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The Comparison of the Effect of Prolonged Sitting on Lumbar Repositioning Error in Asymptomatic and Chronic Low Back Pain Participants with Seated Sedentary Behavior

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Abstract

Lumbar Repositioning Error (LRPE) refers to an individual's capacity to perceive and control the precise position of their lumbar spine. An adequate lumbar repositioning is crucial for sustaining spinal stability and an optimal function during sitting activities. When lumbar repositioning is inaccurate, it can lead to ineffective movement patterns that might contribute to the development of low back pain (LBP). However, the impact of prolonged sitting on LRPE in asymptomatic individuals and those with chronic low back pain (CLBP) remains unexplored. To assess the effects of continuous 30 min sitting on LRPE and pain in asymptomatic and CLBP participants with sedentary behavior, 50 participants (25 asymptomatic and 25 CLBP) were recruited. Their LRPE and pain were measured before and after a 30 min sitting condition. Both groups experienced a significant increase in pain intensity after the 30 min sitting period ($p = 0.001$ for asymptomatic, $p = 0.006$ for CLBP). The LRPE remained unchanged in the asymptomatic group ($p = 0.066$), but it was significantly increased in the CLBP group ($p = 0.001$). Furthermore, the CLBP group exhibited significantly higher levels of LRPE and pain compared to the asymptomatic group after sitting ($p = 0.041$ and $p = 0.001$, respectively). Prolonged sitting posture is a risk of LBP, particularly in sedentary individuals. To prevent the exacerbation of LRPE and LBP, individuals with CLBP, especially those with sedentary lifestyles, should avoid sitting continuously for 30 min. These findings highlight the importance of physical therapists providing such guidance in practice.

Keywords: Proprioception, Prolonged sitting, Joint sense, Spine, Motor control, Low back pain, Sedentary

Introduction

Low back pain (LBP) is highly prevalent among individuals who engage in prolonged sitting with sedentary behavior, particularly in the younger population [1-4]. Studies have reported the percentage of young individuals who experience LBP being between 64.4 and 74.4 % [1-3]. Their pain is often exacerbated by the use of smartphones and laptops or prolonged sitting while studying online [1-3,5]. Low back pain causes decreased work productivity and increased medical costs due to prolonged functional impairment [6,7].

Prolonged sitting, which can be defined as sitting lasting 30 min or more, often leads to increased periods of inactivity and relatively enhanced levels of sedentary behaviors [8,9]. During sitting, the total body energy expenditure drops to a resting level due to the lack of physical activity in the major locomotor muscles, particularly in the muscles of extremities [10-13]. Conversely, muscle fatigue can be defined as an individual's lack of ability to maintain the required or expected force or power output [14]. Prolonged sitting can increase the fatigability of the trunk muscles, which are responsible for sustaining posture over time [4,15]. Sustained contraction of trunk muscles in seated postures has been identified as a cause of increased back muscle fatigue, the progression of which may eventually lead to LBP [4,15].

The muscles responsible for controlling the trunk can be categorized into 2 groups: Superficial and deep [16]. The superficial group comprises large torque-producing muscle, such as the rectus abdominis

(RA) and the thoracic part of the iliocostalis lumborum (ICLT). The deep muscles encompass the lumbar multifidus (LM), transversus abdominis (TrA) and internal oblique (IO). These deep muscles are characterized by their shorter length and direct attachment to the vertebrae. They play a pivotal role in generating sufficient force for segmental spinal stability [4,16]. Previous studies have reported that prolonged sitting can cause TrA and IO muscle fatigue, consequentially increasing spinal load on the lumbar spine [4,17]. Deep trunk muscles fatigue can reduce the lumbar spine's ability to withstand forces and exacerbate LBP [18-20]. These effects are likely due to muscle inactivity, leading to significant compression force from the upper body being transmitted to the passive spinal structures, which results in stress on the soft tissues [4,15,17,18]. On the other hand, some studies have reported that prolonged sitting has no effect on the alternation of trunk muscle contraction after 30 min of sitting [21-23].

