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The Effect of Time of Day on Lumbar Repositioning Sense Variability in Asymptomatic Participants with Seated Sedentary Behavior Over Two Consecutive Days

Pongsatorn Saiklang[1,*], Thiwaphon Chatprem[2,3], Orapin Karoonsupcharoen[1], Nitaya Viriyatharakij[1], Parvinee Saiklang[4] and Rungthip Puntumetakul[2,3]

[1]Department of Physical Therapy, Faculty of Physical Therapy, Srinakharinwirot University, Bangkok 10110, Thailand
[2]School of Physical Therapy, Faculty of Associated Medical Sciences, Khon Kaen University, Khon Kaen 40002, Thailand
[3]Research Center in Back, Neck, Other Joint Pain and Human Performance, Khon Kaen University, Khon Kaen 40002, Thailand
[4]Faculty of Nursing, Chulalongkorn University, Bangkok 10330, Thailand

([*]Corresponding author's e-mail: pongsatornsa@g.swu.ac.th)

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Abstract

Prolonged sitting is associated with sedentary behavior and lumbar repositioning error (LRPE), a factor linked to low back pain (LBP). The measurement of LRPE is commonly used to assess the effectiveness of interventions in preventing LBP. However, the impact of time of day and day-to-day variability on LRPE measurements during a sitting condition remains unclear. The primary aim of the current study is to investigate whether the variability of LRPE in the sitting condition is influenced by the time of day and 2 consecutive days among asymptomatic participants. Fifty asymptomatic participants were enrolled, and LRPE measurements were taken before and after a 30-minute sitting condition conducted in the morning and afternoon over 2 consecutive days. The findings revealed no significant difference in LRPE magnitude between morning and afternoon sessions. However, a slight increase in variability was observed in the afternoon (initial sitting: 1.21 cm, post-sitting: 1.27 cm) compared to the morning (initial sitting: 1.10 cm, post-sitting: 1.16 cm). These findings suggest that future LRPE investigations can be conducted either in the morning or afternoon. However, it is crucial to control for measurement times due to the influence of variability on LRPE outcomes. The study also demonstrated specific levels of natural variation in LRPE measures across different days and times of the day. Any changes beyond the reported results can potentially be attributed to the effects of the intervention.

Keywords: Repositioning error, Circadian fluctuation, Lumbar spine, Proprioception, Time of day, Sedentary, Minimal detectable change

Introduction

Low back pain (LBP) is a prevalent complaint among sedentary workers globally, and prolonged sitting during work hours has been identified as a significant contributor to increased pain [1-7]. Sitthipornvorakul *et al.* (2015) conducted a study involving 367 office workers to evaluate the occurrence of LBP over a year. They found that 14 % of the participants developed new-onset LBP [8]. Furthermore, in a one-year follow-up study of 615 healthy office workers, Janwantanakul *et al.* (2018) reported a first episode of LBP in 16.4 % of the participants [9]. The consequences of LBP on workers include reduced work productivity and increased medical expenses due to prolonged functional limitations [7,10,11]

Proprioception refers to the sense of positioning and movement generated by sensory organs embedded in structures such as ligaments, intervertebral discs, facet joints, and muscles [12-16]. The information originating from these proprioceptors travels to the processing area that then generates the appropriate muscle activation response. Inaccurate afferent input can affect all aspects of motor control, ranging from simple reflex responses to complex movements [15-17]. Several studies have reported a correlation between LBP and decreased acuity in spinal motion and impaired ability to reposition accurately [18-22].

Sedentary behavior is defined as characterized by an energy expenditure less than or equal to1.5 metabolic equivalents (METs) while in a sitting or reclining position when awake [23]. Sedentary workers' experience is associated with increased levels of inactivity, often accumulated through uninterrupted and prolonged sitting for at least 30 min [24]. Prolonged sitting has been associated with fatigue in the trunk muscles caused by continuous contraction even in a seated posture [25,26]. Fatigue in the deep trunk muscles reduces the muscular support provided to the spine, placing more stress on ligaments and intervertebral discs [25-27]. Deep trunk muscle fatigue also leads to a loss of coordination and control of the spinal segment, resulting in impaired lumbar motor control [15,16]. Altered contraction patterns of deep trunk muscles may contribute to a diminished sense of joint repositioning and repeated microtrauma [16,19,20]. Thus, prolonged sitting postures can influence lumbar stability and ultimately lead to LBP [26-29].

