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Review Article

Causal assessment of awkward occupational postures and low back pain: results of a systematic review

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Abstract

BACKGROUND CONTEXT: Low back pain (LBP) is a prevalent and costly musculoskeletal disorder that often occurs in the working-age population. Although numerous physical activities have been implicated in its complex etiology, determining causation remains challenging and requires a methodologically rigorous approach.

PURPOSE: To conduct a systematic review of the scientific literature focused on establishing a causal relationship between awkward occupational postures and LBP.

STUDY DESIGN: Systematic review of the literature 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 experts. Evaluation of methodological quality using a modified Newcastle-Ottawa Scale for observational studies. Summary levels of evidence for each of the Bradford Hill criteria for causality for each category of awkward occupational posture and type of LBP.

SAMPLE: Studies reporting an association between awkward occupational postures and LBP.

OUTCOME MEASURES: Numerical association between different levels of exposure to awkward occupational postures and the presence or severity 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, between awkward occupational postures and LBP.

RESULTS: This search yielded 2,766 citations. Eight high-quality studies reported on awkward occupational postures and LBP. Three were case-control studies, one was cross-sectional, and four were prospective cohort studies. There was strong evidence for consistency of no association between awkward occupational postures and LBP, with only two studies demonstrating significant associations in most of their risk estimates compared with six studies reported mainly nonsignificant associations. Two studies assessed dose response, with one study demonstrating a nonsignificant dose-response trend. Three studies were able to assess temporality, but all demonstrated nonsignificant risk estimates. Biological plausibility was discussed by two studies. There was no available evidence to assess the experiment criterion for causality.

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CONCLUSIONS: There was strong evidence from six high-quality studies that there was no association between awkward postures and LBP. Similarly, there was strong evidence from three high-quality studies that there was no temporal relationship. Moreover, subgroup analyses identified only a handful of studies that demonstrated only weak associations and no evidence for other aspects of causality in certain specific subcategories. It is therefore unlikely that awkward occupational postures are independently causative of LBP in the populations of workers studied.

Keywords: Occupational health; Low back pain; Awkward postures; Kneeling; Squatting; Causality; Systematic review

Introduction

Low back pain (LBP) is a musculoskeletal disorder suspected to be triggered by a combination of chronic overuse or acute injury, psychosocial determinants, and other general health factors, which together culminate in varying degrees of pain and disability [1–3]. The annual incidence of LBP within the general population has been projected to be 5% per year, with a lifetime prevalence of 60% to 90% [4,5]. In the working-age population, LBP has the highest health-care use among all chronic diseases, with conservative estimates suggesting that 100 billion US dollar is spent annually on direct medical treatment [6]. Given its prevalence, health consequences, and economic impact, LBP is a major occupational health concern. To lessen the incidence and consequences of work-related LBP, it is necessary to improve our understanding of the etiology of LBP as it relates to suspected occupational risk factors such as specific physical activities that workers are engaged in.

Awkward postures such as kneeling or squatting are specific physical activities encountered in many occupations. Previous studies have suggested that working in awkward postures can result in static loading of the soft tissues, resulting in an accumulation of metabolites, thereby accelerating disc degeneration and ultimately leading to disc herniation [7–9]. A more thorough comprehension of the causal association between awkward postures and LBP may be beneficial to 1) establish occupational guidelines for the primary prevention of LBP, 2) identify potential work modifications for the secondary prevention of LBP, and 3) provide guidance to stakeholders involved in the adjudication process of occupational LBP claims.

Establishing causal links between specific risk factors and LBP from single studies has proven complex and unreliable in the past because of the limitations imposed by specific research questions, study designs, study populations, study methodological quality, and specific types of statistical analyses [10]. In these situations, a systematic review can help establish causation between isolated risk factors and LBP by summarizing all available evidence in light of the many criteria that have been proposed to determine causation [10,11]. Such a study design can also critically appraise the methodological quality of the studies to establish the degree to which their results are subject to bias or confounding [10,12,13]. To date, no systematic review has been conducted on the causality of awkward occupational postures and LBP.

The purpose of this study was to identify, evaluate, and summarize the best available evidence regarding awkward occupational postures in workers and LBP, using Bradford Hill [14] criteria for causation.

