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# Chronic non-specific low back pain and ankle proprioceptive acuity in community-dwelling older adults

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ABSTRACT

*Background:* For people above 65 years old, low-back pain (LBP) is associated with balance problems and falls. Down-weighting of proprioception due to ageing and LBP may cause such balance problems. While lumbar proprioceptive deficits have been shown in LBP and indications for more generalized deficits have been found, ankle proprioception, which is crucial for balance control, has not been studied in people with LBP.
*Research question:* Is there any difference in ankle proprioceptive acuity between community-dwelling older adults with and without LBP? We hypothesized that ankle proprioception was impaired in community-dwelling older adults with LBP compared to those without LBP.
*Methods:* Thirty participants over 65 years old volunteered. Fifteen had LBP (M/F = 2/13, age = 72.0 (4.6) years), fifteen were healthy controls without back pain (control group) (M/F = 2/13, age = 72.1 (4.8) years). Ankle proprioception was measured in normal weight-bearing conditions, using the Active Movement Extent Discrimination Apparatus (AMEDA). Accuracy on the ankle proprioceptive test was expressed as absolute error (AE), constant error (CE) and variable error (VE).
*Results:* AE was significantly larger ($P = 0.029$, 95 % CI = [0.00, 0.90]) in the LBP group, CE was also significantly larger ($P = 0.046$, 95 % CI = [-0.91, −0.01]), indicating an underestimation of ankle inversion in participants with LBP compared to controls. VE was not different between the two groups ($P = 0.520$, 95 % CI = [-0.20, 0.59]). No significant correlation was found between pain intensity and AE, CE or VE ($P > 0.05$).
*Conclusion:* Ankle proprioception decreased in older people with LBP compared to healthy peers, suggesting impaired central proprioceptive processing. Older people with LBP underestimate the extent of ankle inversion, which may increase fall risk. Thus, evaluation and training of ankle proprioception may be useful in older people with LBP.

## 1. Introduction

Low back pain (LBP) is one of the most common musculoskeletal disorders, with a lifetime prevalence of 84 %.[1] It is the leading cause of years lived with disability, while treatment benefits are at best moderate and recurrence is common, making this a major socioeconomic problem.[15,21] The prevalence of LBP is highest in people aged 40 to 80 years [14], and the prevalence of severe or disabling LBP in community-dwelling older adults aged over 60 years is very high.[23].

Impaired physical functioning in patients with LBP among, other aspects, comprises impaired balance. A majority of studies reported that people with LBP exhibit greater postural sway than healthy people during bipedal standing.[22] Specifically for people above 65 years old, LBP is a major determinant of balance, accounting for 9 % of the variance in balance performance.[19] In addition, adults with LBP aged over 65 years had a greater risk for falls than peers with healthy backs.[26].

Proprioception plays an important role in balance control, and LBP is associated with proprioceptive deficits.[28] Impaired balance control

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and fall risk in people with LBP may thus also be associated with such deficits. Previous studies have shown greater trunk posture repositioning errors in people with LBP than in healthy controls [28], but also greater neck repositioning errors [7]. Thus, proprioceptive deficits are not exclusively limited to the painful area, suggesting a more generalized proprioceptive deficit. Theoretically, proprioceptive information from multiple body parts must be integrated for balance control and in chronic pain patients central processing of proprioceptive information may be disturbed.[29] It is therefore conceivable that patients with LBP down-weight proprioceptive output as a whole. Each body part is weighted by a weighting factor relative to the proprioceptive contribution of the other body parts. Deficient proprioception of a certain body part will affect its own weighting factor (down-weighting) and the weighting factors of other segments (up-weighting).[25] Although patients with LBP increased relative weighting of ankle versus lumbar proprioceptive information for control of upright stance [3], their response to stimulation of ankle muscle proprioceptors is still smaller than in healthy controls [16]. These findings suggest that ankle proprioception is affected by LBP, even though the effect is smaller than the effect on lumbar proprioception.