Lumbar repositioning sense involves assessing the static and dynamic motor control of the lumbo-pelvic complex [24-30]. Röijezon *et al*. [26] and Clark *et al*. [27] reported activities that induced muscle fatigue related to an impairment in lumbar repositioning sense [31]. Impairment in the lumbar repositioning sense, known as lumbar repositioning error (LRPE), may contribute to the adoption of poor postures, leading to a loss of neutral spine alignment and a decreased mechanical advantage of the muscles [25-31]. LRPE can compromise segmental spinal stability, resulting in tissue damage and the progression of LBP [25,31,32]. When comparing lumbar repositioning sense between healthy participants and those with LBP, many studies have reported participants with CLBP exhibiting a higher LRPE compared to their healthy counterparts [29,33,34]. Meanwhile, Asell *et al*. [35] found no difference in LRPE between participants with LBP and healthy participants [36]. Nevertheless, the effect of prolonged sitting on LRPE in asymptomatic individuals compared to those with CLBP has not been investigated.

To our knowledge, this study is the 1st to investigate the effects of continuous sitting for 30 min on LRPE and pain scores in asymptomatic individuals and those with CLBP. This information will contribute fundamental knowledge about preventing LRPE, a potential cause of LBP, thus aiding researchers seeking to develop innovations to mitigate these issues.

Materials and methods

Study design

The study was a cross-sectional study conducted at the physical therapy laboratory. Ethical approval was obtained from the Human Research Ethics Committee of the University of Srinakharinwirot (SWUEC/E-048/2566), and the study was registered at clinicaltrials (registration number: TCTR20230527002).

Participants

All participants provided written informed consent before conducting the study protocol. The sample size was calculated using the *G**Power program (*G**Power version 3.1.9.6, University of Kiel, Germany). The calculation took into consideration the mean and standard deviations of LRPE between asymptomatic and CLBP participants (a pilot study), with an alpha of 0.05, power (1-β) of 80 %, and effect size of 0.83. The calculation determined that 25 participants per group were required.

Twenty-five asymptomatic and 25 CLBP participants were recruited via purposive sampling through electronic posters on social media platforms. Chronic low back pain was defined as pain between T12 and L5, limited to above knees-level, and had been present for at least 3 months [37]. The participants were diagnosed by a physical therapist who had 9 years of experience. The diagnosis was based on patient history and a physical examination. For the asymptomatic group, participants were included if they had been free from of LBP for at least 6 months, were aged between 18 and 39 years old, had a normal body mass index (BMI = 18.5 - 25 kg/m^2), and reported a sedentary lifestyle (continue sitting for more than 2 h per day) [4,10]. For the CLBP group, participants were included if they had been experiencing LBP for at least 3 months, had mild to moderate levels of pain on the numerical rating scale (NRS; 3 - 7 scale), were aged between 18 and 39 years old, had a normal BMI, and reported a sedentary lifestyle (sitting for more than 2 h per day) [4,10]. Participants with neurological deficits, spine pathology (e.g., spinal deformities, history of trauma and surgery in the lower back region), and those who were pregnant were excluded from both groups [4,17,34].