Clinical assessment of proprioception should employ tests for measuring joint position sense [15,16,30]. Lumbar proprioception in the sitting position can be assessed using the lumbar repositioning test that was reported by Enoch *et al.* [30]. This test is commonly used in clinical settings for diagnosis and to reassess the effectiveness of the intervention [30-32]. It measures an individual's ability to control the position of his/her lumbar spine and is known in the name of the lumbar repositioning error (LRPE) [19,20]. Enoch *et al.* (2011) reported excellent reproducibility of the LRPE. They explain this high reliability of LRPE because their study completed the LRPE by experiencing physiotherapies and assessed LRPE only within an hour on 1 day [30]. However, to confirm the reproducibility of the LRPE, day-to-day variability evaluation is needed.

Errors in the measurement can occur due to variations in physiological response or changes in individual performance [17,33,34]. Previous studies reported that circadian fluctuation affects spinal structures with the altered performance of simple motor tasks [17,35]. Researchers have suggested that diurnal variations in spinal mechanics are clinically significant as different lumbar structures experience varying loads at different times of the day, affecting the onset and severity of symptoms [35,36]. For instance, Adams *et al.* (1990) found that spinal mechanics and discal fluid content can vary throughout the day. In the morning, intervertebral discs tend to have higher fluid content, potentially affecting their ability to manage load and increasing stress on the discs and ligaments [35]. Conversely, in the afternoon, discal fluid content was decreased, leading to decreased joint stability and reduced capacity to manage the load on the lumbar spine such as the facet joint capsule during activities [33,37,38].

Varying loads on lumbar structures at different times of the day may induce differences in LRPE response, possibly due to the viscoelastic effects on soft tissues and alterations in proprioceptive neuromuscular reflexes [15,17,39]. Therefore, researchers should carefully control the time of measurement each day as it becomes challenging to determine whether the recorded test response truly reflects natural fluctuations or measurement variation [17,33,40,41]. Thus, measuring the variability of LRPE response over 2 consecutive days is crucial to confidently attribute any observed differences to an intervention rather than estimated time-of-day effects or measurement variation.

To date, there is no previous study that investigated the variability of lumbar repositioning responses in the sitting condition in the morning and afternoon among asymptomatic participants. Therefore, the primary objective of the current study is to examine whether the variability of LRPE in the sitting condition is affected by the time of day and 2 consecutive days among asymptomatic participants. The second objective is to compare the magnitude of LRPE between the morning and afternoon during prolonged sitting. The results of the current study will provide knowledge of natural variations of LRPE response over 2 consecutive days in the morning and the afternoon. So, the researchers could enable our information to determine the time for applying the intervention and assess the LRPE in the clinical setting.

Materials and methods

Study design

A same-participant, test-retest design was employed to investigate the effect of time of day on the variability of lumbar repositioning sense in asymptomatic participants over 2 consecutive days. The study was conducted at the physical therapy laboratory of. Ethical approval was obtained from the Human Research Ethics Committee of the University of (SWUEC/E-048/2566), and the study was registered at clinicaltrials.in.th (registration number: TCTR20230527002).

Participants

Fifty asymptomatic participants, comprising both males and females, were recruited through electronic posters on social media. The participants were included if they had been free from 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 prolonged sitting lifestyle (sitting continuously for at least 2 h per day) [26,34].

Participants with neurological deficits, spine pathology, sacroiliac joint pathology, lower back muscle injury, or who were pregnant were excluded [21]. All participants provided written informed consent before they participated. The sample size was determined based on considerations for establishing clinical test-retest standards, with a minimum requirement of 50 participants as reported by McMillan and Hanson (2014) and Vet *et al.* [42,43].

Experimental apparatus

Lumbar repositioning sense test

To test the LRPE, participants were asked to sit in an adjustable chair and instructed to maintain a sitting posture while keeping their hips, knees, and ankles at 90 degrees. Their feet were supported, arms crossed on their chest, and their lumbar spine held in a neutral position. The pelvis and lumbar spine were manually positioned into an upright neutral position by aligning the inferomedial aspect of the anterosuperior iliac spine (ASIS) and the posterosuperior iliac spine (PSIS) using a Palpation Meter with a spirit level **Figure 1(A)** [44-45]. A 10-centimeter tape measurement with millimeter markings was placed on the first sacral spine (S1) as the starting point **Figure 1(B)**. A Laser Lever device was positioned directly on the start point of the marked line **Figure 1(C)**. Participants were instructed to remember the neutral position and then move their pelvis twice, from maximum anterior to maximum posterior tilt **Figures 1(D) - (E)**, holding each position for approximately 5 s before returning to the neutral position. Participants were allowed to practice the repositioning test twice before the actual test commenced. The procedure was performed 3 times, with one-minute rest intervals, and the average values of the measurements were used for analysis [21,30,31]. The researcher observed the correct movement of the pelvis during the measurement process. Deviance from the start point was measured in centimeters as a LRPE. The value of LRPE was calculated as an absolute error (AE) as it represents error magnitude and is the most used measure. AE is the unsigned difference between start point [19,21,31].

