Pain and Pain-Related Disability Associated With Proprioceptive Impairment in Chronic Low Back Pain Patients: A Systematic Review

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ABSTRACT

Objective: The purpose of this study was to systematically review the evidence on the correlation between lumbar proprioception and clinical low back pain (LBP) characteristics.
Methods: The literature was investigated through a systematic review. Six electronic databases (EMBASE, Scopus, Elsevier, PubMed, ProQuest, and Google Scholar) and reference lists of the relevant articles were searched from inception until December 2017. Studies that investigated the correlation between lumbar proprioception and pain and disability in patients with chronic nonspecific LBP were included in the analytical review.
Results: Five studies (204 patients) were included. Lumbar proprioception was measured via active or passive joint repositioning error or threshold to detection of passive motion. Four of the studies were rated as medium and only 1 as high quality. Four studies had investigated the correlation between proprioception and functional disability scores, all of which found them to be weakly correlated. Although no significant correlation was reported between pain and joint repositioning error (measured in all included studies), one had reported a fair to moderate correlation between pain and threshold to detection of passive motion.
Conclusion: Current literature shows that although LBP pain-related disability is poorly to moderately correlated with proprioceptive functioning, the relationship between pain intensity and proprioception seems to be more complex. (J Manipulative Physiol Ther 2019;42:210-217)

Key Indexing Terms: *Low Back Pain; Proprioception; Review*

INTRODUCTION

Low back pain (LBP) is considered one of the major disabling musculoskeletal problems worldwide.[1] More than one-fourth of LBP cases do not resolve and become chronic.[1] No diagnosed pathoanatomical cause can be attributed to almost 80% of all chronic LBP cases, which will be recognized as chronic nonspecific LBP (CNSLBP).[2]

Various factors including but not limited to longer muscle reflex latencies,[3] alterations in postural control[4,5] and muscle recruitment patterns[6,7] have been associated with CNSLBP. Proprioception impairment has been suggested as a possible mechanism for these alterations, consequently leading to chronic spinal conditions.[8,9] Lumbar proprioception impairment is suggested to alter movement control and accuracy, timing of motor commands, spinal posture, and muscle activity, and subsequently compromise spinal stability and aggravate spinal loading.[10,11] Despite the huge body of literature emphasizing the relevance of proprioception to CNSLBP, the scientific evidence is controversial.[8] Different testing positions (standing or sitting), procedures (active or passive repositioning), planes (sagittal, frontal, or horizontal), targets (neutral or a point out of neutral position), and maybe most importantly, the validity of the outcome measures might be regarded as sources of the inconsistency.[8] Interference of factors such as skin receptor activation, muscle thixotropy, and vestibular afferent alterations during the tests and the contribution of proprioception provided from regions other than the lumbar spine raise questions about the validity of these methods to measure lumbar proprioception.[12]

Although some studies have shown pain and disability reduction after proprioceptive exercises in CNSLBP patients,[13,14] it is not clear to what extent and by which

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mechanisms proprioceptive enhancement might lead to clinical improvement. It is still a matter of debate if these exercises indeed improve proprioception or mechanisms other than proprioception enhancement are involved.[15] The only study that investigated the association between the magnitude of proprioceptive improvement and pain and disability reduction failed to find any significant correlation.[16] Such findings might explain why proprioceptive training still has not been recommended for the management of nonspecific low back pain (NSLBP) by European Guidelines.[17]

Tong et al conducted a systematic review to compare proprioceptive functioning of patients with chronic LBP and in LBP-free participants and failed to find a consistent difference between the 2 groups.[8] There are studies reporting no or weak correlations between proprioception and pain intensity or pain-related disability in chronic spinal pain conditions.[9,18-20]

To predict how helpful implementing proprioceptive training would be in the management of CNSLBP symptoms, it is first necessary to establish a clear picture of the association between these factors. Such an investigation might also shed light on the underlying mechanisms by which between-groups comparisons have resulted in such controversial findings.

Therefore, the aim of this study was to determine if proprioceptive functioning and CNSLBP clinical characteristics (pain intensity or pain-related disability) are correlated by systematically reviewing the literature. The specific questions of the current review were as follows: (1) is there any correlation between impaired lumbar proprioception and clinical CNSLBP characteristics? and (2) which clinical characteristics, if any, are more strongly correlated with proprioception?

