

# Habitual pelvic posture and time spent sitting: Measurement test–retest reliability for the LUMObac device and preliminary evidence for slouched posture in individuals with low back pain

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Hiroshi Takasaki

## Abstract

**Objectives:** It has been difficult to monitor the pelvic position during actual daily life. However, recent developments in wearable device technologies, such as the LUMObac device, provide the possibility to evaluate habitual pelvic posture and time spent sitting during daily life. The current study aimed (1) to investigate test–retest reliability for habitual pelvic posture and time spent sitting with the LUMObac in individuals with prolonged low back pain (low back pain group) and without low back pain (control group), and (2) to preliminarily investigate differences in those measures between groups.

**Methods:** Fifteen individuals in each group wore the LUMObac daily for 2 weeks. Intraclass correlation coefficients were calculated in each group by comparing the mean from the first week with the mean from the second week: (1) for the posture score, which is a proportion of time with neutral posture, and (2) for time spent sitting. The two measures for the first week were compared between the low back pain and control groups.

**Results:** The intraclass correlation coefficients for the posture score were .82 in the low back pain group and .91 in the control group. The intraclass correlation coefficients for time spent sitting were .75 in the low back pain group and .85 in the control group. The posture score in the low back pain group (mean  $\pm$  SD: 37.5%  $\pm$  10.3%) was less than that in the control group (49.6%  $\pm$  6.0%;  $p < .001$ ), but there was no difference in time spent sitting between the groups ( $p > .05$ ).

**Conclusions:** The current study found (1) acceptable test–retest reliability for the posture score and time spent sitting evaluated by the LUMObac device, and (2) preliminary evidence of a difference in the posture score, indicating a more slouched lumbopelvic posture in individuals with prolonged low back pain than those without low back pain.

## Keywords

Habits, posture, test–retest reliability, wearable device

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## Introduction

It is considered that a prolonged awkward posture, which produces continuous mechanical loading to certain tissues in a certain direction, may result in structural damage or symptoms.<sup>1,2</sup> Thus, it may be possible that prolonged slouched posture, which accompanies posterior pelvic tilt, can be a risk factor for the development of low back pain (LBP).<sup>3</sup> However, it has been unclear whether individuals with LBP have more prolonged posterior pelvic tilt than individuals without LBP.

It has been difficult to monitor the pelvic position during actual daily life. However, recent developments in wearable device technologies provide the possibility to evaluate spine

and pelvic posture during everyday life.<sup>4,5</sup> The LUMObac (Lumo Bodytech Inc., Mountain View, CA, USA) device (Figure 1) continuously monitors the pelvic position during everyday life, and data can be saved to an iPhone, iPad or iPod (Figure 2). O’Sullivan et al.<sup>4</sup> reported acceptable

Department of Physical Therapy, Saitama Prefectural University, Koshigaya, Japan

### Corresponding author:

Hiroshi Takasaki, Department of Physical Therapy, Saitama Prefectural University, Sannomiya 820, Koshigaya 343-8540, Japan.  
Email: takasaki-hiroshi@spu.ac.jp



test–retest reliability (intraclass correlation coefficient (ICC)=.84-.87) for the BodyGuard™ (Sels Instruments,