To ensure the reliability of the lumbar repositioning sense test, inter- and intra-rater reliability was assessed in the ten asymptomatic participants. The measurements were analyzed using the intra-class correlation coefficient. The ICC indicated excellent intra-rater reliability ICC (3,1) = 0.95 (95 % CI: 0.84 to 0.98) and inter-rater reliability ICC (2,1) = 0.94 (95 % CI: 0.88 to 0.97).

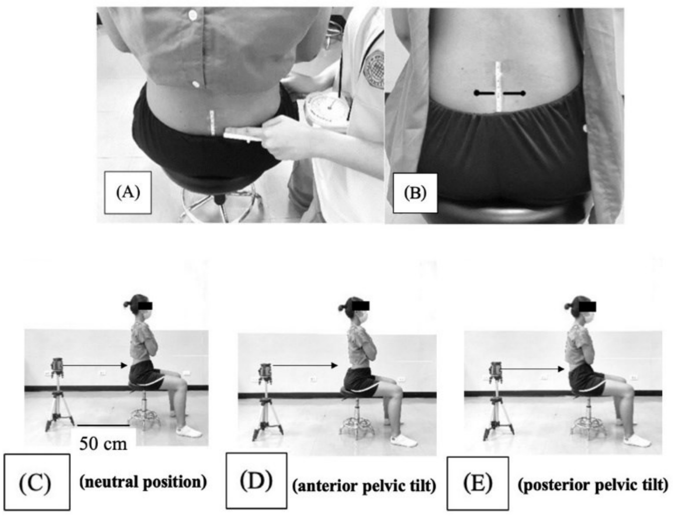


Figure 1 The LRPE testing: (A) the participant was aligned in an upright neutral position by the Palpation Meter (PLAM) with a spirit level, (B) the S1 level was marked, (C) A Laser Lever device was positioned directly to the start point of the marked line, (D) The participant performed anterior pelvic tilt, and (E) The participants performed posterior pelvic tilt.

Procedure

The study procedure consisted of sequential steps as follows in **Figure 2**. Participants were screened for inclusion criteria, and appointments were scheduled for them to attend the laboratory room on 5 separate days. On the first day, all participants attended a familiarization session to become acquainted with the study protocol. Participants were then randomized to different sessions using a complete block design, with session allocation kept confidential using a closed, opaque box. The participants were randomly assigned to either the morning or afternoon measurement testing in week 1, and then switched to the opposite session in week 2, with a one-week interval between the two measurement periods.

Participants assigned to the Morning testing group were measured in the morning during week 1 (on the second and third days) and in the afternoon during week 2 (on the fourth and fifth days). Conversely, participants assigned to the Afternoon testing group underwent afternoon measurements in week 1 (on the second and third days) and morning measurements in week 2 (on the fourth and fifth days).