Methods

This review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement guidelines.[21] The protocol was not registered before study performance, which might be a limitation of the review.

Data Source and Search Strategy

EMBASE, Scopus, ELSEVIER, PubMed, ProQuest, and Google Scholar databases were searched for the keywords from inception until December 2017. The reference lists of the relevant studies were then checked in an attempt to find any extra studies not found during the primary search. The keywords used were "low back pain" OR "back pain" OR "lower back pain" OR "lumbar pain" OR "LBP" OR "spine pain" OR "low backache" OR "backache" AND "proprioception" OR "movement sense" OR "motion sense" OR "movement perception" OR "kinesthesia" OR "force perception" OR " movement threshold" OR "motion threshold" OR "repositioning" OR "position sense" OR "error."

Inclusion Criteria

The papers were included if they met the following criteria: (1) recruiting patients with CNSLBP (with more than 3 months' pain duration) and (2) assessing the correlation between proprioception and pain intensity or pain-related disability. Studies including LBP with specific pathoanatomic diagnoses like radiculopathy, spinal fracture, spondylolisthesis, or discopathies and theses and case reports were excluded. We also excluded studies not using sound proprioception measurements that heavily depended on sensory afferents other than lumbar proprioception or motor functions.[22] We put no limitation on language.

Study Selection

The search results were screened by the titles and abstracts of the articles and if not sufficiently informative, the entire article was checked. There is evidence on compensation of lumbar proprioception deficit through sensory reweighting of other regions by the central nervous system in the presence of LBP.[23] It may thus be concluded that, to have a valid picture of the proprioceptive functioning of the lumbar spine, other regions should not be involved in the tests. Hence, we excluded studies in which regions other than the lumbar spine contributed to the proprioception tests.

Data Extraction

The categories of extracted data were study type, year of publication, type of LBP, number and sex of participants, test protocol, outcome measures (pain intensity, disability scores, and proprioception), and the correlation among them.

Quality Assessment

All included studies were assessed using a quality assessment checklist with 15 criteria. This checklist includes relevant criteria for cross-sectional studies obtained from the National Institute for Health and Care Excellence,[24] National Institutes of Health,[25] Hailey's criteria,[26] and Critical Appraisal Skills Programme system for case-control studies (Public Health Resource Unit).[27] We rated studies successfully fulfilling less than 50% of the criteria as low quality, 50% to 75% as moderate, and more than 75% as high quality.

The methodological evaluation of the included studies in this review was based on the correlation between proprioception and clinical LBP characteristics. Because in most of the included studies this correlation was not the primary outcome, the quality ratings attributed to the articles are not expandable to the whole study but only to their subsection concerning this correlation.

The "outcome measures description" item was scored based on the description of the measurement tools, positional condition, starting and target positions of the test, number of measurement and practice trials, and formulation of the

Table 1. *Quality Assessment of the Included Studies*

Quality Assessment Item	Hu et al[19]	O'Sullivan et al[28]	Georgy et al[20]	Taimela et al[29]	Kim et al[27]
Clear statement of the research objective or question	Yes	Yes	Yes	Yes	Yes
Use of an appropriate method to answer research question	Yes	Yes	Yes	Yes	Yes
Clear specification of the study population	Yes	Yes	Yes	Yes	Yes
Prespecification of the inclusion and exclusion criteria and their uniform application to all participants	Yes	Yes	Yes	No	Yes
Sample size and its justification rationale	Yes	No	No	Yes	Yes
Outcome measures description	NR	NR	Yes	Yes	No
Reliability assessment of the measurements	NR	No	Yes	Yes	NR
Assessors' and analyzers' blindness	NR	No	Yes	NR	Yes
Confounding factors control	Yes	Yes	Yes	Yes	No
Proper use of statistical tests	Yes	Yes	Yes	Yes	Yes
Missing results	Yes	Yes	Yes	Yes	Yes
Thorough and clear reporting of the results	Yes	Yes	Yes	Yes	Yes
Precision of the results	No	No	No	No	No
Statistical summary	Yes	Yes	No	No	No
Consistency of the conclusions and the presented data	Yes	Yes	Yes	No	No
Total score	11	10	12	10	9

NR, not reported.

outcomes. The "precision of the results" item was judged by the magnitude of *P* values, coefficients of correlations, and confidence intervals width. Whenever several factors contributed to an item, the rating would be performed based on a weighted average of all included factors. If most factors were adequately considered and no important factor was ignored, a positive score would be devoted to that item. The checklist is presented in Table 1. Among different sources of bias, selection and detection bias items were applicable for the included studies,[28] all of which were free from these bias items.

