Lumbar joint position sense measurement of patients with low back pain

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• Lumbar position sense can be assessed by measurement instruments including the goniometer, isokinetic dynamometry, and electronic motion monitoring equipment, which have demonstrated relatively high reliability.
• This literature provides a comprehensive overview of influencing factors of lumbar position sense measurement, including repositioning method, fatigue degree, and posture during the reposition. It highlights the significant role of muscle proprioception, which contributes to greater accuracy in active reposition compared to passive reposition.
• The differences in lumbar position sense with different measurement positions may be explained by the presence of mechanoreceptors in the load-bearing structures of the lumbar spine, especially in the facet joint capsules. These mechanoreceptors play a crucial role in providing sensory feedback and proprioceptive information pertaining to the position and movement of the lumbar spine.
• Individuals with low back pain (LBP) demonstrate alterations in lumbar position sense compared to those without LBP. The auto motor sensory feedback transmission mechanism of patients with non-specific LBP was more unstable than that of healthy people. These findings suggest that lumbar position sense may play a potential role in the development and perpetuation of LBP.
• At present, the commonly used clinical assessment methods for determining position sense include both active and passive repositioning. However, neither method exhibits high sensitivity and specificity, leading to the poor comparability of relevant studies and posing challenges for clinical application.

Introduction

Low back pain (LBP) is a common condition experienced by adults of all ages. Epidemiological studies indicate that 50–80% of individuals experience LBP at least once during their lifetime (1). Non-specific LBP (NLBP), the most prevalent form of LBP, does not have a specific identifiable pathological cause (2). The consequences of NLBP go beyond pain and limited movement. NLBP can also affect the proprioception of the lumbar spine, and the degeneration of proprioception can aggravate the symptoms of the patients (3). The main inducing factors of NLBP are decreased lumbar stability and muscle strength, and poor spinal stability and posture control is an important pathological mechanism of recurrent symptoms in patients with NLBP (4, 5). Patients with NLBP have reduced lumbosacral tactile and proprioceptive acuity, and sensory and motor deficits further affect the postural cognitive interaction in patients with NLBP, resulting in postural control defects (6).

Proprioceptive senses contain the senses of body position, movement, vibration, and force. These senses can be measured separately in clinical examination (7). Joint position sense, which is one part of proprioception, is evaluated by the ability to reposition after body shifting. This sense often manifests as a consistent repositioning error, which represents the calibration deviation of the proprioceptive mechanism (8). The decrease or absence of position sense in the low back spine is closely related to poor postural control of patients with NLBP (9).

An increasing number of studies have investigated lumbar joint position sense, especially on the measurement methods of position sense and the relationship between position sense and LBP. However, most studies only focused on a certain aspect of lumbar position sense, and current studies lack a comprehensive summary.
of lumbar position sense and a summary of research status. Therefore, this study summarizes the research progress of lumbar position perception from the aspects of measurement methods and instruments, influencing factors, reliability studies, and the relationship between lumbar pain and position sense.

**Measurement of lumbar position sense**

*Measurement method*

Joint reposition is a common method for measurement of lumbar position sense and can be divided into active joint reposition and passive joint reposition (Fig. 1). Absolute error (AE) is used as the evaluation index, which is the difference between the target and actual angles. A small value of AE indicates better joint position sense (10). AE is one of the most frequent indexes for the measurement of joint position sense.

**Active lumbar reposition measurement**

In active lumbar reposition measurement, the instrument drives the subject’s trunk to move from the initial position to the target angle without the interference of vision and hearing. The subject is familiar with the position for some time and returns to the initial position. The subject holds the machine switch button and then presses the pause button when he or she moves actively to the target position identified by himself or herself (11). The active lumbar reposition measurement can be performed in multiple positions, including sitting and standing (12). The active reposition takes place in the sagittal plane of the body, where the subject flexes or extends and reaches the corresponding angle. This is also the position and motion plane of the lumbar position sensing measurement that is widely used in clinical practice (13).

Shawn et al. (14) found that reduced low back skin sensitivity had a slight effect on neuromuscular control of active low back proprioceptive sense in healthy individuals. In this study, position sense measurement involved active lumbar reposition in the sagittal and axial planes. Sagittal repositioning was carried out while seating on a kneeling chair, and axial repositioning was processed while seating on a rotating platform.