If a generalized effect of LBP on proprioception exists, it may add to age-related ankle proprioceptive deficits [9] and down-weighting of proprioception [24], which are associated with balance impairments and increased risk of falls [6]. However, whether a generalized proprioceptive deficit exists and extends to the ankle joints is unknown. Therefore, the aim of this study was to investigate the difference in ankle proprioception between older adults with and without LBP.

## 2. Methods

### 2.1. Participants

Fifteen males and females aged over 65 years old with LBP and 15 without back pain were recruited by advertising in local communities. To be eligible for the study, the LBP participants had: (1) a history of persistent LBP for>3 months, (2) pain between the rib margins and buttocks (between T12 and gluteal folds), (3) to be capable of walking over 50 m unaided, and (4) obtain a Mini-Mental State Examination (MMSE) score no<24 out of 30 indicating no cognitive impairment [20]. Exclusion criteria were: (1) recognizable, known specific pathology causing LBP (e.g. infection, tumor, osteoporosis, fracture, structural deformity, inflammatory disorder, radicular syndrome, or cauda equina syndrome) [17], (2) a history of vestibular disorder, neurological or respiratory disease, (3) a history of lower limb or spinal surgery, (4) lower extremity injury within the past 6 months, and (5) symptoms for “Red Flag” pathology (e.g. night pain, unexplained weight loss) [17]. The control group consisted of 15 participants who had never experienced back pain with a duration longer than 3 consecutive days [31]. They were matched with the LBP group for gender, age and body mass index.

The level of pain in participants with LBP was assessed using the Visual Analogue Scale (VAS) before the experimental test. The participants in the LBP group were outside of an episode of LBP at the time of testing. An “episode” of LBP was defined as “a significant increase in pain compared to their level of pain on a daily basis which affects their mobility in daily activities for at least one day [5]”. Given that the ankle proprioceptive assessment only involves natural standing for<10 min, no participant reported pain aggravation after the test The participants were asked to rate the worst pain they had in the past 7 days, by using the VAS. Prior to the test, written informed consent was obtained. The study was approved by the Human Research Ethics Board at Shanghai University of Sport (Shanghai, China) (No. 102772020RT015).

### 2.2. Experimental protocol

Ankle proprioceptive acuity was assessed with the Active Movement Extent Discrimination Apparatus (AMEDA) [13], which involves active movements made under normal weight-bearing conditions, without physical constraints, and permits general vision while obscuring vision of the target position. In this test, the participants were instructed to stand upright unaided and barefooted with their dominant foot placed on an adjustable foot plate while fixing their gaze horizontally (Fig. 1). The angle-adjustable footplate can be tilted along its central axis by actively inverting the ankle joint. The footplate has 4 lateral tilt angles: 10°, 12°, 14° and 16° of inversion, which were taught to the participants as positions 1, 2, 3 and 4, respectively. Before data collection, the participants were familiarized with the 4 positions for 3 repetitions starting with position 1 and progressing to position 4 (12 practice trials in total). The participants then undertook a total of 40 trials for the testing proper. In each trial, the 4 positions were presented 10 times randomly. For each trial, the participants were asked to invert their ankle actively to rotate the footplate from the horizontal start position until the footplate contacted the adjustable stop, which was pre-set by the tester, and then actively return to the start position. Participants were then asked to identify which position (1, 2, 3 or 4) they had just perceived without any visual information about the ankle movement, or feedback from the tester. The total test took <10 min.

### 2.3. Data analysis

Ankle proprioceptive acuity was calculated as the difference between the perceived position by the participants and the actual position, converted to angle differences based on the position-angle relationship described above. Ankle proprioceptive acuity was expressed as absolute error (AE), constant error (CE) and variable error (VE) (unit of measurement: degree). AE was calculated as the absolute numerical deviation of the response given from the actual target position, representing error magnitude without error direction. CE was the signed difference between perceived position and the actual position, representing bias towards over- or underestimating inversion angle. A positive CE indicated that the participant overestimated the depth of ankle inversion, while a negative CE indicated that the participant underestimated the depth of ankle inversion. VE was the standard deviation of CE, representing error consistency.[28] For example, if the position perceived by the participant was 2 (12°), while the actual position presented to the participant was 3 (14°), then the difference between the perceived position by the participant and the actual position would be 12°-14° = −2°. Thus, the corresponding absolute error was 2°, while the constant error was −2°. The averages of the absolute errors and constant errors of the total 40 trials were taken to represent the errors of the participant.