Methods

Literature search

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 relevant articles using a comprehensive strategy combining indexed terms and free text with three main components: 1) setting (ie, work related), 2) etiology (ie, awkward postures), and 3) outcome (ie, LBP) (note: full search strategy and results are available from the primary author on request). In addition, a hand search of three occupational health journals (*Occupational and Environmental Medicine*, *Scandinavian Journal of Work Environment and Health*, and *Journal of Occupational and Environmental Medicine*) with the highest impact factor ranking was performed for the period January 1997 to April 2008 .

The search was also expanded to include gray literature by reviewing the following sources of information: conference proceedings from the International Society for the Study of the Lumbar Spine and the North American Spine Society, Web sites of members of the International Network of Agencies for Health Technologies Assessment, Occupational Safety and Health database, National Institute for Occupational Safety and Health database, and 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 to uncover studies that may have been overlooked by the search strategy.

Eligibility criteria

The inclusion criteria (ie, all must be present) were as follows:

1) Published in English or French
2) Related to occupational exposure
3) Related to low back pain
4) Related to etiology or causation
5) Related to awkward postures (ie, any kneeling or squatting activities, awkward back positions, or working in uncomfortable postures)

The exclusion criteria (ie, none could be present) 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, and cadaver studies
7) Less than 30 exposed subjects
8) Whole body vibration, psychosocial or environmental risk factors only
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, ON, 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 or for which insufficient information was available to determine eligibility (eg, no abstract).

Methodological quality assessment

The methodological quality of studies was assessed independently by two reviewers using a modified version of the Newcastle-Ottawa Scale for observational studies (eg, case-control and cohort studies) [12]. Disagreements between reviewers were resolved by discussion until consensus was reached. Only studies in which most of the nine items on the Newcastle-Ottawa Scale were deemed satisfactory (ie, score of 5 or higher) and in which appropriate statistical analysis was conducted (eg, multivariate or risk adjusted) were considered of high methodological quality. Multivariate analysis or other acceptable methods of adjusting for risk were required to meet this criterion to ensure that studies did not report biased results, which failed to account for the multiple known or suspected risk factors for LBP and to minimize the potential for confounding.

Data abstraction

Data pertaining to the following elements were abstracted from all studies deemed 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 posture (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 intervals, or raw data necessary to calculate these measures of association
8. Study funding source and reported author conflicts of interest.

Categories of outcomes

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

The following categories of occupational postures were considered: awkward/uncomfortable and kneeling/squatting.

As bending and twisting involved a more dynamic movement as opposed to maintaining a posture, this category of physical activity was analyzed in a separate systematic review [15].

The following types of LBP were considered:

1) Low back pain or injury (any)
2) Low back pain or injury (chronic)
3) Low back pain or injury (subacute)
4) Low back pain or injury (severe)
5) Sick leave because of LBP (chronic)
6) Sick leave because of LBP (subacute)

Analysis

The following Bradford Hill criteria for causation were evaluated for each category of outcome:

Table 1
Statistical assessment for 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	[17]
	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	[18]
	T test	Clinically significant: >10% change in effect	[19]
Consistency	Sackett's strength of evidence	Strong: >75% of studies (at least two high quality)	[13]
Dose response	Pearson correlation	Protective: <0.0 Weak: 0.1–0.29 Moderate: 0.3–0.49 Strong: >0.5	[23]
	Logistical regression	Protective: <0.0 Weak: 0.1–0.29 Moderate: 0.3–0.49 Strong: >0.5	[23]
	Confident intervals on estimates	Significant: nonoverlapping Trend: overlapping confidence interval	

* 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 a level of evidence level (Table 2) refers to how strong the evidence supporting a conclusion is.

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 (eg, separate results for sub-populations within the study), 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. Other Bradford Hill criteria for causality were not considered in the analysis because they did not apply or could not be assessed.

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 type of awkward posture and 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 [20], Oxford Centre for Evidence-Based Medicine [13]) (Table 2).

