Insufficient Evidence for Load as the Primary Cause of Nonspecific (Chronic) Low Back Pain

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Insufficient Evidence for Load as the Primary Cause of Nonspecific (Chronic) Low Back Pain. A Scoping Review

Low back pain is often benign and self-limiting. Around 20% of the world's population experience recurrent or persistent disability due to low back pain.[29,46,62] Chronic low back pain (CLBP) is associated with impaired quality of life, long-term work absenteeism, and early disability retirement.[46,55] Societal costs of low back pain are among the highest of all health conditions, and impairments in work productivity are the main cost driver.[41,50,53] Despite efforts from clinicians and researchers to understand disease mechanisms and to develop new treatment paradigms, the burden of nonspecific low back pain (NSLBP) continues to rise.[39]

OBJECTIVE: To assess the causal role of the relationship between loading and the onset of nonspecific low back pain (NSLBP) and persistence of NSLBP (chronic low back pain [CLBP]).

DESIGN: Scoping review.

LITERATURE SEARCH: We searched the literature from 2010 until May 2021 using a combination of terms related to (spinal) load and the Bradford-Hill (BH) criteria.

STUDY SELECTION CRITERIA: Operational definitions were developed for every criterion of the BH framework for causality. Study selection was based on the causal role of load in the onset of NSLBP and persistence of chronic low back pain.

DATA SYNTHESIS: The BH criteria were operationalized, and causation was considered established when evidence supported the BH criteria *strength*, *temporality*, *biological gradient*, *experiment*, and *biological plausibility*.

RESULTS: Twenty-two studies were included. There was no consistent support for an association between load and the incidence of NSLBP, or that more load increased the risk of NSLBP/CLBP. Half of the studies did not support specific load exposures to increase incidence of or increase pain in NSLBP/CLBP. Half of studies did not support load preceding NSLBP. No study supported plausible biological explanations to influence the relationship between load and NSLBP/CLBP, or that similar causes have similar effects on NSLBP. Nine of 10 experimental studies did not support that load results in NSLBP or that relieving load reduces NSLBP/CLBP.

CONCLUSION: There was insufficient evidence to support a causal relationship between loading and the onset and persistence of NSLBP/CLBP based on the BH criteria. These results question the role of load management as the only/primary strategy to prevent onset and persistence of NSLBP/CLBP. *J Orthop Sports Phys Ther 2024;54(3):176-189. Epub 25 January 2024. doi:10.2519/jospt.2024.11314*

KEY WORDS: *causality, etiology, loading, low back pain, occupational health, scoping review*

The biomedical paradigm assumes that low back pain is related to the frequency, duration, and intensity of stimuli from biomechanical tissue loading.[5,75] Within this paradigm, heavy physical workload, especially lifting, is assumed to cause low back pain through damage to musculoskeletal tissues of the spine.[52,54,74] Consequently, strategies to unload the spine and reduce tissue strain (eg, minimizing lifting repetitions, intensity, or duration) are applied to prevent or treat NSLBP.[8,23,26]

The effectiveness of unloading strategies is questionable at best.[3,72,73] Findings from medical imaging studies, where many asymptomatic older adults have changes in spinal tissue structures (eg, lumbar disc degeneration), challenge the idea that changes in the spine structures are associated with pain.[7,54] In 2010, Wai et al published a systematic review in which they studied if load was causally related to NSLBP.[73] The Bradford-Hill (BH) framework was applied to assess causality.[47] Based on the application of five of 9 BH criteria, there was insufficient evidence to support a causal relationship between occupational lifting and the onset of NSLBP.[73] This seems to be consistent with the general consensus that NSLBP and CLBP are multifactorial.[29]

Because research with improved methodology may have been performed during the past decade, only lifting was assessed, and because only 5 BH criteria were studied, we reviewed the most recent evidence for all 9 BH criteria. We aimed to review the hypothesis of a causal relationship between load and the onset of NSLBP and the persistence of CLBP. In line with the previous review,[73] we expected insufficient

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evidence to support a causal relationship between loading of the spine and the onset of NSLBP and persistence of CLBP.

METHODS

We used the BH criteria[58,70] as a framework to assess causal relationships. When reporting our scoping review, we followed guidelines for narrative reviews[1,19,22] and scoping review methods.[25]

Search and Article Selection

We used the electronic database PubMed for literature research. For each BH criterion, a separate search string was designed. We searched indexed search terms and free-text terms (**SUPPLEMENTAL APPENDIX 1**).

We included studies published in English or Dutch between January 2010 and May 2021 that focused on the causal role of loading in the onset of NSLBP and the persistence of CLBP. Positioning of the spine and carrying/lifting weighted objects are 2 types of loading and were both included in the terms "(spinal) load," "(spinal) loading," and "back load" in the questions of the BH criteria. Each BH criterion had additional inclusion criteria (**SUPPLEMENTAL APPENDIX 2**). Studies were excluded when the population, exposure, and/or outcome were not specified; nonscientific studies, such as letters to the editor; the study described an intervention without addressing specific risk factor(s); the study was about chronic pain other than low back pain, or mixed populations that could not be separated. Narrative reviews were excluded for all the BH criteria, except biological plausibility and coherence.

Two reviewers performed a title and abstract selection. In case of a conflict, the reviewers discussed and resolved any discrepancies. One of the reviewers performed an additional full-text selection. Four authors were involved in the analysis of selected articles after a full-text search. Consensus across all 4 authors on the analysis and data interpretation of all included papers was achieved during consensus meetings.

Analysis

The operationalization of each BH criterion and how evidence was handled to establish each BH criterion is described in **TABLE 1**.[15,58,70] Qualification of the strength of the relationships was performed according to the criteria described in **SUPPLEMENTAL APPENDIX 3**. Causation was established when evidence is supportive of all of the following 5 criteria: *strength*, *temporality*, *biological gradient*, *experiment*, and *biological plausibility*.[73] Causation was

TABLE 1 Description of Bradford-Hill Criteria and Their Criteria for Satisfaction

	Criteria	Description	Criteria for Satisfaction
1.	Strength:	There should be a strong association between loading and NSLBP/CLBP, and low imprecision in effect estimate.	Criteria for satisfaction in **SUPPLEMENTAL APPENDIX 3**.
2.	Consistency:	There should be consistency in strength and direction of associations.	Criteria for satisfaction in **SUPPLEMENTAL APPENDIX 3**, or multiple sources suggesting a strong positive correlation between load and NSLBP/CLBP, respectively.
3.	Temporality:	There should be a temporal relation between the moment of exposure and the moment of result. The causative variable should take place before the outcome. If exposure is removed or reduced, the outcome should also decrease.	Established with consistent evidence that NSLBP or CLBP is found in people who have been exposed to intense load of the spinal structures prior to the incidence of NSLBP or CLBP, or a reduction in NSLBP or CLBP after reduction in load onto spinal structures, or no or low loading of the spine should lead to low NSLBP or CLBP incidence.
4.	Biological gradient:	There should be evidence for a relationship between the dose of exposure and the magnitude of the response.	Criteria for satisfaction in **SUPPLEMENTAL APPENDIX 3**.
5.	Specificity:	There should be evidence that a specific outcome is related to a specific exposure. An adjusted exposure will lead to an adjusted outcome.	Established with evidence of higher incidence or prevalence of NSLBP/CLBP in populations with high load compared to otherwise comparable workers.
6.	Biological plausibility:	The biological mechanism explaining the association between load exposure and the pain response should be plausible.	Established with evidence of a consistent association between (more) structural changes in the spine and (more severe) low back pain.
7.	Coherence:	There should be consistency of the causal relationship between load and NSLBP/CLBP with what is already known about NSLBP/CLBP, dependent on the extent on the amount of knowledge available.	Established by evaluating alternative, biological plausible explanations for the observed association between load and NSLBP/CLBP.
8.	Experiment:	Evidence gathered from experiments to show the consistency of exposure developing into the same outcome at higher prevalence in the experimental group compared to the control group is clear and hard evidence of causation.	Criteria for satisfaction are given in **SUPPLEMENTAL APPENDIX 3**.
9.	Analogy:	There should be evidence that similar causes have similar effects.	Established with similar postures or lifting movements/weight resulting in NSLBP/CLBP in different studies.