### 2.4. Statistical analysis

All data were analyzed using RStudio version 1.4.1717 (© 2009–2021 RStudio, PBC). The Mann Whitney $U$ test was used to compare AE and VE between the two groups, since AE and VE data were not normally distributed (Shapiro-Wilks, $P < 0.05$). The independent-groups $t$-test was used to compare CE between the two groups, since CE data was normally distributed (Shapiro-Wilks, $P > 0.05$). Spearman's correlation coefficient ($r_s$) was used to evaluate the relationship between ankle proprioception and pain intensity among scores from participants in the LBP group, since VAS was not normally distributed. Data are presented as means and standard deviations (SD) for normally distributed outcomes or as median and interquartile range (IQR) for non-normally distributed outcomes. Significance was set at $P < 0.05$.

## 3. Results

The participants were aged 65 to 81 years and the ankle proprioception of the right foot was tested, since all participants were right leg dominant, as classified by the Waterloo Footedness Questionnaire [37]. All LBP participants completed the test without provoking symptoms.

**Fig. 1.** Depict of ankle proprioceptive accuracy measurement using the Active Movement Extent Discrimination Apparatus (AMEDA). The left picture illustrates the horizontal start position, the right picture illustrates one of the four inversion angles.

Characteristics of the participants are detailed in Table 1.

### 3.1. Difference in ankle proprioceptive accuracy between groups

The values for ankle proprioceptive acuity in both groups are presented in Table 2 and Fig. 2. AE was significantly larger in the LBP group than in the control group (23.1 % larger, $P = 0.029$, 95 % CI = [0.00, 0.90], effect size = 0.71). CE was significantly larger (more negative) in participants with LBP, indicating that they underestimated actual ankle inversion depth ($P = 0.046$, 95 % CI = [−0.91, −0.01]). VE was not different between the two groups ($P = 0.520$, 95 % CI = [−0.20, 0.59]).

### 3.2. Correlation of pain intensity with ankle proprioception

No significant correlation was found between pain intensity and AE ($r_s = 0.262$, $P = 0.345$), CE ($r_s = 0.098$, $P = 0.728$), or VE ($r_s = 0.497$, $P = 0.059$).

## 4. Discussion

To our knowledge, this is the first study to investigate ankle proprioceptive acuity in older adults with and without LBP. Compared to back-healthy older adults, older adults with LBP demonstrated significant differences in absolute error and constant error but not variable error of ankle proprioception, indicating a proprioceptive deficit in older adults with LBP, who were pain-free and the test did not provoke any symptoms. In the LBP group, the ankle proprioceptive deficit was not correlated with pain intensity. This LBP-related deficit may add to an age-related deficit [36], but we did not include a young adult reference group.

**Table 1**
Characteristics of the participants.

| | LBP (n = 15) | control (n = 15) | $P$ |
|---|---|---|---|
| Gender | 2 M/13F | 2 M/13F | 1 |
| Age (years) | 72.0 (4.6) | 72.1 (4.8) | 0.939 |
| Height (cm) | 157.8 (11.0) | 156.9 (6.0) | 0.791 |
| Weight (kg) | 56.5 (13.7) | 58.2 (8.7) | 0.695 |
| BMI (kg/m$^2$) | 22.4 (2.7) | 23.6 (2.8) | 0.270 |
| MMSE | 28.5 (2.1) | 28.4 (1.8) | 0.852 |
| VAS (0–10) | 4.8 (1.7) | N/A | |

Data are present in mean (SD). LBP, chronic non-specific low back pain group; control, pain-free control group; BMI, body mass index; MMSE, Mini-Mental State Examination; VAS, Visual Analogue Scale; N/A, not applicable. There were no significant differences between LBP and control participant characteristics ($P > 0.05$).