Results

Overall, the electronic and manual search strategies yielded a total of 2,766 citations, of which 275 were deemed potentially relevant. On review of the full text copies of the 275 articles, 27 satisfied the inclusion/exclusion criteria. Figure summarizes the retrieval, screening, abstraction, and analysis processes undertaken to obtain the eligible studies. A total of 19 studies were considered of low methodological quality, and 8 studies were of high methodological quality. The mean Newcastle-Ottawa Scale score was 4.1 (standard deviation [SD] 1.4). The characteristics of the included high-quality (Table 3) and low-quality (Table 4) studies are summarized below.

The 27 studies enrolled a total of 69,980 participants (mean 2,952; SD 4,894). The mean prevalence of LBP

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

Evidence*	Requirements
Strong	Two or more high-quality studies with consistent multivariate results
Moderate	One high-quality study or two low-quality studies with consistent multivariate results
Limited	One 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)

* 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.

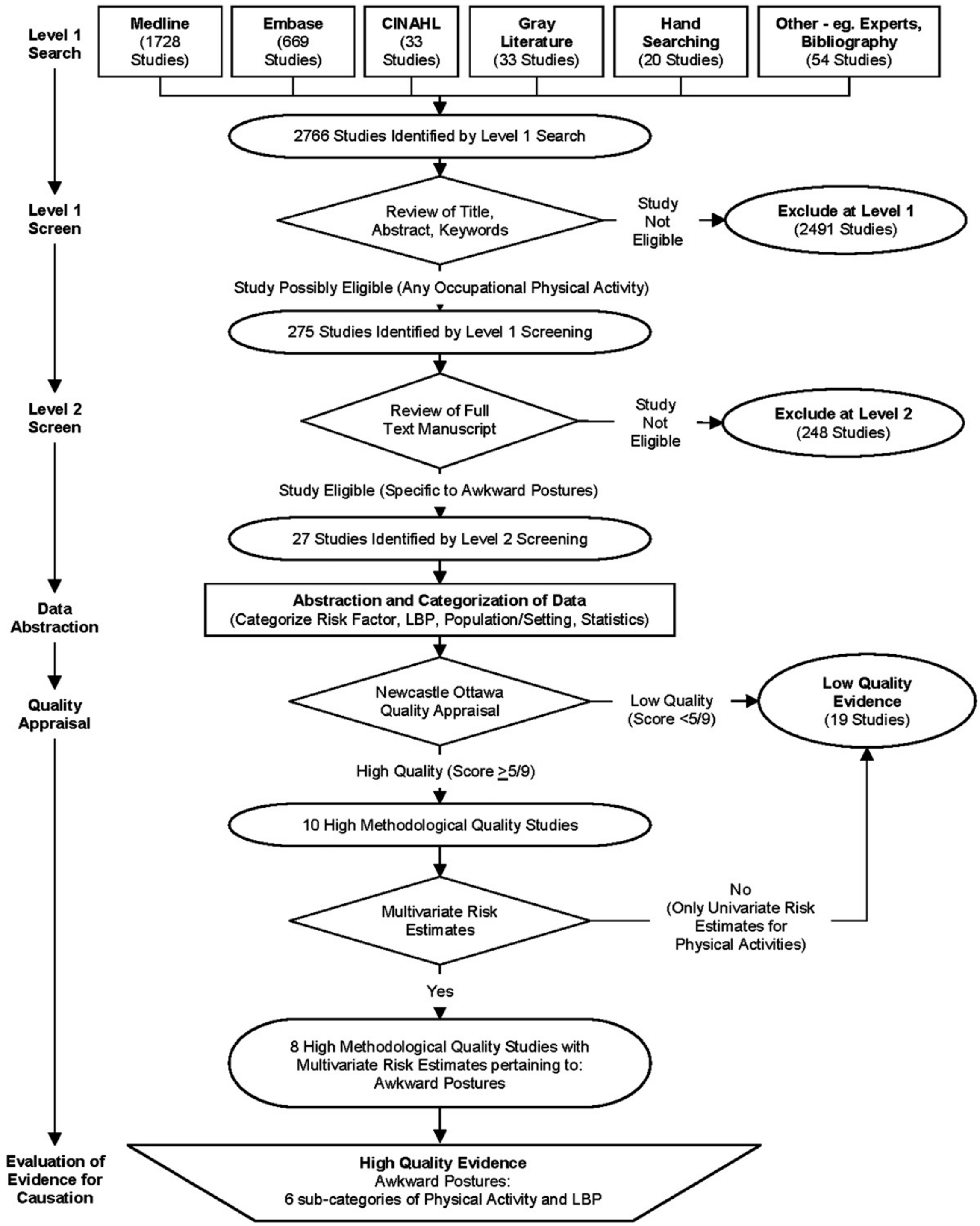

Figure. Study flow diagram.