Abbreviations: CLBP, chronic low back pain; NSLBP, nonspecific low back pain.

strengthened if there was consistent evidence in favor of the following 4 criteria: *consistency*, *specificity*, *coherence*, and *analogy*.[73] Strength of evidence relating to the BH criteria was assessed using an order of quality of study type, from strong to weak: meta-analysis, systematic review, narrative review, randomized controlled trial, and intervention/observational study.[24] Evidence statements were created to summarize the evidence for each criterion separately. We propose that clinical relevance can be suggested if change in load is likely to (1) impact prevalence of work-related NSLBP, (2) guide management of NSLBP/CLBP, and (3) predict the prognosis of NSLBP/CLBP.

RESULTS

A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the literature search and screening processes is presented in the **FIGURE**. All included articles are shown in **TABLE 2**.

BH Criteria: Strength, Consistency, Biological Gradient, Specificity

"Is a higher and/or specific loading of the spine consistently positively associated with a higher incidence and/or intensity of NSLBP?" (**TABLE 3**)

A meta-analysis of 8 longitudinal studies reported a positive association between higher loading and the incidence of NLBP.[12] When considering estimated risks of the 8 individual studies for both intensity and frequency of lifting in relation to back pain, there were weak estimated odds ratios (OR = 1.03-1.35; **SUPPLEMENTAL APPENDIX 3**). The health impact analysis based on these 8 studies showed that regular lifting was expected to increase the incidence of low back pain by 4% compared to workers not exposed to lifting. However, the definitions of low back pain incidence in seven of eight of their included studies were broad, including any episode in the past year, making it impossible to differentiate between work-related or non–work-related causation.

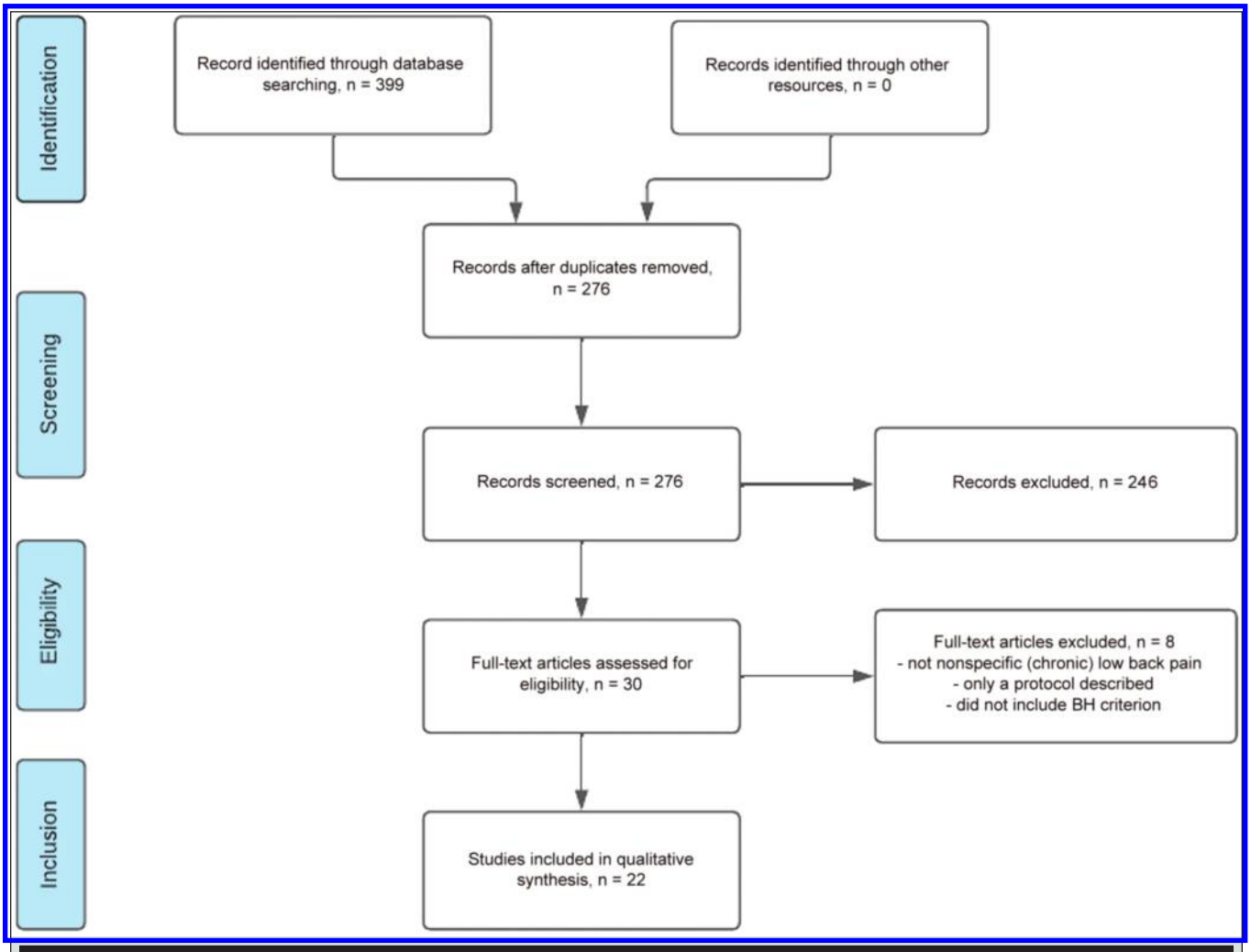

FIGURE. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram describing the literature search and screening process.

TABLE 2 Bradford-Hill Criteria Represented by Studies: #1 Strength, #2 Consistency, #3 Temporality, #4 Biological Gradient, #5 Specificity, #6 Biological Plausibility, #7 Coherence, #8 Experiment, #9 Analogy

			Clinical Trials/RCT			Systematic Reviews	BH Criteria								
#	Study	Type of Study	Study Design	Mean Age (SD)	N	Number of Studies	#1	#2	#3	#4	#5	#6	#7	#8	#9
1.	Dreischarf et al[17]	Systematic review				139	N	N	-	N	-	N	-	-	-
2.	Demoulin et al[16]	Systematic review				9	N	N	N	N	N	-	-	-	-
3.	Marras et al[44]	Narrative review					-	-	-	-	-	-	N	-	-
4.	Chilibeck et al[10]	Systematic review				52	C	C	-	-	-	-	-	-	-
5.	Harris-Adamson et al[27]	Intervention study	Crossover	47.9 (7.9)	16		-	-	-	N	S	-	-	-	-
6.	Coenen et al[12]	Systematic review + meta-analysis				8	S	S	S	S	-	-	-	-	-
7.	Shahvarpour et al[59]	Intervention study	Cross-sectional	Unknown	12		-	-	-	N	-	-	-	-	-
8.	Hasegawa et al[30]	Observational study	Cross-sectional case control	23.9 (3.3)	67		-	-	-	-	S	-	-	-	-
9.	Pathak and Conermann[51]	Narrative review					-	-	-	-	-	N	N	-	-
10.	Urban et al[66]	Narrative review					-	-	-	-	-	-	N	-	-
11.	Saragiotto et al[57]	Systematic review				33	-	-	-	-	-	-	-	N	-
12.	Smith et al[61]	Systematic review + meta-analysis				29	-	-	-	-	-	-	-	N	-
13.	Van Middelkoop et al[68]	Systematic review				37	-	-	-	-	-	-	-	N	-
14.	Parreira et al[49]	Systematic review				19	-	-	-	-	-	-	-	N	-
15.	Wegner et al[76]	Systematic review				32	-	-	-	-	-	-	-	N	-
16.	Franke et al[21]	Systematic review				12	-	-	-	-	-	-	-	N	-
17.	Hayden et al[31]	Meta-analysis				27	-	-	-	-	-	-	-	N	-
18.	Macedo et al[42]	Systematic review				15	-	-	-	-	-	-	-	N	-
19.	Van der Giessen et al[67]	Systematic review				10	-	-	-	-	-	-	-	N	-
20.	Oesch et al[48]	Systematic review				23	-	-	-	-	-	-	-	S	-
21.	Brox et al[8]	RCT	RCT	42.6 (7.9)	124		-	-	-	-	-	-	-	-	N
22.	Mannion et al[43]	RCT	RCT	41.2 (8.3)	473		-	-	-	-	-	-	-	-	N
Summary per BH criterion in % of not supportive studies[a]							50	50	50	80	33	100	100	90	100