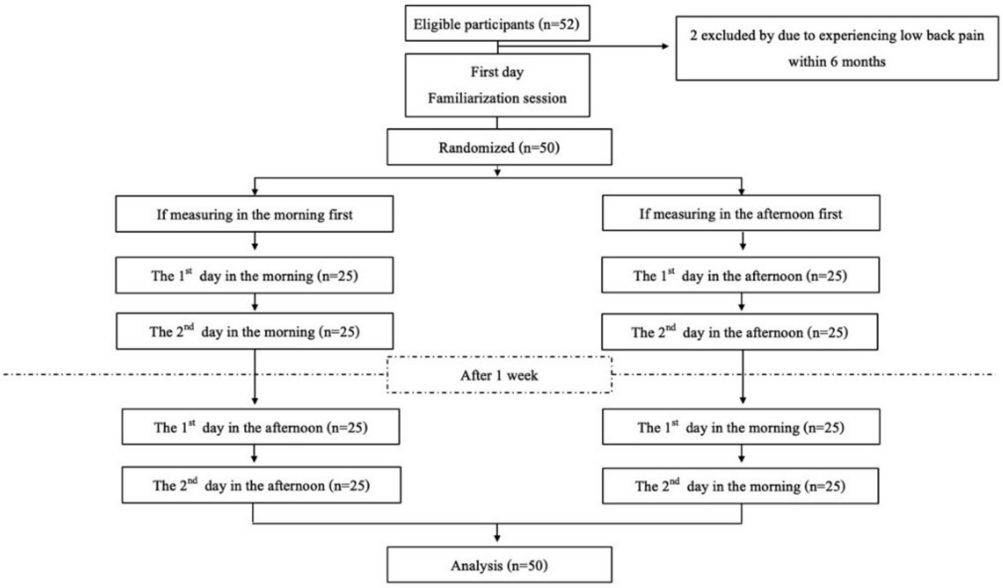


Figure 2 The study flowchart.

Conditions

Morning condition

Participants attended in the laboratory room between 8 and 10 am [33,34] and assumed the upright sitting position on the adjustable chair, as described in the lumbar repositioning sense test section.

Afternoon condition

Participants were asked to attend between 2 and 4 pm [33,34], and the same procedure as in the morning session was followed.

Experimental

On the experimental days, participants arrived in the morning condition between 8 and 10 am, and in the afternoon condition between 2 and 4 pm. On the day of measurement, they were instructed to engage in normal activities of daily living without heavy physical performance [17]. The experimental procedure, including time points and outcome measurements, is shown in **Figure 3**. Participants sat in the adjustable chair without a backrest as described earlier. A baseline lumbar repositioning sense measurement set was recorded (T1). During the 30-minute experiment, the participants are allowed to sit in their preferred position while keeping their feet on the floor. They can engage with the mobile device without any support for 30 min [24,46]. The lumbar repositioning sense (T2) was then measured. Participants were not allowed to stand during the test trials.

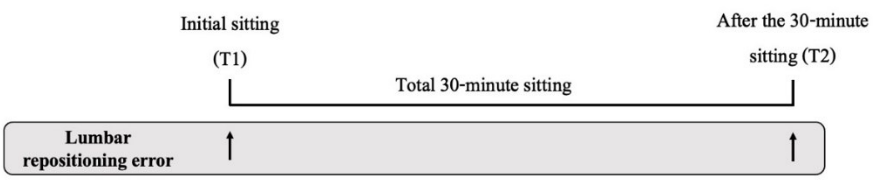


Figure 3 An overview of the experimental procedure. Arrows illustrate times of lumbar repositioning error measurement.

Data analysis

Before statistical analysis, the Shapiro-Wilk test was used to assess the normal distribution of the LRPE value, which confirmed the assumption of normal distribution ($p > 0.05$). Paired t-tests were employed to examine the differences in the magnitude of LRPE between the time of day (Morning and Afternoon) and over 2 consecutive days. The means of standard deviations (Mean ± SDs) between the 2 consecutive days were calculated in centimeters. Regarding the report of the variability of LRPE, mean±standard deviation (SD), standard error of measurement (SEM), and minimal detectable change (MDC) were evaluated. Mean ± SDs were determined by averaging the standard deviation of the LRPE response between the 2 days for everyone. Lower Mean ± SD scores relative to the means indicate smaller measurement variability [33,34,40]. The SEM was calculated to reflect the random variability of an individual's scores on repetitive examinations. The SEM defines the range of magnitude of LRPE that can be expected on repetitive examination [33,34,40]. The MDC was calculated using the formula: $MDC = SEM \times \sqrt{2} \times 1.96$. In order to give clinicians information about the minimal change that is not due to the measurement error. The MDC signifies the smallest detectable difference in a measured variable that can be confidently attributed to actual change rather than measurement error or random variability. Low MDC scores relative to the means indicate smaller measurement variability. It serves as a benchmark for determining the significance and meaningfulness of observed changes in the variable under investigation [30].

A significance level of p-value < 0.05 was used for all statistical evaluations. Data analysis was performed using SPSS version 21.

Results and discussion

Fifty participants completed the study experiment. The demographic characteristics of the participants are presented in **Table 1**.

Table 1 Baseline characteristics of the participants (n = 50).