reported across all studies was 47.8% (SD 21.4%). These studies were conducted in 14 countries, most commonly from the Netherlands (6 studies) and Sweden (5 studies). A total of 44 different occupations were represented by these studies, the most common being administration (n=6), followed by nurses (n=3), plumbers (n=3), supervisors (n=3), and postal workers (n=3). There were 7 prospective cohort studies, 16 cross-sectional studies, and 4 case-control studies. There were seven studies that did not report performing statistical analysis in which results were adjusted for known confounders in LBP.

Overall association of occupational postures with LBP

Collectively, these 27 studies reported a total of 111 estimates of the association between specific categories of

Table 3
Characteristics of high-quality studies

Author, year [reference]	Country	Study design (FU)	Occupation(s) studied (industry)	Mean age (y)	n	NOS score
Elders, 2001 [46]	The Netherlands	Cross-sectional	Scaffolders, supervisors, administrators (scaffolding company)	37.9	288	5
Elders, 2003 [26]	The Netherlands	Pros. cohort (3 y)	Scaffolders, supervisors, administrators (scaffolding company)	NR	288	6
Harkness, 2003 [28]	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
Miranda, 2002 [21]	Finland	Pros. cohort (1 y)	Administrators, forestry workers (large forest industry company)	45.0	3,312	5
Daltroy, 1991 [22]	United States	Case-control (NR)	Administration (US Postal Service)	37.0	456	5
Engels, 1996 [27]	The Netherlands	Case-control	Nurses (nursing homes [four homes])	29.0	846	7
Andersen, 2007 [47]	Denmark	Pros. cohort (2 y)	Multiple (multiple [39 workplaces])	27.8	174	6
Yip, 2004 [25]	China	Case-control	Multiple (general population and patients from family practice unit)	NR	418	5

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

awkward occupational postures and specific types of LBP outcomes; 53 (48%) were reported as statistically significant. Of these 53 statistically significant estimates of association, 35 (66%) were classified as ''weak,'' 9 (17%) were classified as ''moderate,'' 4 (7%) were classified as ''strong,'' 3 (6%) were classified as protective, and 2 (4%) could not be classified because of insufficient information. There was a difference noted in the proportion of estimates considered statistically significant for high-quality (35%) versus low-quality studies (57%).

There were four types of LBP or injury/sick leave because of LBP outcomes reported in the included studies: any, chronic, subacute, and severe. 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. LBP outcomes were defined as ''severe'' based on the study's use of the Von Korff Disability Scale [46], LBP with sciatica [21], LBP lasting more than 2 weeks [24], or an increased severity of LBP compared with baseline [47]. LBP outcomes were defined as ''chronic'' if the study stated that LBP persisted past 3 months [46] or that individuals ''suffer regularly'' [27]. ''Subacute'' outcomes were defined as lasting more than 2 weeks [26].

A total of eight high-quality (score 5–7) studies using multivariate analysis (odds ratio, prevalence odds ratio, and hazards ratio with 95% confidence interval) reported on an association between occupational posture and LBP [21,22,25–28,46,47]. Three were case-control studies [22,25,27], one was a cross-sectional study [46], and four were prospective cohort studies [21,26,28,47]. A total of 6,407 participants were analyzed in these eight studies. Two studies were on scaffolders, supervisors, and administrators [26,46]; one was on nurses [27]; one was on postal workers, shippers and receivers, supervisors, and maintenance [22]; one was on forestry workers and administrators [21]; and three were on multiple occupations [25,28,47].