All clinical trials and RCT consisted of 1 study.
Abbreviations: BH, Bradford-Hill; C, conflicting; N, not supportive; RCT, randomized controlled trials; S, supportive; SD, standard deviation; (-), not included in BH criterion.
[a]*Percentages are calculated based on the article rate numbers not 'established/total.'*

A systematic review included 139 studies and established a positive association between spine positioning and loading in terms of intervertebral disc pressure.[17] The review was based on assumed causality between intervertebral disc pressure and the onset or persistence of back pain and, therefore, only studied proxies (in vivo and computational models). A study that was not included in the review elaborated on this and showed that young men with preexisting low back pain had higher intervertebral disc compressive forces compared to counterparts without low back pain,[30] once again assuming causality. In addition, interventional studies observed that higher spinal loading affects intervertebral pressure, disc degeneration, muscle

TABLE 3 Bradford-Hill Criteria: 1. Strength, 2. Consistency, 4. Biological Gradient, and 5. Specificity

Study	Type of Article	Topic	Global Results	Conclusions on Causality
1[17]	Systematic review	Estimation of loads on lumbar spine, in vivo and computational models	In vivo: IDP measured in subjects without degenerative intervertebral discs. During relaxed standing: IDP: 0.7-0.9 MPa in L3-L4 and L4-L5 discs, compressive force: ~530 N (range 444-594 N) in L3-L4 and L4-L5 discs. Comparisons: - upright standing to unsupported sitting: inconsistent results (increase 40%/increase 15%/reduction 10% IDP). - standing to bending (20 degrees) forward: IDP: increase between 1.5 and 3.6 times the back load. - squat lifting with both hands—stoop lifting: IDP: inconsistent results of precise IDP, but consistent in stoop lifting higher back load. Highest resultant force on the spine when lifting weight from the ground. Computational model: hard to compare, not the same measures were used. The computational model is less reliable because it may not take all the contributing factors into account.	Strength: criterion not met; based on % changes in loading of the spine criterion met, however, not linked directly to NSLBP/CLBP Consistency: criterion not met Biological gradient: criterion not met; due to no direct connection with NSLBP
2[16]	Systematic review	Preventive back educational interventions for low back pain	Eight out of 9 studies found no difference between groups in low back pain–related outcomes. One study had a higher injury rate in control group ($P<.05$). Outcomes classified: (self-reported) incidence of back pain or injury rate (based on statistics), disability, low back pain–related restricted workdays or sick leave. No changes in pain and disability after reducing the spinal load after the intervention.	Strength, consistency, biological gradient, and specificity: criteria not met; due to no effect
4[10]	Systematic review	Risk assessment/recommendations PA	Fifty-two studies on low back pain, of which 6 articles were included on NSLBP and 32 on CLBP. Total adverse events in exercise were 7% among low back pain patients, reported across resistance, aerobic endurance and stretching training. Adverse events included back or leg pain and back stiffness. Twenty-three percent of the 7% adverse events dropped out; 0.8% of the total events were serious adverse events as disc herniation and fractures. However, it is uncertain whether this was in patients with NSLBP/CLBP or low back pain. The incidence of adverse events is in agreement with previous research. Authors made a decision tree for recommendations of PA based on previous research. Recommendations for patients with low back pain without serious pathology can safely perform a variety of PAs, avoid high-impact PAs, heavy resistance training, extreme trunk flexion, extension, rotation that induces pain.	Strength: criterion not met; due to small injury rate, which may not have been in NSLBP Consistency: criterion not met; previous research confirmed small incidence rate
5[27]	Clinical trial	Mattress lift tool/bottom sheet type—impact on room cleaners making beds	Pain measured at baseline. In follow-up, the accuracy, speed, consistency, ease of use, comfort, and overall preference of the mattress lift tool was assessed, next to biomechanical measures. Spinal accelerations were consistently high across all conditions. Seventeen of 18 measured kinematic values exceeded high risk reference values. Using the tool reduced muscle activity, effort, and number of lifting beds in hotel room cleaners. Fitted sheet reduced duration making beds and effort. Accuracy, speed, consistency, ease of use, comfort, and overall preference in hotel room cleaners, who experience low back pain, improved by use of the tool.	Biological gradient: criterion not met; due to no direct connection with NSLBP. Specificity: criterion met

(Table continues on next page.)

TABLE 3 Bradford-Hill Criteria: 1. Strength, 2. Consistency, 4. Biological Gradient, and 5. Specificity (continued)

Study	Type of Article	Topic	Global Results	Conclusions on Causality
6[12]	Systematic review + meta-analysis	Effect of occupational lifting on NSLBP	Intensity in terms of the weight of heavy lifting and increased frequency of repetitive lifting precede NSLBP.	Strength: criterion met Consistency: criterion met Biological gradient: criterion met
7[59]	Clinical trial	Trunk response to sudden forward perturbations	Variables investigated: preload magnitude (50-100 N), sudden load magnitude (50-100 N), initial trunk posture (upright standing vs flexed posture) and abdominal preactivation (0 vs 10% at EO). Preperturbation activity of the back muscles was significantly affected by preload; abdominal muscles unaffected. Preload did not influence trunk displacement, where sudden load increased it (max. velocity and max. acceleration increased when sudden load increased. In flexed posture the background EMG of the back muscles was significantly higher. In preload of the abdominal muscles the antagonist preactivation was significantly higher. Increased muscle preactivation did not affect any measured parameters except reflex peak. Changes in sudden load magnitude affected both muscles reflex and kinematics.	Biological gradient: criterion not met; due to no direct connection with NSLBP
8[30]	Clinical trial	Relation back load and NSLBP during static standing	Intervertebral disc compressive force odds ratio: 2.308; 95% CI: 1.229, 4.333; $p<.01$) and low back moment larger in group with NSLBP compared to without low back pain. A significant difference in kinematics in specific low back moments during flexion between the patient group and the control group.	Specificity: criterion met

Abbreviations: CI, confidence interval; CLBP, chronic low back pain; EMG, electromyograph; EO, external oblique; IDP, intervertebral disc pressure; LBP, low back pain; NSLBP, nonspecific low back pain; PA, physical activity.

activity, effort, muscle reflex and kinematics.[17,27,59] Higher loading did induce higher strain on bodily tissues yet did not establish a causal link to back pain. In an intervention study, the association between exposure to sudden load and muscle activity in the back muscles was associated with changes in load magnitude and trunk posture.[59]

An interventional study showed that reducing spinal load mechanically led to less back muscle activity during hotel bed cleaning.[27] This was related to perceived exertion, but pain was not measured. In contrast, a systematic review considered loading (exercise) was safe in people with existing low back pain; however, it was recommended that high-impact loading should be avoided initially *if* it induces pain.[10] The included studies demonstrated that higher loading led to tissue strain but not necessarily pain. The included studies shared an implicit assumption of causality and studied proxies of low back pain or single risk factors. There was direct evidence from a systematic review of no association between low back pain and education directed at reducing spinal load.[16] Educating people to reduce spinal load had no effect on low back pain. We considered this indirect evidence because the review did not control for actual load, only the teaching.

Summary We found insufficient evidence of a direct positive association or a biological gradient between load and the onset of NSLBP and the persistence of CLBP. In summary, the reported findings were inconclusive (1 systematic review supporting with weak ORs and undefined population, 1 systematic review not supporting and 2 intervention studies indirectly supporting), inconsistent (evidence was either not supportive or conflicting considering a consistent association), and not coherent.

Evidence Statement The BH criteria for strength, consistency, specificity, and biological gradient were not met.