Characteristics	Mean ± SD
Sex (male/female)	27/33
Age (years)	19.44 ± 0.79
Body mass (kg)	57.59 ± 11.94
Height (cm)	163.40 ± 7.48
Body Mass Index (kg/m^2)	21.53 ± 4.08

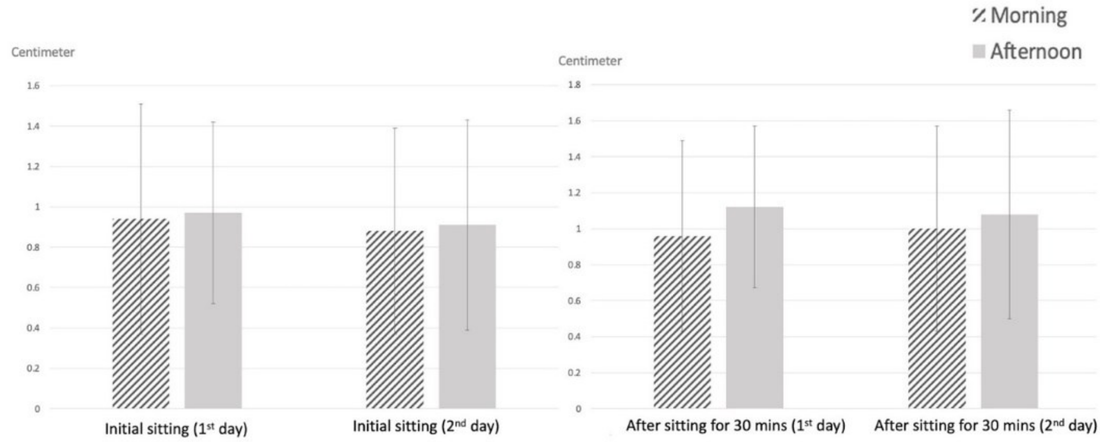
Abbreviation: SD; standard deviation, kg; kilogram, cm; centimetre, m^2; square meter.

Comparing the effect of a 30-minute sitting condition on the magnitude of LRPE. The LRPE before and after the 30-minute sitting did not show a significant difference (**Table 2**). In the afternoon condition, there was a tendency for LRPE to increase, but the difference was not statistically significant (Morning in day 1 p-value = 0.811; Morning in day 2 p-value = 0.091; Afternoon in day 1 p-value = 0.201; Afternoon in day 2 p-value = 0.081).

Table 2 The Absolute LRPE response before and after the 30-minute sitting.

	Morning		**Afternoon**	
	1st day	2nd day	1st day	2nd day
Initial sitting	0.94 ± 0.57	0.88 ± 0.51	0.97 ± 0.45	0.91 ± 0.52
After sitting for 30 min	0.96 ± 0.53	1.00 ± 0.57	1.12 ± 0.45	1.08 ± 0.58
p-value	0.811	0.091	0.201	0.081

Comparing the effect of the magnitude of LRPE on 2 consecutive days and at different times of the day. As **Figure 4**, the LRPE response on 2 consecutive days did not significantly differ between the morning (initial sitting p-value = 0.494; After sitting p-value = 0.675) and afternoon (initial sitting p-value = 0.513; After sitting p-value = 0.694) sessions for both 1st and 2nd day. Furthermore, there were no significant differences in the LRPE response between morning and afternoon measurements on 1st day (initial sitting *p*-value = 0.711; After sitting *p*-value = 0.100) and 2nd day (initial sitting *p*-value = 0.720; After sitting *p*-value = 0.455).



Initial sitting (centimeter)			
	1st day	2nd day	P-value
Morning	0.94±0.57	0.88±0.51	0.494
Afternoon	0.97±0.45	0.91±0.52	0.513
P-value	0.711	0.720	

After sitting for 30 mins (centimeter)			
	1st day	2nd day	P-value
Morning	0.96±0.53	1.00±0.57	0.675
Afternoon	1.12±0.45	1.08±0.58	0.694
P-value	0.100	0.455	

Figure 4 The LRPE responses were at different times of the day for 2 consecutive days.

The variability of LRPE responses at different times of the day on 2 consecutive days in participants is presented in **Table 3**. The results showed slightly higher variability of LRPE in the afternoon compared to the morning.

Table 3 Variability of LRPE response at different times of day on 2 consecutive days in asymptomatic participants (N = 50).