**Passive lumbar reposition measurement**

The initial stage of passive lumbar reposition measurement is the same as that of active lumbar reposition measurement. The difference is that the subject moves passively driven by the instrument and presses the pause button when he or she consciously reaches the target position; the actual angle of the lumbar spine at this time is recorded and used to calculate AE. Lee et al. (15) selected 24 subjects with NLBP and 24 healthy people and used a specially designed apparatus to measure their position sense. The apparatus was modified to offer rotations in three anatomic planes while fastening the body above the waist. A study using passive joint repositioning found patients with NLBP had a higher motion perception threshold than the healthy group, which indicated that impairments in position sense could be found in patients with LBP (16).

**Measurement instruments**

*Goniometer*

The goniometer is a classical instrument that is often used by many clinical healthcare professionals to measure the angle of joint reposition (Fig. 2). The same measurement protocol is not used for the clinical use of a goniometer. During the lumbar position sense measurement, the tester placed the goniometer vertically at the selected lumbar position to measure the lumbar reduction angle (17). In this age of the Internet, there have been numerous studies comparing goniometers with other designs and methods, such as Internet goniometers, digital goniometers, and electronic goniometers (18). After getting familiar with the target angle, the participants were usually asked to complete three or five consecutive active lumbar reposition measurements from different positions, and AE was recorded (19). To determine the effect of short-period application of Kinesio tape on body position...
Isokinetic dynamometry

The trunk isokinetic dynamometry is recognized as the most objective and accurate instrument for measuring the position sense of the trunk (21) (Fig. 3). Learman et al. (22) used the Biodex Type 3 System (Biodex Medical Inc, Shirley, NY, USA), took 33 patients with NLBP as the subjects, and selected 30° (flexion or extension) as the target angle. The subjects completed six consecutive active lumbar reposition measurements as required, and AE was then calculated.

Reza et al. (23) recruited 20 healthy athletes and 20 individuals with patellofemoral pain (PFP), used Biodex System 3 (Biodex Medical Inc.) for measurement, and selected 30° and 60° trunk flexion as the target angles. The results suggest that patients with PFP may experience impaired trunk position sense specifically in the flexion direction. Patients with PFP commonly exhibit increased lumbar lordosis, and their impaired sense of lumbar position may be associated with active and passive trunk structures (24, 25). The discrepancy in length between the spindle near the lumbar spine and adapted resting length due to lumbar lordosis posture in patients with PFP, which is a peripheral proprioceptor, may account for the increased spindle activity and the sum of spindle discharges, ultimately influencing the accuracy of joint reposition (26, 27). To investigate the short-period impact of creep deformation on body position sense, Abboud et al. (28) recruited 20 healthy participants and instructed them to move from a slightly curved trunk position. The reposition test was conducted using an isokinetic device (LIDO Active Loredan Biomedical, West Sacramento, CA, USA). The subjects were securely fastened to the device.

Figure 2
Electronic goniometer. The basic pattern of an electronic goniometer that measures angle changes by wearing it on a subject.

Figure 3
Isokinetic dynamometry. The basic form of isokinetic dynamometry, makes subjects move at the same speed as the instrument to ensure the accuracy of measurement.
using three straps placed around the lower limbs, hips, and trunk. This study suggested that decreased ability to 
sense joint movement and joint position adversely affects 
spine stability and increases the risk of LBP or injury.

Electronic motion monitoring equipment

Electronic motion monitoring devices are widely used in 
sports biomechanics as well as in lumbar position sensing 
research because they can accurately describe joint 
motion (Fig. 4). Electronic motion monitoring equipment 
fundamentally incorporates inertial sensors, camera-
based motion-capture systems, and three-dimensional 
(3D)-calibration frame to record the movement of various 
body parts, including the lumbar spine, hip joint, and 
pelvis (29). It would help determine the extent to which 
lumbar motion is influenced by hip and pelvic motion, 
allowing for a more accurate assessment of lumbar flexion 
and extension and avoiding misinterpretation of hip or 
pelvic motion as lumbar motion. Gill et al. (30) used a 
lumbar motion monitor to observe the movement of 20 
healthy adults and 20 patients with LBP in two positions 
(standing position and four-point kneeling position). The 
subjects held their hands to the chest and completed 
active lumbar reposition measurements in all directions 
as standing. In the four-point kneeling position, with the 
shoulders and knees fixed, AE was calculated by bending 
the trunk and arching the back to the target angle. 
Sheeran et al. (12) employed 90 subjects with NLBP 
and 35 asymptomatic controls as subjects and adopted 
a 3D kinematic motion analysis system (VICON S12, 
VICON Motion Systems Ltd., Oxford, UK) to obtain target 
repositioning data and evaluate lumbar position sense. 