BH Criteria: Temporality and Analogy

"Does exposure to loading of the spine precede (a) the incidence of NSLBP and/or (b) lead to similar incidence of NSLBP in similar cohorts/studies? Does unloading lead to pain relief in NSLBP and CLBP?" (**TABLE 4**)

Four studies were included.[8,12,16,43] In 1 systematic review, there was a small temporal relationship between spinal load in terms of intensity and frequency, but not duration, of lifting weight and NSLBP in the short term.[12] The review did not investigate long-term exposure nor long-term NSLBP. Therefore, this relationship may not apply for CLBP. Education directed at reducing spinal load did not relate to a change in low back pain,[16] which may—at least indirectly—show that education directed reduction of load does not change the risk of having back pain. Two studies that intended to relieve pain by unloading the spine through fusion surgery showed no significant difference between the surgical and the nonsurgical group.[8,43]

Summary Loading the spine can precede the incidence of NSLBP. There was

TABLE 4 Bradford-Hill Criteria: 3. Temporality and 9. Analogy

Study	Type of Article	Topic	Global Results	Conclusions on Causality
2[16]	Systematic review	Preventive back educational interventions for low back pain	Eight out of 9 studies about preventive back educational interventions showed no difference between groups in low back pain–related outcomes. One study reported a higher injury rate in control group ($P<.05$). Outcomes classified: (self-reported) incidence of back pain or injury rate (based on statistics), disability, low back pain–related restricted workdays or sick leave. No changes in pain and disability after reducing the spinal load after the intervention.	Temporality: criterion not met; due to no effects
6[12]	Systematic review + meta-analysis	Effect of occupational lifting on NSLBP	Intensity in terms of the weight of heavy lifting and increased frequency of repetitive lifting precede NSLBP.	Temporality: criterion met
21[8]	RCT	Surgical vs nonsurgical treatment for CLBP; 4-year follow-up	Lumbar fusion surgery was not superior to cognitive intervention and exercises in patients with CLBP without history of surgery for disc herniation, even though beliefs in surgery were presurgery stronger among both groups. Oswestry disability index: Lumbar fusion: baseline (44.4 ± 10.6), 4 years (29.1 ± 20.1). Cognitive/exercise: baseline (43.0 ± 11.1), 4 years (27.7 ± 19.9).	Analogy: criterion not met; Surgical unloading did not lead to better outcomes than cognitive intervention/exercises.
22[43]	RCT	Comparison spinal fusion vs nonsurgical treatment for CLBP	Fifty-five percent of the patient group completed the FU. Fifty-four percent of this group had fusion surgery, the others multidisciplinary cognitive-behavioral and exercise rehabilitation. No statistically significant or clinically relevant group differences between patients randomized to lumbar fusion or to multidisciplinary cognitive-behavioral and exercise rehabilitation. Both groups showed significant improvement related to CLBP disability (ODI) or any secondary outcomes were observed at FU, Score at FU for ODI (0% no disability, 100% totally disabled/bedridden)	Analogy: criterion not met; Surgical unloading did not lead to better outcomes than cognitive intervention/exercises

Abbreviations: CLBP, chronic low back pain; FU, follow-up; ODI, Oswestry Disability Index; RCT, randomized controlled trial.

no consistent evidence to support the assumption that unloading the spine reduces the risk of occurrence and persistence of low back pain. Interventions aiming at unloading did not show reduction of low back pain. Also, no study supported the criterion analogy.

Evidence Statement The BH criteria temporality and analogy were not met.

BH Criteria: Biological Plausibility and Coherence

"Is there a plausible biological mechanism influencing the association between the exposure and the response in both NSLBP and CLBP?" (**TABLE 5**)

Four studies were included.[17,44,51,66] A narrative review examined the role of age-related changes and disc degeneration (aberrant, cell-mediated response to progressive structural failure, not age-related) in an increased risk for annular tearing.[51] Many individuals with *magnetic resonance imaging*–verified intervertebral disc degeneration were asymptomatic,[51] suggesting that disc degeneration was a result of aging, rather than a specific cause of NSLBP or CLBP.[51] This is supported by another biologically focused narrative review concluding that back pain was not caused by loading in isolation. Rather, it was related to multiple factors (ie, aging, a fall in nutrient supply, heritability, and a progressive cycle of aberrant cellular signaling and structural damage).[66] Therefore, a plausible biological explanation for an association between loading and the onset and persistence of NSLBP was not identified.[66]

Two studies reviewed biological properties of the intervertebral discs.[17,44] One review found increased intervertebral discs pressures as result of different postures and movement, but did not investigate the link between loading and back pain.[17] Another study suggested that inflammation and sensitized nerves may be a link between

TABLE 5 Bradford-Hill Criteria: 6. Biological Plausibility and 7. Coherence

Study	Type of Article	Topic	Global Results	Conclusions on Causality
1[17]	Systematic review	Topic: Estimations of loads on lumbar spine, in vivo and computational models	In vivo: IDP measured in subjects without degenerative intervertebral discs. During relaxed standing: IDP: 0.7-0.9 MPa in L3-L4 and L4-L5 discs, compressive force: ~530 N (range 444-594 N) in L3-L4 and L4-L5 discs. Comparisons: - upright standing to unsupported sitting: inconsistent results (increase 40%/increase 15%/reduction 10% IDP). - standing to bending (20 degrees) forward: IDP: increase between 1.5 and 3.6 times the back load. - squat lifting with both hands—stoop lifting: IDP: inconsistent results of precise IDP, but consistent in stoop lifting higher back load. Highest resultant force on the spine when lifting weight from the ground. Computational model: hard to compare, not the same measures used. Computational model less reliable because it may not take all the contributing factors into account	Coherence: criterion not met, due to no direct connection with NSLBP
3[44]	Narrative review	Relationship of tissue tolerances and low back pain	This study investigated the mechanical and biological properties of the intervertebral disc in relation to low back pain. This study concludes that discs get damaged when there is a mechanical force or external loading that is out of the physiologic range of the tissue. This relation is time dependent. An explanation for back pain can be elevated sensitivity to inflammatory pain in LB (non-painful loading may induce pain, hydrostatic pressure on nerves potentially causing pain, aging, severity of degeneration)	Coherence: criterion not met; due to no degeneration of the disc found in inflammatory low back pain, even after being exposed to high external load on the spine. But inflammatory back pain is not considered NSLBP
9[51]	Narrative review	Lumbosacral discogenic syndrome	Most individuals with intervertebral disc degeneration are asymptomatic. This degeneration can be seen using MRI. Thirty-seven percent of individuals of 20 years of age are asymptomatic. This is 96% in individuals of 80 years of age.	Coherence: criterion not met; due to structural deficits not related to pain Biological plausibility: criterion not met: aging can explain disc degeneration in asymptomatic individuals, but not the symptomatic
10[66]	Narrative review	Role of biomechanics and genetics in disc degeneration and low back pain	Disc degeneration can have many etiologies. Many individuals appear to be free of symptoms. Thirty percent of asymptomatic individuals had disc abnormalities.	Coherence: criterion not met; due to structural abnormalities not being related to pain

Abbreviations: IDP, intervertebral disc pressure; LB, lower back; MRI, magnetic resonance imaging.

loading and back pain, without the necessary presence of degeneration of intervertebral discs,[44] providing a neuroscience-based explanation to contrast the biomechanical.

Summary Three studies reported disc degeneration in asymptomatic individuals, opposing a biological plausibility of spinal structures being the primary cause of back pain with load as a mediator. This perspective was strengthened by a study that showed no degeneration of the intervertebral discs in patients with NSLBP. Contemporary explanations for musculoskeletal pain focus more on the role of neurobiology[34] and a more complex (multifactorial) understanding of NSLBP or CLBP.[39] There was no consistent evidence supporting coherence or biological plausibility of load as the primary mechanism to cause of NSLBP or CLBP.

Evidence Statement The BH criteria biological plausibility and coherence were not met.

BH Criterion: Experiment

"Is there consistency in evidence of the association between loading of the spine and the onset and persistence of NSLBP at higher prevalence in the experimental group compared to the control group?" (**TABLE 6**)

Two systematic reviews including 66 studies confirmed the positive effect of interventions that reduce CLBP by changing load.[61,68] A significant reduction of CLBP was found at the short, medium, and long terms after stabilization exercises. The effects were no better than other forms of exercise in the long term.[61] While the ultimate aim of stabilization exercises is to decrease the spinal load, the exercises themselves lead to a short-term