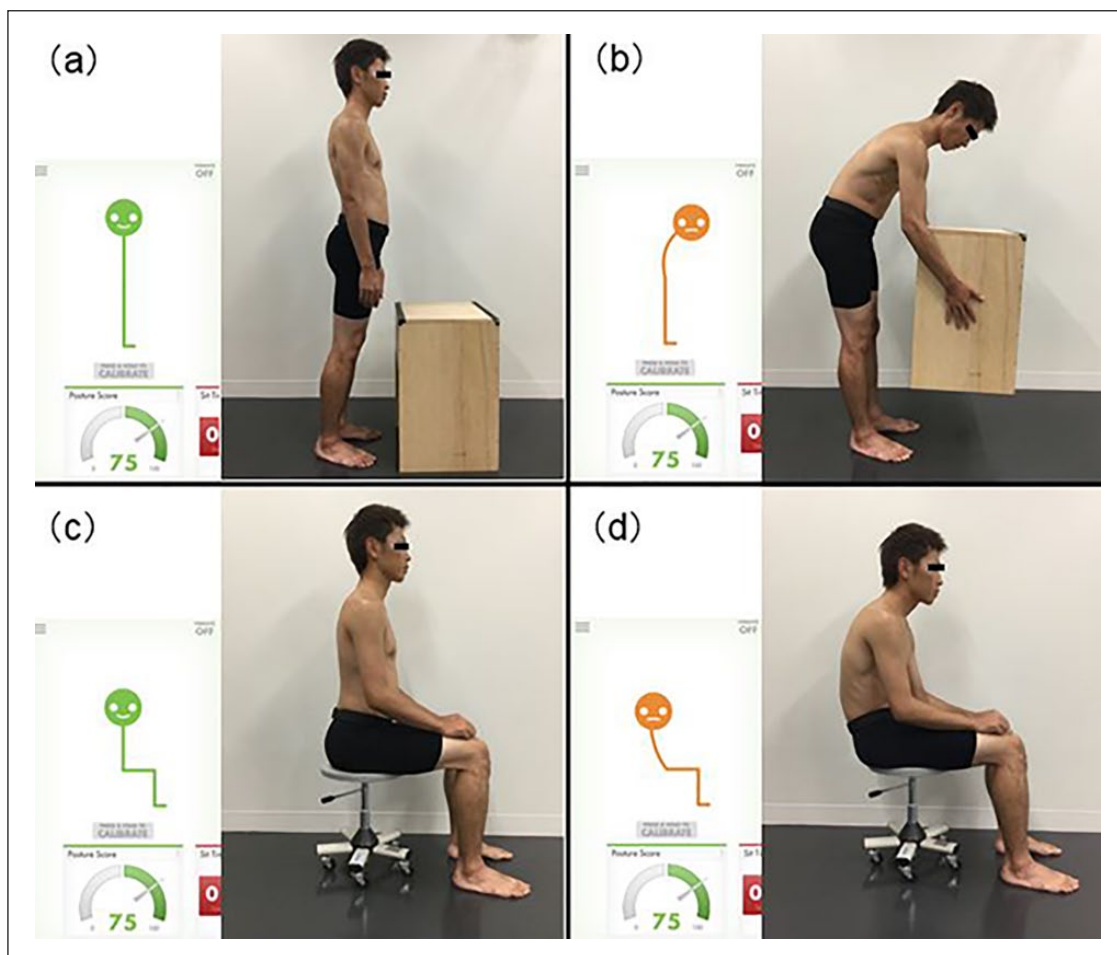


**Figure 1.** LUMObac.  
The LUMObac was placed around L5-S1 level.

Vorselaar, Belgium), wearable device, but this requires two adhesive tapes to fix a strain gauge, which has no feed-back function. In contrast, the LUMObac device is easy to use by simply wearing a belt and has the option to provide real-time feedback of a slouched posture by a vibration alert. As the LUMObac device is relatively inexpensive (approximately US\$150), it has the potential to be used by many people to monitor and therefore improve their habitual lumbopelvic posture.

A first step in the evaluation of the potential application of the LUMObac device is to evaluate measures of test–retest reliability, including the evaluated posture score and time spent sitting, which has not been established yet. It is also clinically important to investigate the minimum detectable change (MDC) of the posture score and time spent sitting in individuals with LBP. The MDC enables us to evaluate the effect of postural education and behavioral modifications on a patient with LBP in clinical practice.