The 2 authors independently performed the above 4 review sections (checking the inclusion criteria, study selection, data extraction, and quality assessment); disparities were resolved by discussion, and a final decision was reached through consensus.

Results

Study Selection

After removing duplicates, the electronic databases search provided a total of 249 studies. One additional study was identified through hand-searching a reference list of relevant studies. These 250 articles were further explored through screening titles and abstracts or going through the full texts to check for the compatibility with the inclusion criteria. A total of 234 papers were disregarded for not having conducted any correlational analysis. Of the remaining 16 studies, 11 more were excluded by subsequent evaluation: 1 case report study and 4 theses, 3 including a mixture of specific and nonspecific LBP patients and 3 more with methodological problems. Proprioception measurement tests had involved regions other than the lumbar spine in 2 studies; another study had applied a test (trunk laterality) heavily dependent on the visual system performance.) Finally, 5 studies (4 observational and 1 interventional) met the inclusion criteria and were included in the quality assessment[19,20,29-31] (Fig 1).

Study Characteristics

The 5 included studies were published between 1999 and 2017, all in English. All studies had investigated the association between proprioceptive impairment and both pain intensity and pain-related disability, except 1 that contained the relationship between proprioception deficit and pain intensity only.[29] The relevant studies defined

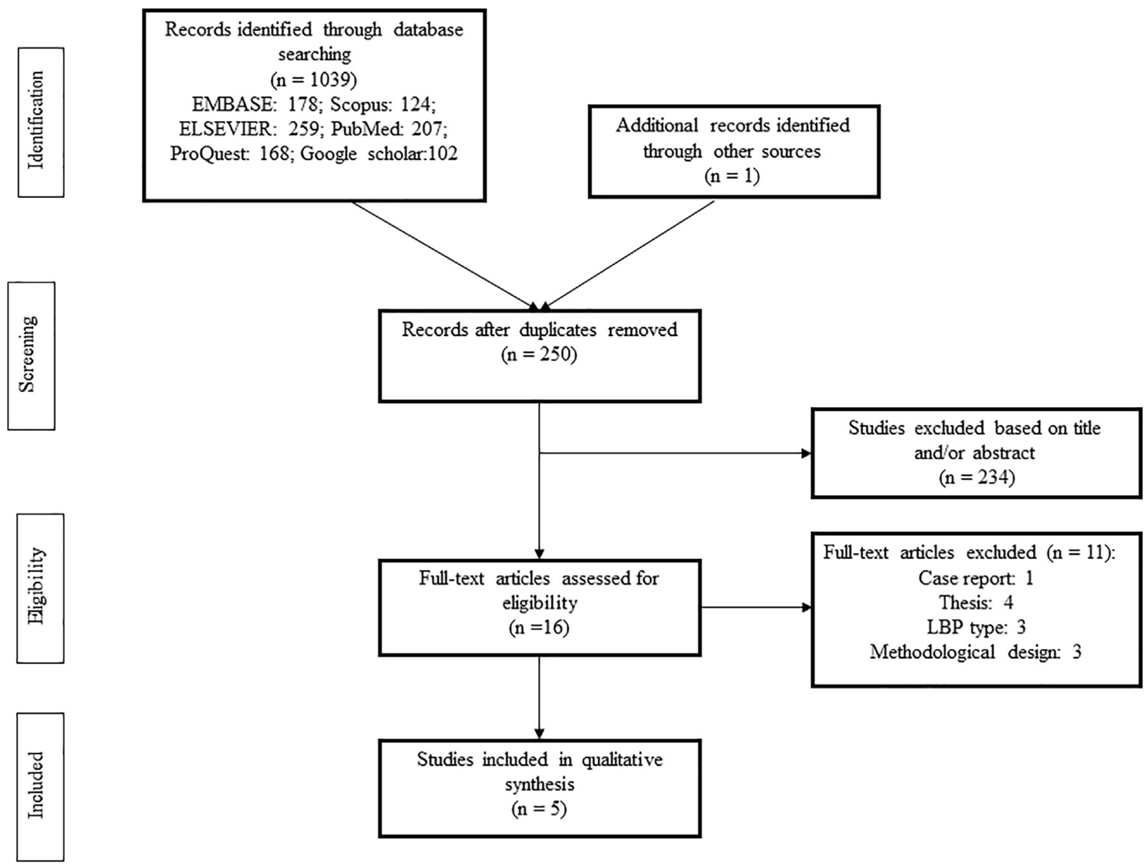

Fig 1. *Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart of study retrieval, screening, and eligibility.* LBP, *low back pain.*