TABLE 6 Bradford-Hill Criteria: 8. Experiment

Study	Type of Article	Topic	Global Results	Conclusions on Causality
11[57]	Systematic review	Motor control exercise for CLBP	People with NSLBP tend to increase spinal stiffness to compensate for lack of spinal muscle control by increasing superficial muscle activity. Compared to other exercises MCE there was no clinically important difference for short, intermediate, and long-term follow-ups. Compared with minimal intervention MCE there is inconsistent evidence for the effect of reducing pain at all follow-up periods. Compared to manual therapy MCE is of no clinical importance at all follow-up periods for both pain and disability. There is low quality evidence of a clinically important difference between MCE and EPA. Risk and odd ratios: Small <10%; Medium 10-20%; Large >20%	Criterion not met; due to motor control exercises not effective in reducing pain and disability
12[61]	Systematic review + meta-analysis	Stabilization exercises for NSLBP	Stabilization exercises significantly benefit NSLBP in reducing pain at short, medium, and long term. It also benefits NSLBP in reducing disability at short and long term. Outcome measure: pain and/or functional disability mean scores and measure of range. Stabilization was no more effective compared to other exercises in the long term	Criterion not met
13[68]	Systematic review	Exercise therapy for chronic NSLBP	Exercise therapy focuses on biomedical aspects. There was no significant difference between exercise therapy and no treatment or waiting list controls on pain intensity and disability. Compared to usual care, the exercise was effective on pain intensity and disability only at short term follow-up. Exercise therapy was no more effective compared to other exercises in the long term	Criterion not met; due to exercise therapy ineffective compared to no treatment
14[49]	Systematic review	Back schools for CLBP	Only low to very low-quality evidence was found for all comparisons, outcomes and follow-up periods investigated. The meta-analysis showed no difference or effect favoring back school	Criterion not met; due to no effect
15[76]	Systematic review	Traction for NSLBP with/without sciata	Most evidence was imprecise and inconsistent. Authors put little trust in positive effects that had emerged.	Criterion not met; due to effect not shown
16[21]	Systematic review	Muscle energy technique for NSLBP	Poor evidence related to assessing the effectiveness of MET that show that MET Is not effective for NSLBP patients	Criterion not met; because likely not effective
17[31]	Meta-analysis	Exercise therapy for NSLBP	Exercise therapy is shown to be more effective than no treatment or usual care on pain, functional limitations, and global recovery outcomes at short-term follow-up. The therapy is similar effective compared to other comparison treatments for all the same outcomes. Evidence was of poor quality. This therapy is especially recommended to people who work or do activities under heavy physical demands.	Criterion not met; due to exercise therapy minimally effective for persistent NSLBP outcomes.
18[42]	Systematic review	Graded activity + graded exposure in patients with persistent NSLBP	Four of the pooled effects sizes were statistically significant. There results were in support of the graded activity over a minimal intervention for pain and disability at short and intermediate term follow-up. The effect sizes were small and may indicate poor clinical meaning. Graded activity was no more effective compared to other exercises in the long term	Criterion not met; due to no effect ("…may not be clinically meaningful")
19[67]	Systematic review	Graded activity in patients with NSLBP	There is no or insufficient evidence for a positive effect of graded activity compared with usual care on pain, disability and return to work.	Criterion not met; due to graded activity being insufficient
20[48]	Systematic review	Exercise on work disability with nonacute NSLBP	The odds ratio (0.66) suggests that the odds of improvement by exercise in work disability are in the long-term 34% lower if only usual care is given. In short and intermediate term follow-ups there was no significant effect.	Criterion met; due to slightly larger effect compared with usual care

Abbreviations: CLBP, chronic low back pain; EPA, electrophysical agents; MCE, motor control exercise; MET, muscle energy technology; NSLBP, nonspecific low back pain.

load increase. Because the review[61] did not control the extent of the reduced spinal load as a result of the stabilization exercises, we considered this evidence indirect. Exercise therapy had positive effects on pain and disability in the short term.[68] Changing loads through stabilization exercises was no more effective than general exercise, indicating that a change in physical activity, rather than load reduction, was the beneficial component. Seven systematic reviews (representing 138 studies) and 1 meta-analysis[21,31,42,48,49,57,67,76] found minimal to no effect of interventions that were intended to reduce CLBP by reducing back loading. A reduction in back load was not consistently associated with a reduction in CLBP.

Summary Most reviews did not support reducing load to lower the incidence of NSLBP and persistence of CLBP. Unloading the spine may lead to pain relief in those who are already suffering from NSLBP.[61]

Evidence Statement The BH criterion *experiment* was not met; 9/10 did not support the criterion.

DISCUSSION

We aimed to evaluate the evidence for a causal relationship between load and the onset of NSLBP and persistence of CLBP. After reviewing 14 systematic reviews (3 including meta-analysis), results of 3 meta-analyses, 3 narrative reviews, and 5 intervention studies, we found insufficient evidence to support spinal load as the primary cause of NSLBP or CLBP. Our findings are consistent with a previous review that used fewer BH criteria,[73] and 1 other review.[64]

Insufficient Support for Load as the Primary Cause of NSLBP

Our results are consistent with previous work,[73] expand current knowledge, and provide more certainty that, at group level, there is insufficient evidence to support that load is the primary cause of NSLBP or CLBP. The review of Wai et al has been criticized along with other reviews on this topic.[64] In these debates, a clear differentiation between causation and association is lacking, apart from methodological issues such as low back pain complexity, case definitions, and exposures. In line with our results, there seems to be a strong inherent assumption that load *is* causally related to back pain; however, reviews such as ours, Wai et al[73] and Swain et al[64] using BH criteria, consistently found insufficient evidence supporting the hypothesis of loading being the primary cause of NSLBP. In addition, several other studies support our results.[28,36,56]

The evidence does not support a direct, positive association or biological gradient between spinal loading and the onset of NSLBP and/or the persistence of CLBP. Similarly, there was no plausible biological mechanism for the onset of NSLBP, and persistence of CLBP and treatments focusing on decreasing spinal load are overall ineffective. In constrast, evidence supported the temporal concept that load precedes NSLBP.[12]

Albeit, load is 1 factor that can provoke pain at group level,[12] it would seem appropriate to conclude that at population level the role of biomedical loading has been vastly overestimated and that load should be seen as one of many contributing factors that can cause or influence back pain. Focusing on load management as the only or primary strategy for NSLBP or CLBP, and may stand in the way of other, possibly more potent, intervention strategies such as early return-to-work, upskilling organizations in how to understand pain, and supporting workers with flexible arrangements, when possible.[33]

Making Sense of Contradicting Studies and Positive Associations

Nonspecific low back pain is not caused by a single factor, rather a combination of interacting factors.[29,71] Studies show positive associations between loading of the spine and low back pain[13,37,69] or a positive association between load and physical strain in people with specific and/or NSLBP.[12] Together the studies show that higher spinal loading affects intervertebral disc pressure, muscle activity, effort, muscle reflex, and kinematics,[11,17,27,30,59] and that higher loading does induce higher strain on bodily tissues.[12] Such studies may have been prematurely considered to suggest causality. However, while association alone is insufficient to infer a causal relationship between load and NSLBP, the existing evidence base should not be discarded; rather, it should contribute to a more complex understanding why existing NSLBP, in some people, can be aggravated by loading and relieved by unloading.

Pain may be influenced by complex interactions between multiple factors, such as intrapersonal, bodily, or environmental factors.[71] Some people with NSLBP or CLBP have a magnified pain responsiveness, due to adaptation of the nervous system, to nonharmful tissue strain when spinal loading increases.[40] Loading beyond tissue tolerance can lead to tissue injuries, which are strongly associated with acute, transient pain via sensitization of nociceptors.[32,75] Future research may be directed to further understand the adaptations of the nervous system as part of a plausible biological explanation for aggravated pain by increased load. Further research on causal explanations for NSLBP should consider factors beyond spinal structures and load, and may benefit from the extensive body of evidence on factors related to the biopsychosocial model, which includes factors such as neuroimmune interactions, neuroplastic changes, experience, beliefs, expectations, and contextual or societal factors.[18]

Is It Time to Abandon the Biomedical Model for LBP?