The purpose of this study was twofold. The first aim was to investigate test–retest reliability and MDC of the posture score and time spent sitting, from data recorded by the LUMObac device when worn over an extended period of



**Figure 2.** Examples of postures and LUMObac displays: (a) neutral standing, (b) bending forward, (c) neutral sitting and (d) slouched sitting.

time during routine daily living, in individuals with and without LBP. The second aim was to investigate if there was a difference in the posture score and time spent sitting between individuals with and without LBP.

## Methods

### Participants

A sample of convenience from a university setting in Japan was used in this study. Participants contacted the author via university advertisements from August 2016 to September 2016. Individuals between 20 and 60 years of age were eligible. Individuals with diagnosed structural deformity (e.g. scoliosis) or diagnosed neurological disorders or individuals who had activities involving a prolonged trunk extension posture (e.g. ceiling plasterers or painters) were not considered eligible. Specific inclusion criteria for individuals with LBP (LBP group) were persistent LBP lasting for more than 3 months. Those with LBP who had a score of less than 12% on the Oswestry Disability Index (ODI)<sup>6,7</sup> was not considered eligible as 12% is the cut-off score for disability in a Japanese population.<sup>8</sup> Specific inclusion criteria for individuals without LBP (control group) were no history at any time of LBP lasting more than 24h.<sup>9,10</sup>

This study was cleared by the institutional human medical ethics committee of the Saitama Prefectural University (No. 27110). Written informed consent was obtained prior to data collection.

### Measurements

**LUMObac.** The LUMObac device consists of a microcontroller, accelerometer, flash memory, Bluetooth chip and haptic motor. The algorithm on the LUMObac sensor normalizes and calibrates the accelerometer data and transforms into angular data. The LUMObac device measures the angle of a user's pelvis when they are sitting or standing with resolution of 1°. The algorithms in the application (ZERO2ONE, inc; Lumo Back: Real-Time Posture Feedback; <https://itunes.apple.com/app/lumo-back-real-time-posture/id575786694?mt=8>) can detect multiple activity states including running, walking, sitting, standing, laying down and in a car. Participants were instructed to wear the LUMObac at the level of the L5-S1. In the current study, participants were asked to undertake the calibration in neutral standing when they first put on the LUMObac in the morning. Once it is calibrated, the LUMObac device can determine the angle of the pelvis relative to the calibrated angle. The calibration is also undertaken automatically when the user walks for  $\geq 30$ s. The participants were also asked to check whether LUMObac data were correctly saved in the iPhone, iPad or iPod on a daily basis. Familiarization in wearing the LUMObac device, undertaking the calibration, and checking data saving with trouble shooting maneuvers were undertaken with each participant.

**Primary measures.** All participants were asked to wear the LUMObac device daily for 14 consecutive days to enable capture of data regarding posture during daily life except when playing water sports, taking a shower and sleeping. The secondary aim of the study was masked from the participants in order to minimize the possibility that the participants would alter their pelvic posture and time spent in sitting in order to compete against the control group. The participants were asked to act as usual to enable measurement of habitual pelvic posture and time spent in sitting. In the current study, a posture score and time spent sitting in minutes was collected using the LUMObac device and used as the primary measure.

The posture score is a proportion of time with neutral posture to the time with a posture either slouched or hyper-extended above a pre-determined threshold. In the current study, a threshold was chosen as "very slouched" based on consensus opinions as clinically meaningful slouched posture from three expert physical therapists who had achieved a Diploma in the Mechanical Diagnosis and Therapy (MDT) education program. The MDT is one of the most commonly used physical therapy approach for the management of LBP<sup>11-13</sup> and diploma holders have advanced skills of the physical evaluation. Pelvic angles at "very slouched" were  $\geq 7^\circ$  posterior or  $\geq 14^\circ$  anterior tilt of the pelvis relative to the calibrated angle in sitting and  $\geq 8^\circ$  posterior or  $\geq 12^\circ$  anterior tilt of the pelvis relative to the calibrated angle in standing. Technically, the posture score is affected by the hyper-anterior tilt of the pelvis relative to the calibrated angle in standing. However, all participants in the current study were students, who were more likely to sit for prolonged periods, and no subjects reported activities with an extended posture. Thus, the posture score in the current study is most likely to reflect posture of the posteriorly tilted pelvis predominantly.