Subjects with NLBP produced larger error magnitude 
and variability than the asymptomatic controls. The 
recruitment of the trunk muscle and the ability of the 
trunk posture control changed in patients with LBP, 
thereby affecting the ability to complete active reposition 
(31).

Shawn et al. (14) used 100 Hz (Optotrac 3D 
Investigator, Northern Digital, Waterloo, ON, Canada) 
to conduct active lumbar repositioning measurements 
within the sagittal and axial planes. Sagittal repositioning 
kinematic data were obtained from three non-collinear 
markers fixed to the T12 and S1 vertebral levels. Motion 
data for axial repositioning were obtained from rigid 
objects placed on a twisting platform. Sensorimotor 
dysfunctions in NLBP were assessed through repositioning 
measurements to generate relevant data for developing a 
rational diagnostic approach and rehabilitation protocols 
(32).

Influencing factors of lumbar position 
sense measurement

In addition to visual, auditory, attitudes, expectations, 
and tactile influences, there are other influencing factors 
in lumbar position sense measurement (33, 34). In related 
studies, some factors related to the measurement of 
lumbar position sense, such as to repositioning method, 
fatigue degree, and posture during the reposition, have 
been taken as influencing factors (35, 36).

Target angle

In the measurement of lumbar position sense, the 
selection of different target angles affects the test results. 
Descarreaux et al. (35) measured lumbar position sense in 
15 healthy controls and 16 patients with LBP by using target 
angles of 15°, 30°, and 60° flexion and 15° extension. The 
maximum AE was 5.20 ± 0.62 when the target angle was 
60° flexion, while the minimum was 2.13 ± 0.23 when the 
target angle was 15° flexion. This finding indicates that the 
larger the target angle is, the greater the error of lumbar 
reposition angle is. The increase in the motion amplitude 
requires more neural control signals. The same subjects 
completed the same angle of flexion and extension of 
the position sense test, and the results were different. 
The AE values of 15° forward flexion and 15° extension 
were 2.13 ± 0.23 and 1.74 ± 0.23, respectively. Similar 
results were obtained by Lee et al. (15), who suggested 
that when the lumbar reposition measurement of flexion 
and extension was performed at the same target angle, 
the position sense error of extension was less than that of 
forwarding flexion. It has been suggested that this is due 
to less proprioceptive information from muscle spindle 
type Ia afferent receptors when the joint is extended at
a larger angle (37). The larger the selected reposition angle of the joint and its motion amplitude, the larger the AE of the measurement will be because the increase of motion amplitude requires more neural control signals (38). At the waist position with a larger flexion angle, the interaction inhibition between the lumbar muscles in LBP patients in the flexing state is weak, resulting in a large proprioceptive error (39).

The AE significantly increased with trunk flexion within the moderate range of lumbar angles, but at high trunk flexion, the AE was lower at high lumbar angles compared to the moderate range (36). These findings suggest that the misregulation of lumbar angular control may be an important factor contributing to the heightened risk of LBP caused by trunk flexion (40). Gade et al. (41) found that during a flexion task, the increase in the reposition sense error of the lumbar spine was associated with trunk flexion and independent of changes in moment load. The increase in AE may be attributed to the altered alignment of trunk musculature, thereby impairing the ability of muscle spindles to perceive the lumbar spinal angle.

Reposition form

Joint reposition usually has two motion forms, namely, active reposition and passive reposition. The AE obtained using different reposition forms varied. Sherif (42) compared the active reposition and passive reposition of the lumbar spine of the same subjects and found that the AE of the active reposition measurement of the subjects with LBP and healthy people was lower than that of the passive reposition measurement. Hence, the subjects had better sensitivity to the completion of the active reposition measurement. Active exercise is believed to activate motor neurons and enhance the sensitivity of muscle spindles. The muscle spindles are rich in key proprioceptors, leading to the AE of active reposition measurement being less than that of passive reposition.