NSLBP as lumbar pain without a specific established anatomical or neurological cause. Overall, 204 patients with CNSLBP were recruited into these studies, the sample size of each ranging from 15[20,30] to 90.[19] In all studies except 1 including women only,[29] both sexes were included. Pain intensity ranged from 3.3 cm to 6.3 cm on a 0-10 scale. The LBP-related disability was measured by Oswestry Disability Index (ranging from 14.1%[30] to 28.2%[20]) and Roland Morris Disability Questionnaire (score of 24 equivalent to 40.8%)[19] and was not measured in 1 study.[29] Low back pain patients with flexion pattern of movement control impairment (according to O'Sullivan's classification) were included in 1 study.[30] Further details are presented in Table 2.

Testing Task Procedure

Proprioception assessment was performed through the joint repositioning error (JRE) in 4 studies[19,20,29,30] and threshold to detection of passive motion (TTDPM) tests in 1 study.[31] The JRE test measures how accurately a participant can actively or passively reproduce a "target position." Three common JRE parameters are (1) absolute error (AE), which is the unsigned difference between the target and the reproduced position, indicative of repositioning accuracy; (2) constant error, defined as repositioning bias, which shows the overshoot or undershoot repositioning error; and (3) variable error, indicating variability error and calculated from constant error scores.[8] Three of the included studies had assessed active JRE,[20,29,30] whereas passive JRE was assessed in only 1.[19] The testing condition in 1 paper was standing,[19] in 3 papers sitting,[20,30,31] and in 1 study not reported.[29] Target positions were set in flexion, extension, and lateral flexion from the neutral lumbar spine posture. In all studies[19,20,29,30] the number of measurement trials was 3 and the average measures were used for analysis. One to 3 practice trials without feedback were performed before starting the main tests.

The TTDPM test measures sensitivity to detection of passive lumbar spine movement at a constant velocity and indicates the earliest point the participant senses any positional change.[8] Only 1 study had used TTDPM to assess proprioception[31] in which the number of measurement trials was 5, without mentioning the number of practice trials. Further details about testing task procedures are reported in Table 1.

Studies Scoring

The quality assessment of the 5 studies found 4 of them rated as moderate (ranging from 60% to 73%)[19,29-31] and 1

Table 2. *The Description of the Included Studies and the Findings of Each on the Correlation Between Proprioception With Pain Intensity and Disability*