**Secondary measures.** All participants provided demographic information and completed the International Physical Activity Questionnaire short version (IPAQ),<sup>14,15</sup> the P4<sup>16</sup> and the Medical Outcomes Study (MOS) 36-Item Short-Form Health Survey version 2 (SF-36v2) in order to understand characteristic of the participants. The LBP group also provided the ODI and symptom duration, which was defined as the number of months since the last pain-free month according to a previous recommendation.<sup>10</sup> These secondary measures were collected as these were considered to be potential factors influencing the primary measure and/or useful information to understand group characteristics.

The IPAQ is a reliable and valid self-reporting questionnaire for assessing physical activity level.<sup>15,17</sup> The IPAQ has seven items and average activity level is calculated with minutes  $\times$  Mets.<sup>18</sup> The P4 is a reliable and valid four-item questionnaire with four 0–10 numerical rating scales (0: no pain, 40: the highest possible pain level).<sup>19</sup> The SF-36v2 is an established measure for health status<sup>20</sup> and eight health status variables can be evaluated (physical function, role

physical, bodily pain, general health, vitality, social function, role emotional and mental health).<sup>21</sup> The value of 50 is the national standard value and higher value indicates better health status.<sup>22</sup>

### Statistics

Descriptive analysis was used to summarize variables with the mean (SD) and % (number). Parametric analyses were used in the current study. All statistical analyses were performed with SPSS. Statistical significance was set at  $p < .05$ .

To investigate test–retest reliability of the posture score and sitting time, the ICC and Bland–Altman plots were evaluated by comparing the mean value of the first 7 days with the mean values of the second 7 days in the LBP group and the control group, respectively. The duration of 7 days was selected as it was considered that daily activities were dependent on days of the week. The following criteria were used to interpret ICC values: poor reliability,  $<.40$ ; fair–good reliability,  $.40$ – $.75$ ; excellent reliability,  $>.75$ .<sup>23</sup> Furthermore, the MDC was calculated using the following standard formulas

$$\text{SEM} = \text{SD} \times \sqrt{1 - \text{ICC}} \quad (1)$$

$$\text{MDC} = \text{SEM} \times 1.96 \times \sqrt{2} \quad (2)$$

In each Bland–Altman plot, 95% confidence intervals (95% CIs) of the difference from the mean value of the first 7 days to the mean values of the second 7 days were calculated, and Pearson's  $r$  between the difference from the mean value of the first 7 days to the mean values of the second 7 days and average of these values were calculated. A fixed bias was considered negligible when the 95% CIs of the difference from the mean value of the first 7 days to the mean values of the second 7 days included zero. A proportional bias was considered negligible when a statistical significance of Pearson's  $r$  was  $\geq .05$ .

The Fisher's exact test was used to compare gender balance between the two groups. The two-tailed independent sample  $t$  test was used to compare other variables between the two groups. Hedges  $g$  was also calculated for effect size,<sup>24</sup> where Hedges  $g$  value of 0.2, 0.5 and 0.8 represents small, medium and large effect size, respectively.<sup>25</sup>

**Priori sample size estimation.** A priori sample size estimation was undertaken considering the reliability investigation and group comparison. For the reliability investigation, 15 participants were considered the minimum sample size to detect the ICC value of .8 with the null hypothesis of ICC value of 0 ( $\alpha = .05$  and  $\beta = .20$ ; PASS 14 Power Analysis and Sample Size Software 2015, NCSST, LLC, Kaysville, UT, USA). For the group comparison, a priori sample size estimation was undertaken using an internal pilot study<sup>26,27</sup> of the first eight

subjects in each group with the posture score taken from the first 7 days. The pilot study demonstrated an effect size of the group difference of 1.4. The G\*Power 3<sup>28</sup> also demonstrated that 15 individuals in each group were required to detect a significant difference in the posture score ( $\alpha = .05$  and  $\beta = .05$ ). Thus, an additional seven participants in each group were recruited as there was no change in methodology after the pilot testing.