**Table 2**
Ankle Proprioceptive accuracy in both groups (in degrees).

| | LBP | control | 95 % CI | $P$ |
|---|---|---|---|---|
| AE | 1.60 (0.93) | 1.30 (0.48) | 0.00, 0.90 | 0.029* |
| CE | −0.38 (0.74) | 0.07 (0.41) | −0.91, −0.01 | 0.046* |
| VE | 2.06 (0.85) | 1.84 (0.34) | −0.20, −0.59 | 0.520 |

*Significant at $P < 0.05$; CI, confidence interval.
CE: mean (SD); AE, VE: median (IQR).

Proprioceptive deficits can be attributed to peripheral and central mechanisms.[30] Some evidence suggests that lumbar proprioceptive deficits in LBP may be due to peripheral impairments. Nociceptive stimulation can cause abnormally high fusimotor activity, which hampers detection of changes in muscle length.[2] However, the results of the present study may support the concept of a central mechanism underlying proprioceptive deficits, because our participants had no lower limb injury or pain. Combined with the finding of greater neck repositioning errors in people with LBP [7], the present findings indicate that LBP has generalized effects on proprioception, most likely through altered central processing.

Several other studies support the idea that LBP causes altered central processing of proprioceptive information. Extensive sensory cortical reorganization with an enhanced activity in the primary somatosensory cortex and an expanded cortical representation of the back into the neighboring foot and leg areas was observed in people with LBP.[8] Also, processing of ankle proprioception involved increased brain activity in motor regions in people with LBP.[10] Thus, both structural and functional changes in cortical level shed a light on the central mechanism underlying LBP.

Ankle proprioceptive accuracy is significantly associated with balance, mobility and physical function [6]. Thus, it is likely that the combination of deficits in both lumbar and ankle proprioception, rather than lumbar proprioception solely, may cause postural instability and increase fall risk in patients with LBP. In general, impaired ankle proprioception in older people with LBP is likely to cause reduced precision in the control of ankle movement, making it more difficult for LBP patients to perform prescribed exercise interventions, as well as increasing postural instability and the risk for falls. Longitudinal studies are needed to explore this relationship and the role of ankle proprioception in falls in older adult with LBP.

A significant, negative CE was found in the LBP group. Hence, LBP participants perceived a smaller than actual ankle inversion, and this was quite consistent (11 out of 15 participants, 73 %). However, previous studies reported that patients with LBP undershot the target

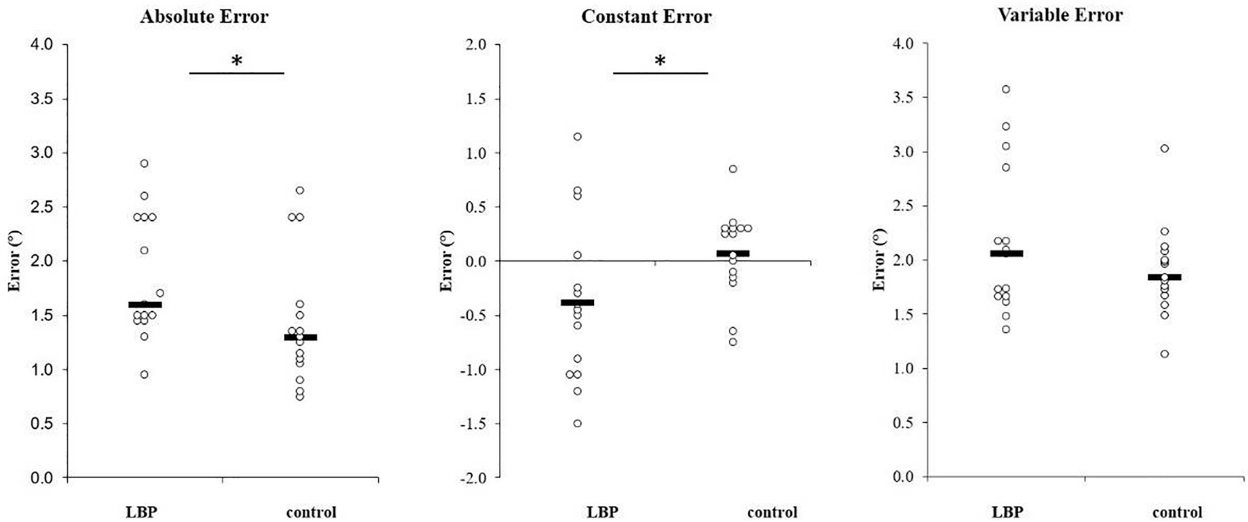


**Fig. 2.** Absolute error (AE), constant error (CE) and variable error (VE) of ankle proprioceptive acuity in LBP and control groups. LBP, chronic non-specific low back pain group; control, pain-free control group. *Significant at P < 0.05.