Our results suggest that the association between occupational load and the onset and persistence of NSLBP is weak if not absent. However, there is a widespread belief in a causal relationship between load and spinal pain,[71] yet campaigns to change beliefs and behaviors have only had modest effects.[63] Part of the explanation as to why biomedical beliefs are so stable may be a bilateral reinforcement between patients and professionals: if one believes or sees effect of this approach, the other may also be more likely to oblige to

it.[4] Prevention and treatment strategies should refrain from using isolated biomechanical explanations to complex pain conditions[9] and instead deploy a biopsychosocial approach capable of adapting a pain narrative in line with how the individual experiences pain.[14,38] Likewise, tailored treatment from evidence-based approaches such as physical activity, exercises, and education on beliefs about causes of NSLBP and mental health may reduce the burden of NSLBP.[28,29]

Positive associations between changed load and NSLBP or CLBP (temporality and biological gradient)[12] imply that load management may help some people. Rather than a causal factor, load can be an aggravating factor for some people, and load management may be a helpful strategy at an individual level. This is very much in line with the consensus on NSLBP and CLBP, which states that they are the result of not one but many, coexisting factors.[28] Others, including patient education, physical activity, and individualized solutions (eg, work hours, adjusted work conditions, or home office) should be considered. Tailored information and physical activity may be better prevention strategies.[6,31]

We expect patients will benefit when the occupational and rehabilitation medicine fields follow the evidence as outlined in our review. This should extend to clinicians, by teaching the evidence in all health care curricula.[45] Preventive measures that emphasize loading as a risk factor[12,35] or inform general guidelines (eg, ergonomic guidelines)[75] are created around the assumption that loading should be avoided. Instead, recommendations regarding loading should only be considered at an individual basis whenever loading seems to aggravate and/or unloading seems to reduce back pain. We suggest that ergonomic guidelines for posture or loading below tissue tolerance levels should be revisited. While the biomedical rationale and evidence underlying these guidelines is insufficiently supported, it is unknown whether keeping or abolishing them will do more harm than good. Theoretically, the presence of a guideline or lifting regulation itself reinforce existing biomedical beliefs of the general public, workers, and health care practitioners. Whether it may even have unintended harmful nocebo effects, associated with anxiety, negative expectations and stress is unknown, and should be subject of study.

Strengths and Limitations

We have built on previous work by adding BH criteria, newer studies with newer methods, and performed a broader search (loading instead of lifting). Wai et al[73] confined to a narrow group of participants/study designs. By including reviews, we broadened our search and could answer the research question extensively without being restrained to a specific group of participants or study design. We were explicit in our inclusion criteria. We are certain that our review included patients with NSLBP/CLBP for the following criteria: strength, consistency, specificity, coherence, experiment, and analogy. Other criteria were in search of alternative explanations for pain and were therefore not restricted to patients with NSLBP/CLBP. It is possible that we might have excluded some studies, in which there was a mix of specific low back pain and NSLBP. Additionally, our review approached the BH criteria more individually, compared to previous studies.[72,73]

Study limitations appear highly related to the quality of included studies,[64] such as heterogeneity in NSLBP complexity, case definitions, and exposures. Some studies reported risk estimates without reporting statistical values or had a low methodological quality, which could have biased toward a positive result. Some of the reviews included intervention studies that reported no effects,[16,42,49] which may be explained by inconsistent application of underlying biomechanical principles, low quality of studies, small sample size, and/or a low number of trials.[23,29,58,71,73] Several included studies (implicitly) assumed that load was linked to pain,[17,27,59] while instead, these studies investigated the relationship between positions, sudden perturbations or activities, and load in terms of kinematic values.

The fact that we searched only 1 database might have led us to inadvertently exclude relevant literature. However, by including reviews the risk of missing relevant literature was mitigated. While we cannot be certain, we estimate that the risk of missing a study and its relevance toward our end conclusion is low.[20] Despite this, our search was limited to the PubMed database and should therefore be regarded as a starting point. To draw more distinct conclusions, future research should include all relevant databases. Although there are limitations to what a scoping review can do, the possibilities of scoping reviews allow us to include a diversity of study types, participants, and 9 subquestions (one for each BH criterion) to summarize the current state of evidence. This could not be done with systematic review methods.

Future studies examining causes of NSLBP should use a more systematic approach to causally link risk factors to NSLBP. Possible publication bias was not reviewed; however, some evidence of publication bias in favor of smaller studies with significant findings was identified by others.[64] Lastly, the BH criteria to study causality have been criticized as overlapping and related to different views of causality, indicating that improvements are needed to incorporate developments in causal thinking.[60,65] It may even be debated whether the use of the BH criteria is appropriate to study 1 factor of a complex interacting context-dependent multifactorial biopsychosocial phenomenon such as back pain. By accepting that back pain is complex, it follows that factors (eg, load) can play anything from an insignificant to a pivotal role for different individuals, and possibly different in the same individual at different time points. We argue that other methods may be supplemental or better at studying the role of load and other factors. Medicine may benefit from making a turn toward ecological perspective, placing more emphasis on understanding human biology

as genuinely interactive, and on how biological processes are integrated with human context and lived experience.[2] From this perspective, it is impossible to prove that loading, or any 1 other factor in isolation, can play a significant role in the back pain in an individual patient.

CONCLUSION

There remains insufficient evidence to support a causal relationship between loading and the onset of NSLBP and the persistence of CLBP. Concerns regarding structural injuries of all structures, including the spine, are still relevant for very heavy, and possibly repeated, loading. All pain is real: this study does not change that. However, our findings question the role of traditional ergonomics and other unidimensional solutions for a complex multidimensional phenomenon such as back pain. ◉

KEY POINTS

FINDINGS: There was insufficient evidence that loading of the spine is the single cause of the onset of nonspecific low back pain (NSLBP) and persistence of (work-related) chronic low back pain (CLBP).

IMPLICATIONS: Among the general public and patients, a biomedical view of back pain and its causes dominates, despite repeated reports finding otherwise (ie, insufficient evidence). Clinicians should implement a biopsychosocial approach to prevent or treat NSLBP and CLBP.

CAUTION: Study limitations are related to search strategy, and the quality of included studies, such as heterogeneity in NSLBP complexity, case definitions, and exposures.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: L.J.E. de Bruin, M.F. Reneman, M. Hoegh and C. Greve are responsible for the conception and design of the study, analysis and/or interpretation of data, drafting the manuscript, and for critically revising the manuscript for important intellectual content. L.J.E de Bruin worked on the acquisition of data. All authors approved the version of the manuscript to be published and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

DATA SHARING: Data sharing is not applicable to this article as no new data were created or analyzed in this study.

PATIENT AND PUBLIC INVOLVEMENT: No patients/athletes/public partners were involved in this literature research.

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REFERENCES

1. Academy of Nutrition and Dietetics. *Narrative review checklist*. Eat Right. https://www.elsevier.com/__data/promis_misc/ANDJ%20Narrative%20Review%20Checklist.pdf. Accessed April 11, 2021
2. Anjum RL, Copeland S, Rocca E (Eds). *Rethinking Causality, Complexity and Evidence for the Unique Patient: A Causehealth Resource for Healthcare Professionals and the Clinical Encounter*. Springer; 2020:1-241. https://link.springer.com/book/10.1007/978-3-030-41239-5
3. Balagué F, Mannion AF, Pellisé F, Cedraschi C. Non-specific low back pain. *Lancet*. 2012;379:482-491. https://doi.org/10.1016/S0140-6736(11)60610-7
4. Barlow DH. Negative effects from psychological treatments: a perspective. *Am Psychol*. 2010;65:13-20. https://doi.org/10.1037/A0015643
5. Bendelow G. Chronic pain patients and the biomedical model of pain. *Virtual Mentor*. 2013;15:455-459. https://doi.org/10.1001/virtualmentor.2013.15.5.msoc1-1305
6. Borisovskaya A, Chmelik E, Karnik A. Exercise and chronic pain. *Adv Exp Med Biol*. 2020;1228:233-253. https://doi.org/10.1007/978-981-15-1792-1_16
7. Brinjikji W, Luetmer PH, Comstock B, et al. Systematic literature review of imaging features of spinal degeneration in asymptomatic populations. *Am J Neuroradiol*. 2015;36:811-816. https://doi.org/10.3174/ajnr.A4173
8. Brox JI, Nygaard ØP, Holm I, Keller A, Ingebrigtsen T, Reikerås O. Four-year follow-up of surgical versus non-surgical therapy for chronic low back pain. *Ann Rheum Dis*. 2010;69:1643-1648. https://doi.org/10.1136/ard.2009.108902
9. Buchbinder R, van Tulder M, Öberg B, et al. Low back pain: a call for action. *Lancet*. 2018;391:2384-2388. https://doi.org/10.1016/S0140-6736(18)30488-4
10. Chilibeck PD, Vatanparast H, Cornish SM, Abeysekara S, Charlesworth S. Evidence-based risk assessment and recommendations for physical activity: arthritis, osteoporosis, and low back pain. *Appl Physiol Nutr Metab*. 2011;36:49-79. https://doi.org/10.1139/H11-037
11. Cholewicki J, McGill KC, Shah KR, Lee AS. The effects of a three-week use of lumbosacral orthoses on trunk muscle activity and on the muscular response to trunk perturbations. *BMC Musculoskelet Disord*. 2010;11:154. https://doi.org/10.1186/1471-2474-11-154
12. Coenen P, Gouttebarge V, Van Der Burght ASAM, et al. The effect of lifting during work on low back pain: a health impact assessment based on a meta-analysis. *Occup Environ Med*. 2014;71:871-877. https://doi.org/10.1136/OEMED-2014-102346
13. Coenen P, Kingma I, Boot CRL, Twisk JWR, Bongers PM, Van Dieën JH. Cumulative low back load at work as a risk factor of low back pain: a prospective cohort study. *J Occup Rehabil*. 2013;23:11-18. https://doi.org/10.1007/S10926-012-9375-Z
14. Cormack B, Stilwell P, Coninx S, Gibson J. The biopsychosocial model is lost in translation: from misrepresentation to an enactive modernization. *Physiother Theory Pract*. 2022;39:1-16. https://doi.org/10.1080/09593985.2022.2080130
15. Cox LA. Critical Reviews in Toxicology Modernizing the Bradford Hill criteria for assessing causal relationships in observational data Modernizing the Bradford Hill criteria for assessing causal relationships in observational data. 2018;48:682-712. https://doi.org/10.1080/10408444.2018.1518404
16. Demoulin C, Marty M, Genevay S, Vanderthommen M, Mahieu G, Henrotin Y. Effectiveness of preventive back educational interventions for low back pain: a critical review of randomized controlled clinical trials. *Eur Spine J*. 2012;21:2520-2530. https://doi.org/10.1007/s00586-012-2445-2
17. Dreischarf M, Shirazi-Adl A, Arjmand N, Rohlmann A, Schmidt H. Estimation of loads on human lumbar spine: a review of in vivo and computational model studies. *J Biomech*. 2016;49:833-845. https://doi.org/10.1016/j.jbiomech.2015.12.038
18. Engel GL. The clinical application of the biopsychosocial model. *Am J Psychiatry*. 1980;137:535-544. https://doi.org/10.1176/ajp.137.5.535
19. Ferrari R. Writing narrative style literature reviews. *Med Writ*. 2015;24:230-235. https://doi.org/10.1179/2047480615z.000000000329
20. Frandsen TF, Eriksen MB, Hammer DMG, Christensen JB, Wallin JA. Using Embase as a supplement to PubMed in Cochrane