Only two studies (25%) reported significant associations in most of their risk estimates [25,27]. Moreover, only 4 of 21 (19%) unique risk estimates within this category were considered significant. As such, there was consistency for no association among all the studies in this category (75% of studies reporting mainly nonsignificant associations). Of the two studies that evaluated multiple doses per exposure of awkward posture [21,28], one study (50%) demonstrated a nonsignificant dose-response trend [28]. Three studies [21,28,48] were able to assess temporality and both had mainly nonsignificant risk estimates and were unable to satisfy this criteria. Only two studies discussed biological plausibility as it related to their observed associations [25,46].

Subgroup analyses

Based on the above classifications, six multivariate subgroup analyses in high-quality studies are presented in Table 5.

Posture (awkward/uncomfortable) and LBP (severe)

Elders and Burdorf [46] indicated that there was a weak association when assessing multiple occupations in a scaffolding company. Although biological plausibility was discussed, there was no available evidence to support any of the other criteria of causation in this subcategory.

Posture (awkward/uncomfortable) and LBP (chronic)

A study on nurses by Engels et al. [27] demonstrated a weak association, whereas a recent study of multiple occupation in a scaffolding company by Elders and Burdorf [46] demonstrated no significant association. Neither study assessed any of the other Bradford Hill criteria for causation.

Table 4
Characteristics of low-quality studies

Author, year [reference]	Country	Study design (FU)	Occupations studied (industry)	Mean age (y)	n	NOS score
Bos, 2007 [29]	The Netherlands	Cross-sectional	Nurses medical radiation technologists (university hospitals [8 hospitals])	38.0	3,169	3
Ghaffari, 2006 [30]	Iran	Cross-sectional	Multiple (car manufacturing)	NR	14,384	3
Nahit, 2001 [31]	United Kingdom	Cross-sectional	Firefighters, retail salespersons, shipbuilders, dentists, army infantry/officers, nurses, podiatrists, postal workers, administrators, police officers, forestry workers (multiple [11 occupation groups])	23	1,081	2
Alexopoulos, 2006 [32]	The Netherlands and Greece	Cross-sectional	Nurses, nurse aides, (nursing homes and hospitals [7 The Netherlands nursing homes, 6 Greek hospitals])	37.9	744	3
Aasa, 2005 [33]	Sweden	Cross-sectional	Paramedics (ambulance service)	38.5	1,185	3
Schneider, 2005 [34]	Germany	Cross-sectional	Multiple (general population)	40.0	3,488	3
van Vuuren, 2005 [35]	South Africa	Cross-sectional	Laborers (metal fabrication), (steel plant)	31.8	366	3
Alexopoulos, 2003 [36]	Greece	Cross-sectional	Nurses (general hospitals)	37.7	351	4
Brulin, 1998 [37]	Sweden	Cross-sectional	Homecare workers, sheltered living employees (Home Care Service)	46.8	361	4
Johansson, 1994 [38]	Sweden	Cross-sectional	Assemblers, packers, punchers, welders, smith workers, lathe operators, millwrights, administrators (large metal industry)	NR	241	4
Bovenzi, 1994 [39]	Italy	Cross-sectional	Drivers (tractor), administrators, multiple (rural district population)	44	1,280	3
Holmstrom, 1992 [40]	Sweden	Cross-sectional	Bricklayers, carpenters, concrete workers, plumbers, roofers, scaffolders, insulators, machine operators, crane operators, (construction [trade union])	39.5	1,773	3
Linton, 1990 [41]	Sweden	Cross-sectional	Multiple (general population)	42	22,180	3
Elders, 2003 [26]	The Netherlands	Pros. cohort (3 y)	Scaffolders (scaffolding company)	NR	144	4
Wickstrom, 1998 [42]	Finland	Pros. cohort	Administrators, plumbers, sheet metal workers, welders, (shipyard and ventilation company)	39	306	2
Merlino, 2003 [43]	United States	Cross-sectional	Sheet metal workers, electricians, plumbers, operating engineers, (construction [four trade unions])	27.7	996	4
Myers, 1999 [44]	United States	Case-control	Multiple (municipal department of education)	40.2	600	7*
Alcouffe, 1999 [45]	France	Cross-sectional	Multiple (multiple small companies)	37.8	7,010	5*
Gheldof, 2007 [52]	Belgium, The Netherlands	Pros. cohort (1.5 y)	Multiple (multiple [10 companies—metallurgical or steel])	39.4	812	4

FU, follow-up; n, number analyzed; NOS, Newcastle-Ottawa Scale; NR, not reported; Pros. cohort, prospective cohort.
* The study has been considered low quality because adjusted analyses were not performed.