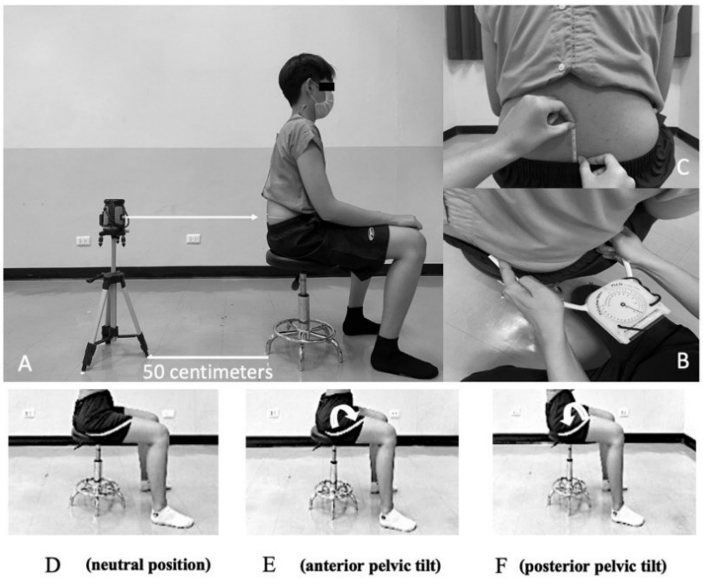

Figure 1 (A) A laser pointer was kept behind the participants for 50 cm and pointed at S1 as it is the starting point of the marked line. (B) A midpoint of the 10 cm tape measure was positioned on S1. (C) The pelvis and lumbar spine were manually aligned in an upright neutral position by sitting on a height-adjustable stool, and the inferomedial aspect of the ASIS and the PSIS were aligned using a PLAM. (D) The participant performed neutral position, (E) anterior pelvic tilt and (F) posterior pelvic tilt.

Experimental apparatus

Lumbar repositioning sense test

The lumbar repositioning sense test consists of 4 steps as follows:

The 1st step involved participants being seated on a height-adjustable stool, then they were individually adjusted to accommodate their sitting posture, ensuring their feet were firmly placed on the floor. The participants were given instructions to maintain alignment of their hips, knees and ankles at 90 º (**Figure 1(A)**).

In the 2nd step, the participants' pelvis and lumbar spine were manually positioned in an upright and neutral alignment. This alignment was accomplished by aligning the inferomedial aspect of the anterosuperior iliac spine (ASIS) and the posterosuperior iliac spine (PSIS), utilizing a Palpation Meter (PLAM) equipped with a spirit level (**Figure 1(B)**) [38,39].

The 3rd step consisted of placing a 10 cm tape measure with millimeter markings at the S1 point to serve as the initial reference point (**Figure 1(C)**). A laser level was positioned behind the participants at a 50 cm distance, and aimed at the S1 point, signifying the starting point of the marked line.

The 4th step involved instructing participants to memorise the neutral position (**Figure 1(D)**). Subsequently, participants were allowed to move their pelvis twice: from maximum anterior tilt (**Figure 1(E)**) to a maximum posterior tilt (**Figure 1(F)**), holding each position for approximately 5 s before returning to the neutral posture. Participants were given the opportunity to practice this repositioning test twice before the actual testing began. This procedure was repeated 3 times, with 1 min rest intervals between repetitions, and the average values of the measurements were used for subsequent analysis [25,34,40].

To ensure the reliability of the lumbar repositioning sense test, intra-rater reliability was assessed in 10 asymptomatic participants and 10 participants with CLBP. The measurements were analysed using the intra-class correlation coefficient (ICC). The ICC indicated excellent intra-rater reliability, with ICC (3,1) = 0.95 (95 % CI: 0.84 to 0.98) for asymptomatic participants and ICC (3,1) = 0.92 (95 % CI: 0.79 to 0.97) for CLBP participants.

Pain measurement

Pain in the lower back was measured using a 0 - 10 numeric rating scale (NRS), with 0 indicating no pain to 10 indicating the worst possible pain [41]. The NRS measurement has excellent test-retest reliability (r = 0.96). In terms of construct validity, the NRS was found to have a high correlation with the visual analogue scale, ranging from 0.86 to 0.96 [42].