Target presentation time

In lumbar reposition measurements, the subjects often need a period of familiarity with the target angle before returning to the initial position and then begin to reach the target angle identified by themselves actively or passively. This period is called target presentation time, which has an important influence on the results of the joint reposition test and further affects the accuracy of lumbar position sense measurements (43). If the time is too short and the subject is not sufficiently familiar with the target angle, then the subject may perform poorly later in the repositioning process due to the ambiguity of the target angle; therefore, the tester may not be able to accurately measure the subject’s lumbar position sense. If the time is too long, then the subject may rely too much on cognitive functions, such as memory and attention, to become familiar with the target angle and reach the target angle through cognitive function rather than position sense during the repositioning process. This phenomenon decreases the value of joint reposition measurement in evaluating position sense.

Goble et al. (44) recruited 13 healthy adults who were actively matched for passively ascertained joint angles (amplitude = 20° or 40° extension) in the absence of sight. They were divided into two groups whose target presentation time was relatively ‘short’ (3 s) or ‘long’ (12 s). Under long-term (12 s) conditions, the subjects had a greater chance of developing an internal representation of the target joint angle, with a markedly less variable error of the matched movements and associated with smoother matched trajectories, compared to the short-time (3 s) condition. It may indicate that increasing the exposure to target sensory stimuli can enhance the correctness of matching performance.

Lumbar fatigue

Abnormal loading to the spine may occur in all kinds of real-life scenarios. Trunk position sense is essential for maintaining the correct position of the spine under load and requires appropriate responses from the surrounding muscles and ligaments. Soft tissues around the spine provide neural responses at each spinal segment and regulate positional sensitivity and muscle tension in specific areas (45). Once overloading occurs faster than the central nerve system responds, damage or injury can ensue. The low back muscles play an important role in coping with sudden overloading. However, long-term response causes lumbar fatigue, which affects muscle response speed (46). Taimela et al. (47) found that lumbar fatigue reduced the body’s ability to perceive changes in the position of the lumbar spine, that is, the sensitivity of lumbar position sense was decreased. The main difference between active and passive lumbar reposition is the activation degree of lower back muscles. Compared with the passive lumbar reposition, the active reposition requires the subjects to actively contract their trunk muscles to achieve the target angle, while in the passive lumbar reposition process, the subjects rely on the device to drive the test. This makes active lumbar reposition more susceptible to lumbar fatigue, whereas the muscles around the lumbar spine are relatively relaxed during passive reposition (48). And it may be a major consideration in the clinical application of active or passive reduction. This finding suggests that the information and changes in lumbar position sense are not accurate due to fatigue after lumbar load activities; as such, measurement of lumbar position sense is not advisable currently.
**Measurement position**

In the measurement of lumbar position sense, active or passive reposition affects the results, and the measurement position varies. Common measurement positions include sitting, standing, and four-point kneeling. Jakobs et al. (49) found that when subjects changed from the standing to supine position, the accuracy of repositioning decreased significantly, even when the other aspects of the measurement procedure remained unchanged. Preuss et al. (50) found that the accuracy of position sense in the four-point kneeling position was lower than that in sitting and standing positions. The differences in lumbar position sense with different measurement positions may be explained by the presence of mechanoreceptors in the load-bearing structures of the lumbar spine, especially in the facet joint capsules. And the changes in the trunk from the load-bearing posture to the non-load-bearing posture can influence proprioceptive feedback (51). Posture and position have an important effect on the accuracy of lumbar position perception. Thus, the measurement of joint position should be considered in the clinical evaluation of lumbar position sense.

**Reliability of measurements for lumbar position sense**

A reliability study is necessary to assess the consistency, stability, and reliability of the measurement results of lumbar position sense measurements. Intraclass correlation coefficient (ICC) was adopted as an indicator to assess reliability. ICC is one of the commonly used reliability coefficient indices to measure and evaluate interobserver reliability and retest reliability (52, 53).