Table 5
Results in high-quality studies for awkward posture

Categories of posture and LBP	Author, year [reference]	Estimates per study	Association	Strength of association	Dose response	Experiment	Temporality	Biological plausibility
Posture (awkward/uncomfortable)—low back pain or injury (any or NR)								
	Elders, 2001 [46]	1	No	NS	NA	NA	NA	NA
	Daltroy, 1991 [22]	1	No	NS	NA	NA	NA	NA
	Level of evidence across studies		No (strong)		NA	NA	NA	NA
Posture (awkward/uncomfortable)—low back pain or injury (chronic or subacute)								
	Elders, 2001 [46]	1	No	NS	NA	NA	NA	NA
	Engels, 1996 [27]	2	Yes	Weak	NA	NA	NA	No
	Level of evidence across studies		Conflicting		NA	NA	NA	No (mod.)
Posture (awkward/uncomfortable)—low back pain or injury (severe)								
	Elders, 2001 [46]	2	Yes	Weak	NA	NA	NA	Yes
	Level of evidence across studies		Yes (mod.)		NA	NA	NA	Yes (mod.)
Posture (awkward/uncomfortable)—sick leave because of LBP (chronic or subacute)								
	Elders, 2003 [26]	1	No	NS	NA	NA	NA	NA
	Level of evidence across studies		No (mod.)		NA	NA	NA	NA
Posture (kneeling/squatting)—low back pain or injury (any or NR)								
	Harkness, 2003 [28]	4	No	NS	Trend	NA	No	NA
	Yip, 2004 [25]	1	Yes	Weak	NA	NA	NA	Yes
	Level of evidence across studies		Conflicting		Yes (mod.) trend	NA	No (mod.)	Yes (mod.)
Posture (kneeling/squatting)—low back pain or injury (severe)								
	Miranda, 2002 [21]	6	No	NS	No	NA	No	NA
	Yip, 2004 [25]	1	No	NS	NA	NA	NA	NA
	Andersen, 2007 [47]	1	No	NS	NA	NA	No	NA
	Level of evidence across studies		No (strong)		No (mod.)	NA	No (strong)	NA

Mod., moderate; NA, not available; NS, not significant; NR, not recorded.

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.

Posture (kneeling/squatting) and LBP (any or NR)

Yip et al. [25] demonstrated a weak association and biological plausibility of results in their study on Chinese middle-aged women, whereas Harkness et al. [28] demonstrated no significant association in any of its risk estimates during their assessment of multiple occupations. Both studies involved multiple occupations. Neither study assessed any other criteria for causation.

The remaining three subcategories had moderate to strong level evidence for no association, suggesting no causal relationships.

Discussion

Working in awkward or uncomfortable postures is found in many occupations. Previous observational studies by Engels et al. [27] and Yip et al. [25] have reported that working in certain awkward postures may result in LBP. However, results from the current systematic review indicate that working in awkward postures did not meet any of the objective criteria required to establish causation for LBP. There was strong evidence of no association and no temporality, and conflicting evidence for dose response and biological plausibility. Based on the evidence reviewed in this study, no causal relationship was identified between awkward occupational postures and LBP.

Among the subgroup comparisons, none of the six subcategories of awkward occupational postures and specific LBP outcomes had any evidence to satisfy at more than two objective criteria for causation. Posture (awkward) and LBP (severe) had a moderate association and moderate biological plausibility, but the strength of the association was weak and none of the other causal criteria were evaluated [46]. It is therefore unlikely that a causal relationship exists between these factors. The remaining five subcategories had conflicting or moderate to strong level evidence for no association, also suggesting no causal relationship.