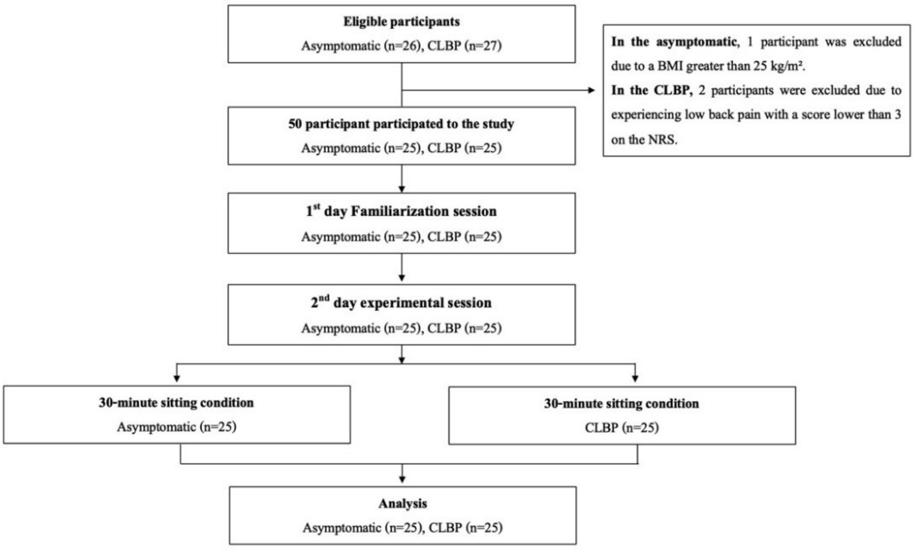

Figure 2 The study flowchart.

Procedure

The study procedure consisted of sequential steps, as shown in **Figure 2**. Participants were screened for the inclusion criteria, and appointments were scheduled to take place in the laboratory room on 2 consecutive days. On the 1st day, all participants attended a familiarization session to become acquainted with the study protocol.

On the 2nd day (experimental session), the participants arrived between 8 am and 10 am to minimize circadian fluctuations before the test trial [37,43]. The participants were instructed to engage in normal activities of daily living without vigorous physical performance [37,43]. The experimental procedure, including time points and outcome measurements, is shown in **Figure 3**. Participants sat in an adjustable chair as described in the lumbar repositioning sense test section. Baseline LRPE and pain measurements were recorded (T1). Throughout the test trials, participants engaged in a freestyle sitting position, without a backrest, ensuring their feet remained on the ground. They were allowed to engage with the mobile device for a duration of 30 min [21]. The participants were not permitted to stand during the test trials. Then, the LRPE and pain were measured (T2).

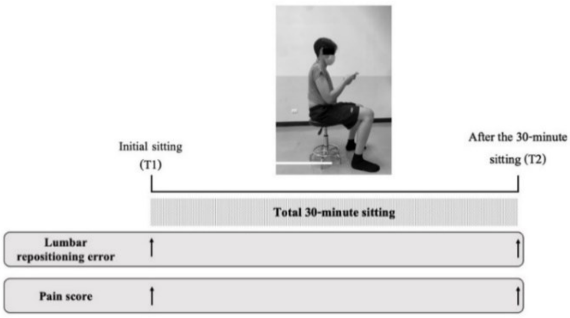

Figure 3 Overview of the experimental procedure. Arrows illustrate times of outcome measurement: Lumbar repositioning error and pain score.

Outcome measurements

The LRPE and pain outcomes were measured at the same time points (T1 and T2). The LRPE, measured in centimeters, was assessed using the lumbar repositioning sense test. For each LRPE measurement (T1 and T2), 3 data values were obtained on average and considered for analysis [12,31,34,40]. The LRPE data was reported in terms of the absolute error (AE) as it represents the error magnitude and is the most used statistic for measuring the LRPE. AE is the unsigned difference between positions [19,34,40]. The pain scale ranged from 0 (no pain) to 10 (worst possible pain). Pain data was assessed over a 30 min sitting condition.

Prior to statistical analysis, LRPE and pain values were assessed for normal distribution using the Kolmogorov-Smirnov test, which confirmed the assumption of normal distribution ($p > 0.05$). Independent paired samples t-tests were employed to examine the differences in LRPE between groups. Differences in LRPE within groups were assessed using dependent samples t-tests. Differences in pain within the groups for non-normally distributed data were analyzed using the Wilcoxon signed-rank test. Differences in pain between the groups were analyzed using the Mann-Whitney U test. A significance level of $p < 0.05$ was used for all statistical evaluations. Data analysis was performed using SPSS version 21.

