically cause injury to lumbar tissues [9–11], only one high-quality study in the present literature review discussed the biological plausibility of their results [25]. Although this does not argue against a biologically plausible association between occupational walking or standing and LBP, it illustrates that this element was largely overlooked in reports of studies evaluating this relationship. This is, perhaps, because authors undertaking such studies may assume that this criterion has been fulfilled elsewhere. However, a brief summary of the biological plausibility of the phenomenon they purport to evaluate may help readers to interpret their results, especially if they do not appear to support other criteria for causality as noted in this review.

There are several potential limitations of this current study, including both weaknesses in the primary studies identified and limitations inherent to the systematic review process. The reporting quality of primary studies was often poor, making consolidation of incomplete results difficult. Commonly noted reporting weaknesses included failure to adopt common operational definitions of LBP, failure to report basic data about the study population (eg, age, gender), failure to describe the type of statistical methods used (eg, univariate vs. multivariate), failure to adjust for known confounders, and a failure to disclose which variables were adjusted for in multivariate analyses. An additional inherent limitation is the possibility that meaningful studies that did not meet our criteria were overlooked. However, the screening process was transparent and confirmed independently to ensure that only the most relevant studies were included. Heterogeneity was noted in some of the categories of standing or walking among the included studies; forcing them into specific categories might have resulted in misclassification. However, this classification process was undertaken before the analysis with two independent reviewers to minimize bias.

Many of the high-quality studies reported risk estimates as ''nonsignificant'' without reporting actual values, making statistical pooling of results impossible. Thus, this systematic review did not rely on statistical pooling in the assessment of causation across studies. Although statistical pooling across studies may have increased the power between studies to detect a difference, it is likely that the studies reviewed had sufficient power to detect an effect. Using an assumption for the overall prevalence of LBP as 35%, an alpha of 0.05, power of 0.80, and equal distribution of risk factors, 30 subjects with the exposed risk factor would have been sufficient to demonstrate a moderate relative risk. This threshold was fulfilled by all studies included in this review. It should be noted that this minimum threshold is based on the assumptions provided and would not apply to specific categories of LBP in which those assumptions would be different. Although the prevalence of LBP across all studies was 43% in this review, larger sample sizes would likely be required for specific categories of outcomes with a much lower expected prevalence (eg, prevalence of sick listed because of LBP could be 5–10% vs. 35% for overall prevalence of LBP).

Many studies uncovered in this systematic review were case-control studies, a design that is subject to recall bias and also insufficiently equipped to ascertain causation, because both the risk factor and the outcome are measured simultaneously. If possible, future studies examining occupational causes of LBP should use a prospective cohort design. Many studies reported only a dichotomous exposure variable (eg, standing or walking—yes/no), making it impossible to determine whether a dose-response relationship was present. This could be corrected by measuring the exposure numerically (eg, % work time spent standing or walking), which could then be categorized into dosage groups.

There are a number of plausible explanations as to why such little positive evidence for causation was found. Establishing causality according to all of the Bradford-Hill [21] criteria can be challenging. For example, no studies assessed the experiment criterion, and all but one study failed to discuss biological plausibility. It may be possible, however, to meet the experiment criterion by measuring the level of exposure to a certain risk factor (eg, standing more than 3 hours on a slippery surface) and the outcome of interest (eg, LBP) both before and after an intervention, aimed at reducing the exposure (eg, worker education or manipulation of the work environment surrounding the task). The Bradford-Hill [21] criteria for causality are used in epidemiologic research to minimize the possibility that important public health decisions are made on the basis of incomplete or flawed evidence. Given the socioeconomic burden of work-related LBP, it would appear that improved information is, in fact, necessary to inform decision making in an evidence-based manner.

Conclusion

The present study was unable to support more than two of the Bradford-Hill criteria for causation evaluated for occupational standing or walking and LBP. It is, therefore, unlikely that occupational standing or walking is independently causative of LBP in workers. However, if a causal relationship between occupational standing and LBP were to exist, it would likely be a very weak one and only likely in specific subcategories. A possible interaction between these occupational physical activities and other known or suspected risk factors for LBP cannot be ruled out on the basis of the evidence evaluated. Future studies examining occupational standing or walking and LBP should endeavor to avoid the common methodological weaknesses uncovered in this review and improve the quality of their reports to help readers interpret their methods and results.

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