### Results

Fifteen individuals with LBP and 15 individuals without LBP participated in the study. Table 1 presents the demographics and comparisons of secondary measures between the two groups. No significant difference in demographic measures and the IPAQ scores indicates demographic comparability between the two groups. The SF-36v2 scores indicate that the LBP group had impaired health status in bodily pain, social function and emotional constructs when compared with the scores of the control group and the national standard (i.e.  $<50$ ). There were no missing values.

Table 2 demonstrates the ICC and 95% CIs. Excellent reliability for the posture score and fair–excellent reliability for time spent sitting were seen in the two groups. Figure 3 presents the Bland–Altman plots for the posture score and time spent sitting in the two groups. Neither fixed bias nor proportional bias was detected in the Bland–Altman plots. Regarding the MDC, that of the posture score was 11.7% in the LBP group and 4.9% in the control group. The MDC of time spent sitting was 126.7 min in the LBP group and 97.4 min in the control group.

Table 3 demonstrates the posture score and time spent sitting between the two groups. The posture score was significantly less in the LBP groups than the control group and the effect size was large while there was no statistical difference in the time spent sitting between the two groups.

The  $p$  value of Pearson's  $r$  between the difference from the mean value of the first 7 days to the mean values of the second 7 days and average of these values are presented in each Bland–Altman Plot.

### Discussion

The current study examined test–retest reliability of the posture score and time spent sitting evaluated by the LUMObac device. The results of the current study indicated acceptable test–retest reliability for these measures in individuals with and without LBP. The LUMObac device has potential to be a promising tool to undertake studies regarding habitual pelvic posture.

There was no difference in time spent sitting between the two groups. However, the current study found a large effect size for the lower posture score in the LBP group compared with the control group, indicating more prolonged slouched lumbopelvic posture in individuals with prolonged LBP than



**Table 1.** Comparisons of demographics and secondary measures.

Variables	LBP group (n = 15)	Control group (n = 15)	p value
Demographic data			
Women (%)	9 (60.0)	13 (86.7)	.21
Age (years)	22.1 (4.3)	21.1 (2.3)	.43
Symptom measures			
Oswestry Disability Index (%)	18.9 (5.8)	0	NA
P4 (range 0–40)	14.4 (7.1)	0	NA
Symptom duration (months)	42.8 (35.8)	NA	NA
Other secondary measures			
IPAQ (minute × METS)	4020.5 (2631.6)	3688.3 (2740.6)	.74
SF-36v2 (national standard value, 50)			
Physical function	52.3 (7.1)	57.4 (1.3)	.01
Role physical	45.0 (11.1)	52.2 (13.7)	.59
Bodily pain	43.4 (8.2)	57.1 (6.3)	<.001
General health	53.3 (5.6)	55.2 (6.2)	.36
Vitality	43.6 (8.5)	49.2 (7.0)	.06
Social function	46.3 (12.6)	56.6 (1.7)	.004
Role emotional	45.0 (11.1)	55.5 (2.2)	.001
Mental health	44.8 (7.2)	48.2 (5.3)	.15

LBP group: individuals with low back pain; Control group: individuals without low back pain; NA: not applicable; IPAQ: International Physical Activity Questionnaire; SF-36v2: Medical Outcomes Study 36-Item Short-Form Health Survey version 2. Values are presented as mean ± SD or numbers (%).

**Table 2.** The intraclass correlation coefficient (ICC) of the posture score and sitting time in individuals with low back pain (LBP group) and individuals without low back pain (Control group), which were calculated by comparing the mean value of the first 7 days with the mean values of the second 7 days.