Results and discussion

The demographic data of all participants are presented in **Table 1**. There were no significant differences in demographic characteristics between the groups ($p > 0.05$).

Table 1 Demographic of the participants (n = 25 in each group).

Characteristics	Asymptomatic group (n = 25)	Chronic low back pain group (n = 25)	*p*-value Between groups
Gender, n			
Male	10	10	
Female	15	15	
Age (years), Mean ± SD	20.48 ± 1.23	20.76 ± 1.27	0.95
Weight (kg), Mean ± SD	59.08 ± 8.58	58.32 ± 8.36	0.69
Height (cm), Mean ± SD	164 ± 8.40	164 ± 7.89	0.87
BMI (kg/m^2), Mean ± SD	22.16 ± 3.97	21.64 ± 3.03	0.42
Sitting time (h), Mean ± SD	5.32 ± 1.49	5.60 ± 1.89	0.47

Note: SD: Standard deviation, cm: Centimeter, Kg: Kilogram, m^2: Square meter and n: Number.

In the asymptomatic group, the LRPE remained unchanged after the 30 min of sitting condition (p = 0.066) (**Table 2**). However, in the CLBP group, there was a significant increase in LRPE after the 30 min sitting condition (p = 0.001). When comparing the groups, the CLBP group exhibited a significantly higher LRPE compared to the asymptomatic group after the 30 min sitting condition (p = 0.041).

Table 2 The results of absolute lumbar repositioning error before and after 30 min of sitting condition in both groups.

Groups/Conditions	Initial sitting (cm) Mean ± SD	After 30-min of sitting (cm) Mean ± SD	Mean difference ± SD (95 %CI) Within group	*p*-value Within group
Asymptomatic	0.89 ± 0.50	1.02 ± 0.54	–0.14 ± 0.37 (–0.29 to 0.10)	0.066
Chronic low back pain	0.96 ± 0.54	2.02 ± 0.66	–1.06 ± 0.85 (–1.42 to –0.71)	0.001
Mean difference ± SD (95 %CI) Between groups	–0.07 ± 0.14 (–0.36 to 0.20)	–0.99 ± 0.16 (–1.31 to –0.68)		
p-value Between groups	0.717	0.041		

Note: SD: Standard deviation, cm: Centimeter and n: Number.

Within-group comparisons showed a significant increase in pain intensity, as measured by the NRS, after the 30 min sitting condition in both the asymptomatic ($p = 0.001$) and CLBP ($p = 0.006$) groups (**Table 3**). When comparing between groups, the CLBP group reported a significantly higher pain intensity compared to the asymptomatic group both at baseline ($p = 0.001$) and after the 30 min sitting condition ($p = 0.001$).

Table 3 The results of the Numeric pain rating scale (NRS) before and after 30 min of sitting condition in both groups.

Groups/Conditions	Initial sitting (score)	After 30 min of sitting (score)	*p*-value Within group
Asymptomatic	0 (0 - 0)	2 (0 - 2.75)	0.001
Chronic low back pain	3 (3 - 3)	4 (3 - 4)	0.006
p-value Between groups	0.001	0.001	

Note: Data presented as median (interquartile range) of pain intensity.

Discussion

The aim of this study was to investigate the effects of prolonged sitting (30 min) on LRPE and pain in asymptomatic individuals and those with CLBP. The results of the study showed a significant increase in pain intensity, as measured by the NRS, in both groups after the 30 min sitting condition. However, the LRPE of the asymptomatic group remained unchanged, while the CLBP group exhibited a significant increase in LRPE after the 30 min sitting condition. Moreover, the CLBP group had significantly higher LRPE and pain intensity values compared to the asymptomatic group after the 30 min sitting condition.