	Measurement on 2 consecutive days (Morning)		**Measurement on 2 consecutive days (Afternoon)**	
	Initial sitting (T1)	**After the 30-minute sitting (T2)**	**Initial sitting (T1)**	**After the 30-minute sitting (T2)**
Mean ± SDs	0.29 cm	0.35 cm	0.40 cm	0.39 cm
SEM	0.40 cm	0.42 cm	0.44 cm	0.46 cm
MDC	1.10 cm	1.16 cm	1.21 cm	1.27 cm

Abbreviation: Mean ± SDs; Means of standard deviations, SEM; Standard error of measurement, MDC; minimal detectable change, cm; centimeter.

Discussion

The primary aim of the current study was to investigate the variability of LRPE in asymptomatic participants after a 30-minute sitting condition to determine the influence of time of day for over 2 consecutive days. The second aimed to compare the magnitude of LRPE at different time points.

For the magnitude of LRPE, the results revealed no significant differences between morning and afternoon sessions and between consecutive days (1st and 2nd day) during the initial sitting and post-sitting conditions. The results of the current study are consistent with the findings of Kwon and Nam (2014), who compared circadian fluctuations in joint repositioning sense in healthy subjects [17]. A possible explanation for this situation may be related to trunk muscle fatigue and altered neuromuscular coordination during the sitting condition [12,19,20]. In addition, the 30-minute sitting duration might not be sufficient to induce trunk muscle fatigue. This is supported by a study by Jung *et al.* (2020), which examined deep trunk muscle fatigue in individuals without LBP during a 30-minute sitting posture. Their study found no significant change in the median frequency of the deep trunk muscles after the sitting posture [46]. The authors suggested that the measured posture might not elicit sufficient fatigue in the trunk muscles within the relatively short period of measurement [46]. Therefore, the lack of difference in the magnitude of LRPE between time points can be attributed to the limited effect of the 30-minute sitting condition on lumbar motor control.

To the best of our knowledge, this study is the first that investigated the variability of LRPE response in the morning and afternoon on a period consecutive day. The results indicated a slightly higher level of variability in LRPE response between two consecutive days in the afternoon compared to the morning (**Table 3**). This may be attributed to the impact of activities performed earlier in the day, which could influence spinal mechanics and discal fluid content [33,35,36,40], leading to day-to-day variability in LRPE.

Considering diurnal variations when assessing LRPE is important [17]. Controlling for the time of day during testing sessions can help minimize confounding factors and provide a clearer understanding of the true variability in LRPE. In asymptomatic individuals, a meaningful response should exceed the values of 1.10 cm (initial sitting) and 1.16 cm (after the 30-minute sitting) in the morning, and 1.21 cm (initial sitting) and 1.27 cm (after the 30-minute sitting) in the afternoon between two consecutive days. Moreover, the results of the current study are higher than those reported by Enoch *et al.* (2011), where they found the MDC within a day to be 0.85 cm [30].

Nevertheless, this study has some limitations. Firstly, the participants consisted of young individuals within a narrow age range, specifically asymptomatic individuals. Therefore, the findings may not be generalizable to other age groups or individuals with symptomatic conditions such as low back pain. Secondly, the activity data of the participants during the measurement day should be considered in future investigations. This data demonstrates that investigators can have confidence in monitoring participants' activities to control factors that could affect the results. For example, smartwatch devices can be utilized for this purpose. Additionally, the short duration of the sitting condition might have limited the significant effect on LRPE. Further research is warranted to explore the impact of sitting on the variability and magnitude of LRPE in older age groups, individuals with low back pain, and those subjected to prolonged sitting conditions. This would help to further validate the value of LRPE as an indicator of lumbar motor control.

Conclusions

The findings of this study indicate that there was no significant difference in the magnitude of LRPE between the morning and the afternoon. These results suggest future studies that LRPE can be conducted either in the morning or the afternoon because the period has no impact on the measured outcomes. However, it should be noted that the variability of measurements influenced the LRPE response at different times of the day. Therefore, careful control of the time at which LRPE investigations are conducted is crucial to minimize potential confounding factors. Based on the results of this study, it can be suggested that for an intervention to elicit a noticeable effect on the LRPE response in young asymptomatic individuals, a response exceeding 1.10 cm (initial sitting) and 1.16 cm (after the 30-minute sitting) in the morning, and 1.21 cm (initial sitting) and 1.27 cm (after the 30-minute sitting) in the afternoon between consecutive days is required. This information can be valuable for guiding future investigations in this field and establishing meaningful benchmarks for assessing the effectiveness of interventions.

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