Variables	ICC (95% CIs)	
	LBP group (n = 15)	Control group (n = 15)
Posture score	.82 (.48–.94)	.91 (.75–.97)
Sitting time	.75 (.26–.91)	.85 (.57–.95)

those without LBP. These findings are in accordance with the conclusion of a systematic review<sup>3</sup> that sitting itself was not a risk factor for LBP and that the risk of LBP increased when prolonged sitting and awkward postures were combined. Another systematic review concluded that there was limited evidence that a sustained flexed posture was a risk factor for LBP.<sup>29</sup> Thus, postural education not to sustain slouched posture would be important in the management of LBP at least for individuals with sedentary life styles.

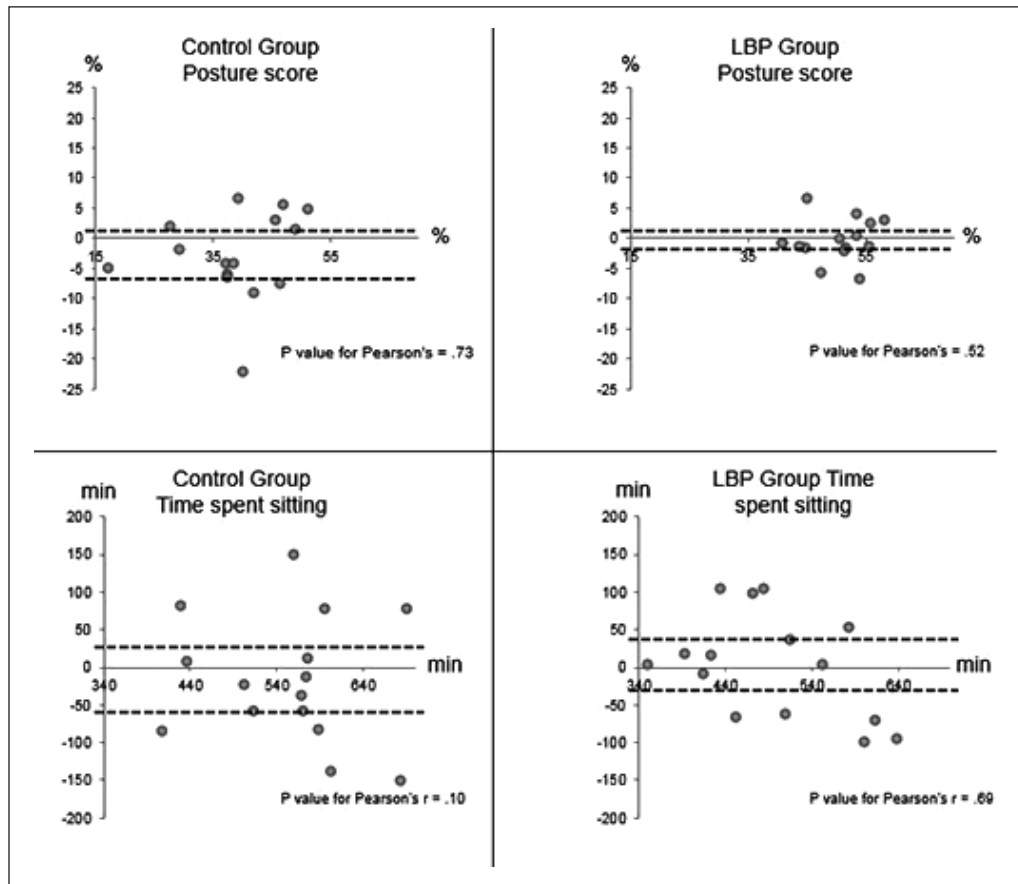
The results of the current study may indicate three possible research agendas. First, it is interesting to investigate whether certain physical therapy approaches change the habitual pelvic posture, by using the LUMObac device as a measure. For example, does postural education only change the habitual pelvic posture and time spent in sitting? Does trunk extensor muscle strength training or soft tissue stretching (e.g. hamstring muscles) change the habitual pelvic posture? The current study also found MDCs of the posture score and time spent in sitting, and we will be able to