reviews differed across fields. *J Clin Epidemiol.* 2021;133:24-31. https://doi.org/10.1016/J.JCLINEPI.2020.12.022

21. Franke H, Fryer G, Ostelo RWJG, Kamper SJ. Muscle energy technique for non-specific low-back pain. *Cochrane Database Syst Rev.* 2015;CD009852. https://doi.org/10.1002/14651858.CD009852.pub2
22. Gasparyan AY, Ayvazyan L, Blackmore H, Kitas GD. Writing a narrative biomedical review: considerations for authors, peer reviewers, and editors. *Rheumatol Int.* 2011;31:1409-1417. https://doi.org/10.1007/s00296-011-1999-3
23. Gibbs MT, Morrison NMV, Marshall PWM. Biomedical beliefs explain the clinical decisions made by exercise-based practitioners for people with chronic low back pain. *Spine (Phila Pa 1976).* 2021;46:114-121. https://doi.org/10.1097/BRS.0000000000003698
24. Glover J, Izzo D, Odato K, Wang L. *EBM Pyramid and EBM Page Generator*. New Haven, CT: Yale University; 2006.
25. Grant MJ, Booth A. A typology of reviews: an analysis of 14 review types and associated methodologies. *Heal Inf Libr J.* 2009;26:91-108. https://doi.org/10.1111/J.1471-1842.2009.00848.X
26. Harris IA, Sidhu V, Mittal R, Adie S. Surgery for chronic musculoskeletal pain: the question of evidence. *Pain.* 2020;161:S95-S103. https://doi.org/10.1097/j.pain.0000000000001881
27. Harris-Adamson C, Lam E, Fathallah F, Tong AD, Hill S, Smith A. The ergonomic impact of a mattress lift tool and bottom sheet type on hotel room cleaners while making beds. *Appl Ergon.* 2019;81:102880. https://doi.org/10.1016/j.apergo.2019.102880
28. Hartvigsen J, Bakketeig LS, Leboeuf-Yde C, Engberg M, Lauritzen T. The association between physical workload and low back pain clouded by the "healthy worker" effect: population-based cross-sectional and 5-year prospective questionnaire study. *Spine (Phila Pa 1976).* 2001;26:1788-1792. https://doi.org/10.1097/00007632-200108150-00011
29. Hartvigsen J, Hancock M, Kongsted A, et al. What low back pain is and why we need to pay attention. *Lancet (London, England).* 2018;391:2356-2367. https://doi.org/10.1016/S0140-6736(18)30480-X
30. Hasegawa T, Katsuhira J, Oka H, Fujii T, Matsudaira K. Association of low back load with low back pain during static standing. *PLOS ONE.* 2018;13:1-12. https://doi.org/10.1371/journal.pone.0208877
31. Hayden JA, Wilson MN, Stewart S, et al. Exercise treatment effect modifiers in persistent low back pain: an individual participant data meta-analysis of 3514 participants from 27 randomised controlled trials. *Br J Sports Med.* 2020;54:1277-1278. https://doi.org/10.1136/bjsports-2019-101205
32. Hoegh M. Pain Science in Practice (Part 3): peripheral sensitization. *J Orthop Sports Phys Ther.* 2022;52:303-306. https://doi.org/10.2519/jospt.2022.11202
33. Hoegh M, Gulseren B, Duygu. Work is therapy, not a goal in itself, for people with chronic pain. *Pain Rehabil.* 2023;23:3-6. https://www.ingentaconnect.com/content/ppa/pr/2023/00002023/00000053/art00002
34. Hoegh M, Stanton T, George S, Lyng KD, Vistrup S, Rathleff MS. Infographic. Pain or injury? Why differentiation matters in exercise and sports medicine. *Br J Sports Med.* 2021;bjsports-2021-104633. https://doi.org/10.1136/bjsports-2021-104633
35. Hulshof CTJ, Pega F, Neupane S, et al. The prevalence of occupational exposure to ergonomic risk factors: a systematic review and meta-analysis from the WHO/ILO Joint Estimates of the Work-related Burden of Disease and Injury. *Environ Int.* 2021;146:106157. https://doi.org/10.1016/J.ENVINT.2020.106157
36. Jaffar NAT, Rahman MNA. Review on risk factors related to lower back disorders at workplace. *IOP Conf Ser Mater Sci Eng.* 2017;226:012035. https://doi.org/10.1088/1757-899X/226/1/012035
37. Jansen JP, Morgenstern H, Burdorf A. Dose-response relations between occupational exposures to physical and psychosocial factors and the risk of low back pain. *Occup Environ Med.* 2004;61:972-979. https://doi.org/10.1136/OEM.2003.012245
38. Kent P, Haines T, O'Sullivan P, et al. Cognitive functional therapy with or without movement sensor biofeedback versus usual care for chronic, disabling low back pain (RESTORE): a randomised, controlled, three-arm, parallel group, phase 3, clinical trial. *Lancet (London, England).* 2023;401:1866-1877. https://doi.org/10.1016/S0140-6736(23)00441-5
39. Knezevic NN, Candido KD, Vlaeyen JWS, Van Zundert J, Cohen SP. Low back pain. *Lancet.* 2021;398:78-92. https://doi.org/10.1016/S0140-6736(21)00733-9
40. Kosek E, Clauw D, Nijs J, et al. Chronic nociplastic pain affecting the musculoskeletal system: clinical criteria and grading system. *Pain.* 2021;162:2629-2634. https://doi.org/10.1097/J.PAIN.0000000000002324
41. Lambeek LC, Van Tulder MW, Swinkels ICS, Koppes LLJ, Anema JR, Van Mechelen W. The trend in total cost of back pain in The Netherlands in the period 2002 to 2007. *Spine (Phila Pa 1976).* 2011;36:1050-1058. https://doi.org/10.1097/BRS.0b013e3181e70488
42. Macedo LG, Smeets RJEM, Maher CG, Latimer J, McAuley JH. Graded activity and graded exposure for persistent nonspecific low back pain: a systematic review. *Phys Ther.* 2010;90:860-879. https://doi.org/10.2522/ptj.20090303
43. Mannion AF, Brox JI, Fairbank JCT. Comparison of spinal fusion and nonoperative treatment in patients with chronic low back pain: long-term follow-up of three randomized controlled trials. *Spine J.* 2013;13:1438-1448. https://doi.org/10.1016/j.spinee.2013.06.101
44. Marras WS, Walter BA, Purmessur D, Mageswaran P, Wiet MG. The contribution of biomechanical-biological interactions of the spine to low back pain. *Hum Factors.* 2016;58:965-975. https://doi.org/10.1177/0018720816657235
45. McCabe E, Jadaan D, Munigangaiah S, Basavaraju N, McCabe JP. Do medical students believe the back pain myths? A cross-sectional study. *BMC Med Educ.* 2019;19:1-6. https://doi.org/10.1186/S12909-019-1676x
46. Meucci RD, Fassa AG, Xavier Faria NM. Prevalence of chronic low back pain: systematic review. *Rev Saude Publica.* 2015;49:1-10. https://doi.org/10.1590/S0034-8910.2015049005874
47. Morabia A. On the origin of Hill's causal criteria. *Epidemiology.* 1991;2:367-369. https://doi.org/10.1097/00001648-199109000-00010
48. Oesch P, Kool J, Hagen KB, Bachmann S. Effectiveness of exercise on work disability in patients with non-acute non-specific low back pain: systematic review and meta-analysis of randomized controlled trials. *J Rehabil Med.* 2010;42:193-205. https://doi.org/10.2340/16501977-0524
49. Parreira P, Heymans MW, van Tulder MW, et al. Back schools for chronic non-specific low back pain. *Cochrane Database Syst Rev.* 2017;8:CD011674. https://doi.org/10.1002/14651858.CD011674.pub2
50. Patel AS, Farquharson R, Carroll D, et al. The impact and burden of chronic pain in the workplace: a qualitative systematic review. *Pain Pract.* 2012;12:578-589. https://doi.org/10.1111/j.1533-2500.2012.00547.x
51. Pathak S, Conermann T. *Lumbosacral Discogenic Syndrome*. In: StatPearls Publishing; 2020. https://www.ncbi.nlm.nih.gov/books/NBK560537/. Accessed May 29, 2021
52. Prego-Domínguez J, Khazaeipour Z, Mallah N, Takkouche B. Socioeconomic status and occurrence of chronic pain: a meta-analysis. *Rheumatology.* 2020;60:1091-1105. https://doi.org/10.1093/rheumatology/keaa758
53. Ricci JA, Stewart WF, Chee E, Leotta C, Foley K, Hochberg MC. Back pain exacerbations and lost productive time costs in United States workers. *Spine (Phila Pa 1976).* 2006;31:3052-3060. https://doi.org/10.1097/01.brs.0000249521.61813.aa
54. Riihimaki H. Low-back pain, its origin and risk indicators. *Scand J Work Environ Heal.* 1991;17:81-90. https://doi.org/10.5271/sjweh.1728
55. Salvetti MDG, Pimenta CADM, Braga PE, Corrêa CF. Disability related to chronic low back pain: prevalence ABD associated factors. *Rev da Esc Enferm.* 2012;46:16-23. https://doi.org/10.1590/S0080-62342012000700003
56. Saraceni N, Kent P, Ng L, Campbell A, Straker L, O'Sullivan P. To flex or not to flex? Is there a relationship between lumbar spine flexion during lifting and low back pain? A systematic review with meta-analysis. *J Orthop Sports Phys Ther.* 2020;50:121-130. https://doi.org/10.2519/jospt.2020.9218
57. Saragiotto BT, Maher CG, Yamato TP, et al. Motor control exercise for chronic non-specific low-back pain. *Cochrane Database*