These results must be interpreted in light of the struggle by scientists in recent decades attempting to establish the causation of LBP. Numerous potential causes of LBP have been proposed, both internal and external. The more general forms of LBP are likely to have multiple etiologies, which would dilute the potential impact of any one isolated risk factor. However, there is a theory that suggests that actual internal derangement related to higher mechanical stresses, such as from continually working in an awkward posture, may lead to more disabling forms of LBP. The study by Elders and Burdorf [46] was one of only two high-quality studies to discuss the biological plausibility of this association [25,46]. Although numerous biomechanical and physiological studies have evaluated possible mechanisms by which awkward occupational postures could theoretically cause injury to lumbar tissues [23,48,49], it is clear that the biological plausibility of this theory requires further evidence from additional high-quality studies.

Many studies reported risk estimates as ‘‘nonsignificant’’ without reporting actual values, making statistical pooling of results impossible. As such, this systematic review did not rely on statistical pooling in 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 of prevalence of LBP as 35%, alpha of 0.05, power of 0.80, and equal distribution of risk factor, 30 subjects with the exposed risk factor would have been sufficient to demonstrate a moderate relative risk; all 27 low- and high-quality studies included in this review had more than 30 subjects per group.

There are several potential limitations with 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.

Because strict eligibility criteria were used, it is possible that worthy studies that did not meet those 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 the categories of kneeling and squatting among the included studies; forcing them into the specific category of awkward postures may have resulted in misclassification. However, this classification process was undertaken before the analysis with two independent reviewers to minimize bias.

The Bradford Hill criteria are the most commonly used framework to assess causality in epidemiologic research [50]. They were developed at a time when epidemiology was nascent and researchers were investigating numerous potentially causal relationships. Anticipating that increased research could lead to needless public health measures about false causal relationships, Sir Austin Bradford Hill proposed criteria that should be considered before accepting causality [50]. These criteria were not intended to be of equal value where a simple majority was sufficient to accept causality [51]. It has been suggested, for example, that temporality is most important because causality cannot be assessed without ensuring that the risk factor occurred before the outcome; others have suggested that experiment is critical because controlling confounders in an experimental setting is the only way to isolate the effects of the causal factor on the outcome [51]. In truth, both views are correct and neither negates the other. Together, they acknowledge the complexity of causality and support the principle that the threshold to declare it should be high.

When viewed in this context, it becomes apparent that most of the studies assessing awkward occupational postures and LBP have addressed only a few of the Bradford Hill criteria. Most of the studies uncovered were cross-sectional, a design that is insufficient to ascertain temporality because the risk factor and outcome are measured simultaneously; all studies were observational in nature. Many studies reported only a dichotomous exposure variable (eg, squatting yes/no), making it impossible to assess dose response. A large number of studies assessing one criterion (eg, association) is not sufficient to overcome a dearth of studies in others (eg, temporality, experiment, dose response). This dearth could be corrected by asking study participants if they had LBP before ever engaging in particular physical activity work (ie, temporality), and measuring the level of exposure to that activity numerically (ie, dose response). If both the presence of LBP and the level of exposure were measured before and after an intervention aimed at reducing the exposure (eg, worker education), the experiment criterion could also be assessed. To strengthen that type of study and provide direct evidence of a causal relationship, results could be compared for participants randomized into groups that do or do not receive the intervention [16]. Given the important socioeconomic burden of work-related LBP, it appears necessary to conduct such studies to inform decision making.

Conclusions

The current study was unable to uncover evidence supporting more than three of the Bradford Hill criteria for causation for awkward occupational postures and LBP. Moreover, there was consistency across many high-quality studies of no association and any identified associations were considered weak. Based on the results of this systematic review, awkward occupational postures do not appear to be independently causative of LBP in workers. The strength of association was rated as weak, and only one study demonstrated a trend toward a nonstatistically significant dose response. Together, this suggests that if a causal relationship were to exist, it would be a weak one. Furthermore, given the lack of evidence to satisfy most of the Bradford Hill criterion, certain categories of awkward postures could contribute to LBP. Specifically, the results suggest that working in awkward postures could have an association with severe types of LBP and that kneeling/squatting may be causative of LBP in certain working populations; however, because of the conflicting or lack of strong evidence identified for the association, dose response, temporality, and experiment criterion, the likelihood of these two physical activities having a causal relationship with LBP seems unlikely. Future studies examining awkward occupational postures and LBP should attempt to fully and clearly report their results and avoid the common methodological weaknesses uncovered in this review that precluded more definite conclusions.

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