Author (y) Design	Participants	Outcome Measures	Measurement Instrument	Test Procedure	Results of the Correlation Analysis
Hu, et al[19] Cross-sectional	NSLBP (N = 90, f = 32) Age: 21.80 ± 3.85 y Pain course ≥ 3 mo Pain intensity: 4.27 ± 1.14 cm Disability score: 9.80 ± 3.19	Repositioning accuracy Pain intensity Disability	Isokinetic (CON-TREX) VAS RMDQ	Standing in neutral lumbopelvic spinal position Passive flexion/extension degree?	RMDQ and AE in flexion (r = 0.32, $P < .01$) RMDQ and AE in extension (r = 0.22, $P = .03$) VAS and AE in flexion (r = 0.27, $P = .01$) No correlation was found between VAS and AE in extension (r = 0.18, $P = .07$).
O'Sullivan, et al[28] Cross-sectional	NSLBP (N = 15, f = 5): Age: 31.3 ± 10.3 y FP movement control impairment Pain course ≥3 mo Pain intensity: 3.3 ± 1.90 cm Disability score: 14.1 ± 7.80%	Repositioning accuracy Repositioning bias Variability error Pain intensity Disability	Strain gage posture monitor (body guard) NRS pain ODI	Sitting in neutral lumbopelvic spinal position Active slumped position (percentage of ?% full ROM)	ODI and AE (r = 0.60, $P = .02$). No correlation was found between ODI and CE (r = -0.28, $P = .32$) or VE ($r_s = -0.12$, $P = .65$). No correlation was found between VAS and AE (r = 0.17, $P = .55$), CE (-0.11, $P = .69$) and VE ($r_s = -0.32$, $P = .24$).
Georgy, et al[20] Cross-sectional	NSLBP (N = 15, f = ?) Age: 40.10 ± 6.1 y Pain course >3 mo Pain intensity: 6.30 ± 8.20 cm Disability score: 28.20 ± 6.50%	Repositioning accuracy Pain intensity Disability	Isokinetic dynamometer VAS ODI	Sitting in neutral lumbopelvic spinal position Active flexion 30°	No correlation was found between VAS and AE (r = -0.04, $P = ?$). ODI and AE (r = 0.52, $P < .05$)
Taimela, et al[29] Cross-sectional	NSLBP (N = 57, f = 30) Age: m: 41.0 ± 7.7; f: 41.7 ± 7 y Pain course >3 mo Pain intensity: m: 52 ± 19, f: 61 ± 23 mm Disability score: m: 21 ± 9, f: 26 ± 16%	TTDPM Pain intensity Disability	Custom measurement device VAS ODI	Sitting in a neutral position Passive rotation with an angular velocity of 1°/s	VAS (r = 0.30, $P < .05$), ODI (r = 0.46, $P < .05$), and TTDPM before fatigue VAS (r = 0.25, $P < .05$), ODI (r = 0.44, $P < .05$), and TTDPM after fatigue
Kim, et al[27] Experimental	NSLBP (N = 53, f = 53) Age: 29.70 ± 3.90 y Pain course >3 mo Pain intensity: 56.10 ± 7.90 mm Disability score: not measured	Repositioning accuracy Pain intensity	Dualer Plus VAS	Starting position? Active flexion 20°/ extension 10°	VAS during movement and AE in flexion (r = 0.83, $P < .01$) VAS during movement and AE in extension (r = 0.67, $P < .01$)

AE, absolute error; *CE*, constant error; *f*, female; *FP*, flexion pattern; *m*, male; *NRS*, numeric rating scale; *NSLBP*, nonspecific low back pain; *ODI*, Oswestry Disability Index; *r*, Pearson correlation coefficient; r_s, Spearmen correlation coefficient; *RMDQ*, Roland Morris Disability Questionnaire; *ROM*, range of motion; *TTDPM*, threshold to detection of passive motion; *VAS*, visual analog score; *VE*, variable error. Scores are presented as mean ± standard deviation. A question mark (?) indicates that the item has not been defined in the paper.

(80%) as high quality.[20] Neither blinding of the assessors (excepting Kim et al[29]) or analyzers nor the measurement reliability characteristics (excepting Taimela et al[31]) were reported in any of the studies. The corresponding authors were contacted to check for these items. Only 2 authors answered,[20,30] and it was found that both items had been observed in only 1 of them.[20] The *P* values were not mentioned in 1 study.[20] In 2 of the studies, the target position of the lumbar spine to be reproduced during the JRE test was not well defined,[19,30] and the "outcome measures definition" item could not thus be adequately observed. Two of the studies did not rationalize their sample sizes, both of which included less than 30 participants in each group.[20,30] To test the correlation between factors, all included studies used Pearson or Spearman coefficients for normally and non-normally distributed variables, respectively, and they were all scored high on "proper use of statistical tests" item.

Correlation Between LBP Clinical Characteristics and Proprioception Impairment

Overall, in patients with CNSLBP, pain-related disability was significantly positively correlated with flexion and extension AE, the correlation coefficients of which ranged from 0.22 to 0.60, indicative of poor to moderate relationships.[32] There was no correlation between pain intensity and AE in any movement directions. Kim et al had reported a statistically significant positive moderate to good correlation between visual analog scale and flexion and extension AE after exercise therapy; however, the correlation between the 2 variables was not reported before the intervention.[29] Taimela et al reported TTDPM to have a significant, positive, and moderate correlation with pain intensity and disability both before and after fatigued conditions.[31]

Discussion

This systematic review aimed to critically appraise the available evidence for the correlation between impaired proprioception and clinical LBP characteristics. Although the limited evidence agrees on a fair to moderate correlation between proprioception impairment and pain-related disability, there is no consensus on such a relationship between proprioception and pain.