Syst Rev. 2016;1037-1038. https://doi.org/10.1002/14651858.CD012004
58. Schünemann H, Hill S, Guyatt G, Akl EA, Ahmed F. The GRADE approach and Bradford Hill's criteria for causation. *J Epidemiol Community Health.* 2011;65:392-395. https://doi.org/10.1136/jech.2010.119933
59. Shahvarpour A, Shirazi-Adl A, Mecheri H, Larivière C. Trunk response to sudden forward perturbations - effects of preload and sudden load magnitudes, posture and abdominal antagonistic activation. *J Electromyogr Kinesiol.* 2014;24:394-403. https://doi.org/10.1016/j.jelekin.2014.03.007
60. Shimonovich M, Pearce A, Thomson H, Keyes K, Katikireddi SV. Assessing causality in epidemiology: revisiting Bradford Hill to incorporate developments in causal thinking. *Eur J Epidemiol.* 2021;36:873-887. https://doi.org/10.1007/S10654-020-00703-7
61. Smith BE, Littlewood C, May S. An update of stabilisation exercises for low back pain: a systematic review with meta-analysis. *BMC Musculoskelet Disord.* 2014;15:416. https://doi.org/10.1186/1471-2474-15-416
62. Stevans JM, Delitto A, Khoja SS, et al. Risk factors associated with transition from acute to chronic low back pain in US patients seeking primary care. *JAMA Netw Open.* 2021;4:e2037371. https://doi.org/10.1001/jamanetworkopen.2020.37371
63. Suman A, Armijo-Olivo S, Deshpande S, et al. A systematic review of the effectiveness of mass media campaigns for the management of low back pain. *Disabil Rehabil.* 2021;43:3523-3551. https://doi.org/10.1080/09638288.2020.1743777
64. Swain CTV, Pan F, Owen PJ, Schmidt H, Belavy DL. No consensus on causality of spine postures or physical exposure and low back pain: a systematic review of systematic reviews. *J Biomech.* 2020;102:109312. https://doi.org/10.1016/j.jbiomech.2019.08.006
65. Thygesen LC, Andersen GS, Andersen H. A philosophical analysis of the Hill criteria. *J Epidemiol Community Health.* 2005;59:512. https://doi.org/10.1136/jech.2004.027524
66. Urban JPG, Fairbank JCT. Current perspectives on the role of biomechanical loading and genetics in development of disc degeneration and low back pain; a narrative review. *J Biomech.* 2020;102:109573. https://doi.org/10.1016/j.jbiomech.2019.109573
67. Van Der Giessen RN, Speksnijder CM, Helders PJM. The effectiveness of graded activity in patients with non-specific low-back pain: a systematic review. *Disabil Rehabil.* 2012;34:1070-1076. https://doi.org/10.3109/09638288.2011.631682
68. Van Middelkoop M, Rubinstein SM, Verhagen AP, Ostelo RW, Koes BW, van Tulder MW. Exercise therapy for chronic nonspecific low-back pain. *Best Pract Res Clin Rheumatol.* 2010;24:193-204. https://doi.org/10.1016/j.berh.2010.01.002
69. Van Oostrom SH, Verschuren M, De Vet HCW, Boshuizen HC, Picavet HSJ. Longitudinal associations between physical load and chronic low back pain in the general population: the Doetinchem Cohort Study. *Spine (Phila Pa 1976).* 2012;37:788-796. https://doi.org/10.1097/BRS.0B013E31823239D1
70. Van Reekum R, Streiner DL, Conn DK. Applying Bradford Hill's criteria for causation to neuropsychiatry: challenges and opportunities. *J Neuropsychiatry Clin Neurosci.* 2001;13:318-325. https://doi.org/10.1176/jnp.13.3.318
71. Wade DT, Halligan PW. The biopsychosocial model of illness: a model whose time has come. *Clin Rehabil.* 2017;31:995-1004. https://doi.org/10.1177/0269215517709890
72. Wai EK, Roffey DM, Bishop P, Kwon BK, Dagenais S. Causal assessment of occupational carrying and low back pain: results of a systematic review. *Spine J.* 2010;10:628-638. https://doi.org/10.1016/j.spinee.2010.03.027
73. Wai EK, Roffey DM, Bishop P, Kwon BK, Dagenais S. Causal assessment of occupational lifting and low back pain: results of a systematic review. *Spine J.* 2010;10:554-566. https://doi.org/10.1016/j.spinee.2010.03.033
74. Walsh K, Varnes N, Osmond C, Styles R, Coggon D. Occupational causes of low-back pain. *Scand J Work Environ Heal.* 1989;15:54-59. https://doi.org/10.5271/sjweh.1891
75. Waters T, Putz-Anderson V, Garg A, Fine L. Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics.* 1993;36:749-776.
76. Wegner I, Widyahening IS, van Tulder MW, et al. Traction for low-back pain with or without sciatica. *Cochrane Database Syst Rev.* 2013;2013:CD003010. https://doi.org/10.1002/14651858.CD003010.pub5