Analysis of the included studies (Table 1) indicated that most of the current measurements of lumbar position sense have good retest reliability, indicating that their test results are reliable. Research on the reliability of the lumbar position sense measurement focuses on verifying the reliability of different test methods and instruments. To explore the reliability of the two lumbar position sense testing methods, Ravi et al. (54) adopted the classical position sense testing instrument goniometer and required subjects to conduct joint rotation tests in multiple directions. They concluded that the two methods seemed reliable. Swinkels (55) and Gill (30) found that assessment of lumbar position sense in subjects with NLBP in the upright state by lumbar joint reposition error appeared to be reliable (0.11 < ICC < 0.78) as well as in halfway (0.34 < ICC < 0.90) standing and four-point kneeling positions (ICC=0.86). O’Sullivan et al. (56) studied the reliability of a new instrument, namely, BodyGuard (Wireless Posture Monitor), to measure lumbar position sense and reported the good reliability of the device. Brumagne et al. (57) tested the reliability of using Piezoresistive electrogoniometer (ICC=0.72) and 3D video analysis (ICC=0.64) for measurement in active joint reposition in standing position.

To improve the popularity and operability of lumbar position sense measurement, Alejandro et al. (58) proposed to use iPhone® Inclinometer Application to measure lumbar position sense and conducted a reliability study. They selected standing and sitting positions to perform joint reposition. The results suggest that the iPhone® inclinometer appeared reliable for measuring lumbar position sense with reposition error in patients with NLBP in standing (ICC=0.96) and sitting (ICC=0.93) positions. More details about reliability are presented in Table 2.

**Differences in lumbar position sense between subjects with and without LBP**

The link between lumbar position sense and NLBP has become increasingly strong. The loss of position sensor is one of the causes of NLBP, which leads to the degeneration of lumbar position sense. However, further research is needed to provide additional evidence. An overview of the characteristics of the studies included is presented in Table 3.

Hidalgo et al. (59) found the AE of patients with LBP had shown damaged position sense compared with controls in sitting positions. They also measured active lumbar reposition in four-point kneeling (FPK) position and found a 2.4° higher AE in patients compared with controls. However, no significant variation in the AE was found between the patients and controls in standing positions (60). Lin et al. (61) measured active lumbar reposition in supine and side-lying positions and found no significant difference in AE between the patient and control groups. Bilge et al. (62) measured AE in passive lumbar reposition in sitting positions and found no
Table 2  Reliability of lumbar position sense for LBP patients.

<table>
<thead>
<tr>
<th>Study</th>
<th>Measuring instrument</th>
<th>Measuring methods</th>
<th>Test-retest reliability</th>
<th>Inter-rater reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
<td>Device</td>
<td>Method/position</td>
<td>ICC</td>
</tr>
<tr>
<td>Silfies et al. (42)</td>
<td>ISK</td>
<td>Designed to passively move the lumbar spine in a transverse plane</td>
<td>AR</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>EMME</td>
<td>Fastrak</td>
<td>PR</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>EMME</td>
<td>Lumbar motion monitor</td>
<td>AR</td>
<td>&lt;0.754–&lt;0.860</td>
</tr>
<tr>
<td></td>
<td>EMME</td>
<td>Standing</td>
<td>4-point kneeling</td>
<td>0.852</td>
</tr>
<tr>
<td></td>
<td>EMME</td>
<td>Standing upright</td>
<td>Halfway flexed</td>
<td>&lt;0.11–0.78</td>
</tr>
<tr>
<td>Swinkels &amp; Dolan (55)</td>
<td>EMME</td>
<td>Fastrak</td>
<td>AR standing</td>
<td>0.72</td>
</tr>
<tr>
<td>Brumagne et al. (57)</td>
<td>GM</td>
<td>Piezoresistive EG</td>
<td>AR sitting</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>EMME</td>
<td>BodyGuard wireless posture monitor</td>
<td>AR Standing</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>GM</td>
<td>Dualer IQ digital inclinometers</td>
<td>AR NLP</td>
<td>0.75–&lt;0.85</td>
</tr>
<tr>
<td></td>
<td>GM</td>
<td>iPhone® Inclinometer Application</td>
<td>AR TLP</td>
<td>≤0.93</td>
</tr>
<tr>
<td></td>
<td>GM</td>
<td>Sitting</td>
<td>AR Standing</td>
<td>0.96</td>
</tr>
<tr>
<td>Hidalgo et al. (59)</td>
<td>EMME</td>
<td>3D tracking system</td>
<td>AR Sitting</td>
<td>0.94</td>
</tr>
</tbody>
</table>

ICC values are between 0 and 1, where 0 means completely untrustworthy, 1 means completely trustworthy, 0.75–1 means good reliability, 0.4–0.75 means medium reliability, and less than 0.4 means poor reliability.