Disability and Proprioception

Optimal postural control is achieved by motor decisions via central processing of inputs from the proprioceptive, vestibular, and visual systems.[33] Proprioception impairment has been attributed as a possible mechanism for the poor postural control of patients with CNSLBP[4,34] by adversely affecting movement control and recruitment timing of motor commands.[10] Decreased sensory feedback has been proposed to be responsible for the assumption of poor postures by desensitizing the CNS against deviations from neutral posture.[35] This may put the muscles in poor mechanical advantage and limit their protective role for the spine.[8] These alterations might predispose participants to pain and injury via microtraumas during postures and activities of daily living,[36] subsequently leading to long-term functional disability.

Pain and Proprioception

Motor control and planning involves prioritization among abundant factors the CNS encounters as the internal and environmental constraints.[37] The pain interference model suggests that, in the presence of pain or fear of pain, the CNS chooses to suppress the motor activity in the pain-related region as a protective mechanism.[38] In other words, this model claims that the choice of the motor control system in the presence of pain is to limit muscular activation to protect the painful area. However, in most of the recent studies, impaired proprioception could not be explained by pain.[9,18,30] Most of the included studies in the current systematic review also failed to show any correlation between the 2 factors.[19,20,30] The complex, multifactorial, and subjective nature of pain perception might have affected this relationship, and thus it is not easy to rule out the relevance of proprioception to pain. Lack of considerable correlation between pain intensity and proprioceptive functioning, however, might call into question the interference of pain with proprioceptive afferents. The only 2 studies showing significant correlations between pain and proprioception had remarkable differences with the others: Taimela et al had assessed proprioception using TTDPM[31] and not JRE, and Kim et al had assessed this correlation immediately post-physical treatments addressing LBP,[29] not at baseline. Such discrepancies prevent direct comparison of the results of the included studies. It might be indicative that the outcome measure representing proprioception and the state at which patients are evaluated have a significant impact on the results. The JRE test includes memory and motor skills besides sensory components[39] which reduces its validity to characterize proprioception as a sensation. The TTDPM has an advantage over JRE in that no memory or motor capabilities interfere with its results.[8] The other difference between the 2 tests is that although JRE predominantly relies on position feedback, TTDPM primarily responses to velocity feedback.[8] These differences might partly explain that although TTDPM scores are more likely to detect alterations of proprioception in LBP,[40,41] and unlike JRE scores, they were found to be correlated with pain intensity.

Study Strengths, Limitations, and Recommendations for Future Research

Only 5 studies matched our inclusion criteria and were analyzed for their design and performance quality. This indicates that too few studies have already investigated the correlation between impaired proprioception and clinical LBP characteristics in CNSLBP. We excluded studies with mixed types of LBP because it is preferable to include a homogeneous population in systematic reviews.[28] However, the remaining articles were still not homogenous enough for their data to be pooled and performance of a meta-analysis. The search strategy was not limited by language so that any relevant findings were not missed.

Overall, the methodological quality of the studies was moderate[19,29-31] to high.[20] Many criteria regarding the internal validity of the included studies were not fulfilled. Although the LBP patients' characteristics were almost consistently well described in all included studies and they all had made proper use of statistical analyses, assessor and analyzer blinding, reliability assessment, confidence interval reporting, and rationalizing the sample size constitute the major methodological shortcomings of the studies.

The few number of studies conducted on this clinically important issue warrants further investigation, especially clinical trials examining the effect of therapeutic interventions on the proprioception improvement and its correlation with clinical LBP characteristic recovery.

Conclusion

The findings of the current systematic review indicate that although proprioceptive functioning and pain-related disability seem to be associated, the relationship between pain intensity and proprioceptive deficits may be more complex. This might be related to the complex and subjective nature of pain perception. More studies investigating the association between proprioception and clinical LBP characteristics are needed before firm conclusions may be made.

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Contributorship Information

Concept development (provided idea for the research): A.H.K.
Design (planned the methods to generate the results): A.H.K., L.Gh.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): A.H.K.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): L.Gh.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): A.H.K., L.Gh.
Literature search (performed the literature search): L.Gh.
Writing (responsible for writing a substantive part of the manuscript): A.H.K., L.Gh.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): A.H.K.

Practical Applications

- Although proprioceptive functioning and pain-related disability seem to be associated, the relationship between pain intensity and proprioceptive deficits seems to be more complex.
- This might be related to the complex and subjective nature of pain perception.
- More studies investigating the association between proprioception and clinical LBP characteristics are needed before firm conclusions may be made.

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