position in repositioning of the lumbar [2] and cervical spine [7], indicating overestimation of actual deviations from neutral. Whether such a discrepancy in the direction of bias between the spine and limbs is consistent or depends for example on the test method needs verification.

The correlation between ankle proprioception and pain intensity was also investigated in this study. Neither AE, CE nor VE was correlated with pain intensity. A systematic review found the AE of passive lumbar movement to be weakly correlated with pain.[18] This may reflect a more direct effect of nociception on local proprioception as mentioned above.

Generalizability of our findings is limited by the fact that we had a high proportion of female participants in each group in our study. Considering the fact that LBP is more common in females [14], that there is no significant gender difference in ankle proprioceptive accuracy [36], and that the control group was matched with the LBP group by sex, the results are unlikely to have been greatly affected by this limitation. Research has shown that both peripheral and central mechanisms account for proprioceptive performance. [12,13] People with LBP tend to decrease physical activity [11], which may lead to disuse of the muscles crossing the ankle. It is conceivable that proprioceptive receptors around the ankle joint would become impaired by disuse of the ankle joint in older people with LBP. Supporting the notion that usage is important for proprioceptive functioning, Symes et al. [27] found that ankle proprioception was significantly better in the movement range usually exposed in daily activities. One limitation of this study was that we did not collect data to elucidate if the ankle proprioceptive impairment observed was mediated by peripheral, central, or both factors. Future studies may address the underlying mechanism.

The magnitude of the differences between groups is small (i.e. 0.45°), although a relatively small ankle joint angle change could result in increased tripping risk during the gait [4,34], it is unclear whether this observed proprioceptive change can account for an increased fall risk. The other limitation was that participants were outside of an episode of LBP at the time of testing. It has been shown that pain may further impair neuromuscular control in people with LBP. [32] Therefore, it could be hypothesized that participants may perform even worse on the ankle proprioception test during an episode of LBP. Future empirical studies are needed to test this hypothesis. It is not typically the first choice for the majority of Chinese people with LBP to take medication for pain relief [33]. Only one participant in the current study took pain killers. It has been shown that some pain relief medication is associated with an increased risk of falls [35]. Future study should investigate the effects of pain medication on ankle proprioception in this group. Additionally, the cross-sectional design of the study does not allow us to demonstrate a cause-effect relationship between decreased ankle proprioceptive accuracy and the presence and/or development of LBP. It is unclear whether the reduced ankle proprioceptive sensitivity observed here is a result of or part of the cause of LBP.

## 5. Conclusions

This is the first study to demonstrate impaired ankle proprioception in older adults with LBP compared with their peers without back pain. This suggests impaired central mechanisms underlying proprioceptive processing in older people with LBP, causing generalized effects. Older participants with LBP underestimated ankle inversion, which could cause an increased risk of falls. Therefore, evaluation and training of ankle proprioception in addition to trunk proprioception may be useful in older people with LBP. Pain intensity did not correlate with ankle proprioception. Future studies should investigate whether older adults with LBP demonstrate balance impairments during functional tasks, and longitudinal studies are needed to explore the role of ankle proprioception in falls in older adults with LBP.

## CRediT authorship contribution statement

**Fangxin Xiao:** Conceptualization, Methodology, Investigation, Visualization, Writing – original draft, Writing – review & editing. **Huub Maas:** Writing – review & editing, Visualization, Supervision. **Jaap H. van Dieën:** Writing – review & editing, Supervision. **Adrian Pranata:** Writing – review & editing. **Roger Adams:** Writing – review & editing. **Jia Han:** Conceptualization, Methodology, Writing – review & editing, Supervision, Funding acquisition.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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