AR, active reposition; EG, electrogoniometer; EMME, electronic motion monitoring equipment; GM, goniometer; ICC, intraclass correlation coefficient; ISK, isokinetic dynamometry; NLP, neutral lumbar position; PR, passive reposition; TLP, target lumbar position.

marked variation between the patients and controls. Astfalck, O’Sullivan, Sheeran, et al. (16, 63, 64) measured AE during active lumbar reposition in sitting positions and found damaged position sense in subjects with O’Sullivan flexion patterns of LBP.

Sabina et al. (65) found that young grownups with NLBP and middle-aged adults, regardless of their NLBP status, had lower lumbar reposition ability. This finding probably manifests latent age-related degeneration in the processing of lumbar position sense signals by central and peripheral systems. More information about position perception in LBP patients and healthy subjects is presented in Table 4. Long-term injurious stimulation reduces the impulse frequency of motor neurons in patients with NLBP and results in the decline in the recruitment of motor neurons and the number of tuberous muscle fibers involved in contraction; this stimulation reflexively inhibits the overall activity of lumbar and dorsal muscles, leading to a decline in the stability of the lumbar spine during flexion (66). The auto motor sensory feedback transmission mechanism of patients with NLBP was more unstable than that of healthy people (15). During daily activities, patients with NLBP need to maintain spinal stability by increasing the recruitment of lumbar dorsal muscle fibers (67). This self-protective reflex interferes with the normal movement of the lumbar muscles, leading to a larger spinal displacement angle.

The intensity of pain in patients with NLBP was negatively correlated with their ability to control trunk posture and their level of position perception (68). The muscle nerve noise generated by the pain signal induced wrong proprioception, leading to the decline of the overall coordination of spinal movement (69). Degraded lumbar position sense, decreased stability, and decreased trunk postural control are also important reasons for NLBP recurrence.

Discussion

Lumbar position function and LBP appear to be correlated (70). However, the lack of research on the reliability and validity of the measurement of lumbar position sense in most relevant literature has led to no definitive conclusions regarding the relationship between lumbar position sense and LBP. Several studies have begun to investigate the internal mechanism of the connection between LBP and position perception, but the relationship between the intensity of LBP and the degradation of position perception is more complicated and may be related to the complexity and subjectivity of pain sense (71, 72). The proprioceptors located in lumbar ligaments, joint capsules, facet joints, and skin are more involved in passive movement (3, 73). Thus, the passive joint reposition may be primarily associated with proprioceptive receptors in these structures. We propose utilizing passive lumbar
Table 3  Cohort characteristics of the studies included.

<table>
<thead>
<tr>
<th>Reference/groups</th>
<th>Sample size, n</th>
<th>Age, years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>M</td>
</tr>
<tr>
<td>Astfalk et al. (63)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCLBP</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>CON</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>Georgy (16)</td>
<td>LBP</td>
<td>15</td>
</tr>
<tr>
<td>CON</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Hidalgo et al. (59)</td>
<td>NLBP</td>
<td>10</td>
</tr>
<tr>
<td>CON</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>Kara et al. (60)</td>
<td>NLBP</td>
<td>18</td>
</tr>
<tr>
<td>CON</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>Lee et al. (15)</td>
<td>LBP</td>
<td>24</td>
</tr>
<tr>
<td>CON</td>
<td>24</td>
<td>14</td>
</tr>
<tr>
<td>Lin &amp; Sun (61)</td>
<td>LBP</td>
<td>20</td>
</tr>
<tr>
<td>CON</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>O'Sullivan et al. (64)</td>
<td>NCLBP</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>CON</td>
<td>15</td>
</tr>
<tr>
<td>Sheeran et al. (12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCLBP</td>
<td>90</td>
<td>31</td>
</tr>
<tr>
<td>CON</td>
<td>35</td>
<td>13</td>
</tr>
<tr>
<td>Tsai et al. (70)</td>
<td>LBP</td>
<td>16</td>
</tr>
<tr>
<td>CON</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Yilmaz et al. (62)</td>
<td>NCLBP</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>CON</td>
<td>20</td>
</tr>
<tr>
<td>Pinto et al. (65)</td>
<td>NCLBP</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>CON</td>
<td>73</td>
</tr>
</tbody>
</table>