The lower-back pain intensity increased in both groups after a 30 min sitting condition. This finding is supported by several studies [4,21,22]. The static load on the lumbar spine during prolonged sitting is associated with compression of the lumbar structures [20]. Sustained loading can increase the stress on the spinal structures [44], reduce local nutrition [45] and potentially lead to an increase in LBP. Moreover, Greene *et al*. [46] reported that both individuals with and without a prior history of LBP could have experienced transient pain developed over 1 h of sitting. They concluded that sitting-induced LBP did not appear due to posture or muscle activity; however, it may be related to micro-movement strategies (fidget frequency).

In our study, the LRPE in the asymptomatic group remained unchanged following a 30 min sitting condition. There are 2 plausible explanations for this observation. Firstly, our study did not specifically control and enforce a sustained sitting posture, such as a slump sitting posture. Previous research has shown that maintaining a slump sitting posture for just 5 min can induce LRPE in healthy individuals [47], possibly due to the viscoelastic effects on soft tissues and alterations in proprioceptive neuromuscular reflexes [26,28,47]. Secondly, the relatively short sitting duration of 30 min sitting in the asymptomatic group may have no impact on proprioceptive impairment. Activities inducing muscle fatigue can adversely affect proprioception, thereby leading to an increase in LRPE [25-31]. The previous study was reported by Jung *et al*. [21], who investigated the effects of smartphone use during a 30 min sitting condition on trunk muscle fatigue in healthy participants. They found that smartphone use during a 30 min sitting condition did not affect trunk muscle activity, but the participants reported significantly higher discomfort after prolonged sitting. The authors suggested that the relatively short measurement time may not have been sufficient to elicit significant fatigue in the trunk muscles, which could explain the lack of changes in muscle activity [21]. A similar finding was reported by Baker *et al*. [22], who found that trunk muscle fatigue in their participants did not change significantly, but discomfort in the lumbar region significantly increased after 2 h of prolonged sitting. Therefore, the lack of specific sitting posture control and the relatively short duration of the sitting condition in this study may explain why the asymptomatic individuals did not demonstrate LRPE after the 30 min sitting condition.

In contrast, participants with CLBP showed a significant increase in LRPE after the 30 min sitting condition, exceeding the minimal detectable change (MDC) for LRPE (mean difference: 1.06 cm). According to Enoch *et al*. [25], the MDC for LRPE is 0.92 cm. Previous studies have reported that individuals with CLBP have higher LRPE compared to healthy participants [19,34]. Tong *et al*. [19]

reported that patients with LBP have impaired lumbar proprioception compared to healthy individuals when measured in a sitting position. There is a possible link between sitting, especially prolonged sitting, and the exacerbation of LBP. A previous study reported that sitting for a duration ranging from 20 to 30 min can induce deep trunk muscle fatigue in CLBP participants [4]. Trunk muscle fatigue during prolonged sitting can increase the transmission of force to passive spinal structures, resulting in stress on the soft tissues. An impaired lumbar positioning sense may contribute to the maintenance of poor posture, which can lead to lumbar instability and LBP [15,17,18].

Based on the results of this study, it is recommended that individuals, particularly young people with sedentary behavior, should avoid continuous sitting for more than 30 min, especially those with CLBP, to prevent LRPE that may contribute to increased lumbar spine problems. However, it is important to acknowledge the limitations of this study. First, the investigation was conducted on young participants within a narrow age range in a laboratory setting. Future studies should be broadened in some workplace settings to replicate real-life situations. Secondly, this study did not control for specific sitting posture during the 30 min test period. Future studies should explore fidgeting, as it has been reported to be associated with the development of LBP. Finally, the relatively short duration of the 30 min sitting trial might not have had a significant impact on proprioceptive impairment in the asymptomatic group. A longer sitting trial could potentially reveal differences in lumbar proprioception.

Conclusions

The results of the current study indicate that continuous sitting for 30 min can increase pain intensity in both asymptomatic individuals and those with CLBP. Specifically, the CLBP group experienced a significant increase in LRPE after the 30 min sitting condition. Therefore, prolonged sitting for 30 min appears to impact back pain. Accordingly, physical therapists should advise people with sedentary lifestyles with low back pain to refrain from sitting for 30 min.

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