understand if pelvic posture and time in sitting is changed over a course of an intervention in case studies. Second, the LUMObac device may enhance the treatment effect for people who need postural correction to reduce their LBP when the feedback of vibration is on. A randomized control trial will be required. Third, recurrence of LBP is high<sup>30–33</sup> and therefore it may be of interest to investigate if the use of the LUMObac device can reduce recurrence of LBP in those who needed postural correction to reduce their LBP.

### Study limitations

There are four potential limitations in the current study. One is regarding the generalizability of the results due to the limited sample and sampling method. The participants in this study were relatively young and university students. Furthermore, the limited sample size could have potentiated the gender imbalance. These might have contributed to the preliminary findings in the comparisons of the posture score and time spent in sitting. Further investigations will be required to fully understand if there is a difference in the habitual pelvic posture and time spent sitting in general.

The second limitation is that the LUMObac device is not suitable for understanding lumbar movements or segmental movements specifically. This study selected a threshold for slouched posture as “very slouched,” as the LUMObac device can only provide binary data for the posture score. The posture score from the LUMObac device has a technical limitation in that it is not able to differentiate a posture of an excessive anteriorly tilted pelvis from a posture of an excessive posteriorly tilted pelvis. Other systems (e.g. ViMove)



**Figure 3.** Bland–Altman plots for the posture scores and time spent sitting in the low back pain (LBP) and control groups. A vertical axis presents the difference from the mean value of the first 7 days to the mean values of the second 7 days. A horizontal axis presents mean value of the 14 days. Upper dot lines present the upper limit of the 95% CI and lower dot lines present the lower limit of the 95% CI.

**Table 3.** Comparisons of the posture score and sitting time between individuals with low back pain (LBP group) and individuals without low back pain (Control group).

Variables	LBP group (n = 15)	Control group (n = 15)	p value	Hedges g
Posture score (%)	37.5 (10.3)	49.6 (6.1)	.001	1.39
Sitting time (min)	544.9 (89.0)	496.6 (78.3)	.13	0.56

Values are presented as mean  $\pm$  SD.

would be more appropriate to understand specific measures of the habitual lumbar movements or angle data although widespread use of such an advanced system is not feasible.

The third limitation is that the current study did not assess reliability of the LUMObac sensor toward established motion measurements. Further understanding of reliability will be required to fully establish reliability of the assessment of habitual pelvic posture and time spent sitting using the LUMObac device.

The final limitation is that the results of the current study might be confounded by imperfect blinding of the LUMObac scores (i.e. the posture score and time spent

sitting). The secondary aim of the study was masked from the participants in order to minimize the possibility that they would change their habitual pelvic posture and time spent in sitting and therefore compete with the control group. In this regard, participants were asked to act as usual to enable measurement of habitual pelvic posture and time spent in sitting. However, it was impossible to blind the LUMObac scores as the participants saw the LUMObac scores during data saving. Nevertheless, it is likely that the influence of imperfect blinding of the LUMObac scores on the results were negligible as there was no merit for the participants to have consistent LUMObac scores, and in any case would have required substantial mental effort to achieve.

## Conclusion

The current study found acceptable test–retest reliability for the posture score and time spent sitting evaluated by the LUMObac device. The current study also revealed a preliminary finding that individuals with prolonged LBP had different habitual pelvic posture, which is assumed to be a more slouched lumbopelvic posture, in comparison with individuals without LBP.

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## Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Ethical approval

Ethical approval for this study was obtained from The Saitama Prefectural University (27110).

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## Informed consent

Written informed consent was obtained from all subjects before data collection.

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