Inclusion criteria

- LBP > 12 weeks of VAS > 3/10 experienced most days of week
- LBP of VAS > 5/10, lumbar ROM < 50% normal range and >3 months duration
- LBP without radiation into leg > 6 months
- LBP > 2 years
- LBP > 3 months
- LBP > 2 weeks with mild-moderate impairment of physical function
- LBP > 3 months in subgroup of flexion pattern of motor control impairment (O’Sullivan classification)
- LBP > 12 weeks with clinical diagnosis of flexion or active extension pattern of motor control impairment (O’Sullivan classification)
- LBP within past 2 years
- LBP > 3 months with no radiation below knee level. No neurologic impairment, current lower limb problems, systemic disease that can affect proprioception
- Non-specific CLBP that required medical treatment and lasted over 3 consecutive months in the last year and LBP intensity of at least 5/10 on a 11-point NPRS

Joint repositioning to assess the clinical improvement of proprioceptive function. The passive reposition is less affected by the lumbar fatigue than the active reposition because the muscle in the vicinity of the lumbar spine is relatively relaxed (45, 48). In addition, measurement instrument varies in complexity, and some require an additional power supply and auxiliary equipment configuration, thus lacking portability. The extended testing process has been highlighted as an issue for specific testing methods, especially aimed at testing large numbers of samples.

The performance obtained under measurement speed and angle in different forms of lumbar joint reposition test may not be relevant (74, 75). The testing conditions do not closely resemble normal motion patterns, as daily activities typically do not involve slow-paced passive limb movements. Therefore, the current popular lumbar reposition methods need further study to understand the role of position sense in daily activities and sports activities. And the detailed analysis of these factors is less research on the extent of the impact of different methods and instruments, which is the direction of subsequent researchers. Moreover, no unified standard has been established regarding measurement methods for different groups, posture to choose when using the same test method and target angle, representation form, and target presentation time to choose in the same research.

Future proposals

At present, the commonly used clinical determination methods include active and passive reposition, and neither method has high sensitivity and specificity, which makes the comparability of relevant studies poor and difficult to carry out clinically. The goniometer and isokinetic dynamometry seek to minimize irrelevant variables by using slow movement speeds, passive movement, non-weight-bearing conditions, and isolating the corresponding joint segments so that position sense can be examined in a controlled condition. In contrast, most daily activities require active movement at a normal functional speed. The emerging electronic
motion monitoring equipment, such as the assessment of the posture using Microsoft Kinect and other 3D technologies, provides the possibility of examining the function of lumbar position sense under more natural conditions (76, 77, 78). These technologies can enable the use of measurement conditions that closely mimic normal functional movements, allowing for a more accurate evaluation of lumbar position sense.

**Conclusion**

1. Lumbar position sense measurement is suitable for the assessment of lumbar function and is common in the clinical application of NLBP.
2. Goniometer and electronic motion monitoring equipment are commonly used to perform active repositioning tests for lumbar joints due to their
portability and flexibility. Isokinetic dynamometry is often used for passive joint repositioning tests because of its objectivity and accuracy.

3. Patients with NLBP have a less stable auto motor sensory feedback transmission mechanism than healthy individuals. These findings imply that lumbar position sense potentially contributes to the development and persistence of LBP.

4. Although some instruments have good retest reliability, most studies do not test reliability, especially for inter-group reliability.

5. Efforts are needed to develop a standardized and innovative measurement of lumbar position sense, integrating advanced technologies like motion capture, virtual reality, and wearable sensors, to assess the complete function of lumbar position sense.

ICMJE conflict of interest statement
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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Availability of data and materials
All data included in this study are available upon request by contact with the corresponding author.

Author contribution statement
X-Q Wang conceived the review. Q-H Yang drafted the protocol and searched the literature to identify eligible trials, extracted and analyzed data, drafted the manuscript, and revised the tables in the drafted manuscript. All authors approved the final manuscript.

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