Postural Indices and Limits of Stability in Subjects Having Chronic Low Back Pain versus Healthy Control: A Cross-Sectional Comparative Study

Wskaźniki posturalne i granice stabilności u pacjentów z przewlekłym bólem w odcinku krzyżowym kręgosłupa w porównaniu ze zdrową grupą kontrolną – przekrojowe badanie porównawcze

Mohamed Hussein Hisham

Department of Physical Therapy, College of Applied Medical Science, University of Ha'il, Saudi Arabia
Department of Basic Science, Faculty of Physical Therapy, Cairo University, Egypt

Keywords
Balance, Biodex, low back pain, motor control, postural performance

Abstract
Introduction: Balance and postural performance measures are quite variable. These measures can be influenced by chronic musculoskeletal problems. In the literature, contradicting results are given regarding the effects of postural stability indices and limits of stability measures in subjects having chronic low back pain. Additionally, the available work on this topic is still scarce.
Aim: The aims of this study were to compare differences in limits of stability and postural indices among participants having chronic mechanical low back pain (LBP) and a matched healthy group.
Materials and Methods: This is a cross-sectional comparative study in which the LBP group consisted of 60 participants while the healthy control group comprised 30 subjects. The severity of pain was measured using the Visual Analogue Scale (VAS). Postural stability indices (overall, anteroposterior and mediolateral) and limits of postural stability (directional control and time) were measured using the Biodex balance device.
Results: Both groups were similar regarding baseline characteristics ($p \geq 0.05$). The overall and anteroposterior stability indices demonstrated statistically significant differences in favour of the healthy subjects ($p<0.05$). These findings were supported by a high effect size (Cohen's $d>2.8$). Additionally, limits of stability measures indicated a statistically significant difference ($p<0.05$) between groups, in favour of the healthy subjects, with a high effect size (Cohen's $d>0.9$).
Conclusions: Chronic low back pain adversely affects postural stability indices and limits of stability.

Słowa kluczowe
równowaga, system Biodex, ból w dolnym odcinku kręgosłupa, kontrola motoryczna, stabilność posturalna

Streszczenie
Wstęp: Równowaga i poziom stabilności posturalnej są dość zmienne. Przewlekłe problemy związane z układem mięśniowo-szkieletowym mogą mieć wpływ na ich poziom. W piśmiennictwie znajdują się sprzeczne wyniki dotyczące stabilności posturalnej i granic stabilności u osób z przewlekłym bólem w odcinku krzyżowym kręgosłupa. Co więcej, wciąż jest bardzo mało prac dostępnych na ten temat.
Cel badań: Celem niniejszego badania było porównanie różnic w granicach stabilności posturalnej pomiędzy grupą pacjentów cierpiących na przewlekły mechaniczny ból w dolnej części odcinka kręgosłupa (ang. LBP – low back pain) i dopasowaną grupą zdrowych uczestników.
Materiały i metody: Jest to badanie przekrojowo-porównawcze, w którym grupa LBP składała się z 60 pacjentów, podczas gdy

The individual division of this paper was as follows: A – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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grupa zdrowych uczestników liczyła 30 osób. Nasilenie bólu mierzono za pomocą skali VAS (ang. Visual Analogue Scale). Wskaźniki posturalne (całkowite, przednio-tylne i środkowo-boczne), wskaźniki stabilności oraz granice stabilności posturalnej (kontrola kierunkowa i czas) mierzono za pomocą platformy Biodex Balance.

Wyniki: Obie grupy były podobne pod względem charakterystyki wyjściowej ($p \geq 0,05$). Wskaźniki stabilności ogólnej i przednio-tylnej wykazały istotne statystycznie różnice na korzyść osób zdrowych ($p<0,05$). Wyniki te zostały poparte odnotowaną dużą siłą efektu (*d* Cohena>2,8). Dodatkowo, wykazano istotną statystycznie różnicę ($p<0,05$) granic stabilności pomiędzy grupami na korzyść osób zdrowych, przy dużej sile efektu (*d* Cohena >0,9).

Wnioski: Przewlekły ból w dolnym odcinku krzyżowym kręgosłupa niekorzystnie wpływa na wskaźniki stabilności posturalnej oraz granice stabilności.

INTRODUCTION

Low back pain (LBP) affects almost everyone at least once per life. Hence, it has been considered one of the most common musculoskeletal problems[1]. Back pain is among the leading reasons for seeking health services. It can tremendously affect the working ability of a person and may lead to permanent disability[2].

Recently, several attempts have been conducted to elaborate the possible underlying mechanism of LBP[3,4], and consequently, tailoring the intervention accordingly[5-7]. The disturbance of coordination between muscular and neural systems may have a role in LBP[8]. This might be manifested as impaired limit of stability (LOS).

LOS has been defined as "the area which is much smaller than the base of support and over which individuals can move their center of mass and maintain equilibrium without adjusting their base of support"[8]. Decreased LOS can affect postural performance, decrease balance and increase the risk of falling. Limited studies have been conducted to investigate LOS in LBP subjects[8,9].

Sipko and Kuczynski[8] compared functional LOS between asymptomatic subjects and those having either a high or low level of LBP. They reported a decline in LOS in the forward direction for both LBP categories, while posterior LOS was only affected in the high LBP group. In another study, the influence of perturbation of the supporting surface on the postural responses in subjects with LBP was investigated. The researchers used a force platform mounted to a movable base to obtain the outcomes. In this case, it was concluded that LBP subjects demonstrate abnormal size and timing compared to the norms, which indicated impaired motor control[9].

Additionally, Soliman et al.[10] reported deviation in postural mechanisms and dynamic LOS in LBP. Moreover, Sipko and Kuczynski[8] noticed a reduction in LOS. This reduction was not affected by the level of perceived LBP. In other studies, an increased risk of falling was reported among subjects experiencing chronic LBP, which was attributed to poor postural mechanisms[11-13].

On the other hand, in a systematic review, no consensus was reported regarding the deficits of postural stability and balance in the LBP population[14]. In multiple studies[15-17], no significant differences were noted in balance-related tests among those with LBP and the healthy controls.

Reaching a definite conclusion concerning the relationship between postural problems and LBP could improve awareness with regard to the pathophysiology of LBP[18]. Consequently, better treatment strategies could be developed. In the current study, an attempt was made to try and solve the posed research question: 'Are there any differences in terms of postural stability indices (PSIs) and LOS between subjects experiencing chronic LBP and healthy controls?'. The purpose of the current study is to compare PSIs and LOS values in subjects with chronic LBP versus healthy controls.

MATERIALS AND METHODS

Study design

This study is an observational, comparative, cross-sectional trial.

Settings

The current study was conducted in the period between March and June 2019 at the outpatient physical therapy clinic of a local university. All subjects signed a consent form before participation in the study.

Subjects

The study group in this experiment consisted of 62 subjects with chronic LBP. These subjects comprised the sample that had participated in a previous study[19]. The participants had LBP for more than 3 months[4], at least moderate pain intensity that exceeded 45 mm on the VAS scale, and were free of other pathological conditions in the back and lower limbs. Subjects who experienced specific LBP, was taking regular medications affecting balance, had middle ear problems, was pregnant and had spinal deformity, was excluded.

The control (healthy) group was a convenient sample (n=30) recruited from the community of a local university campus. These subjects were free of back pain, previous abdominal, back or lower limb surgeries, and with no discrepancies in leg length. Additionally, they did not participate in any regular physical activity or sport.

Outcome measures

Age, weight and height measurements were recorded for each subject. Moreover, all subjects were asked to rate their LBP intensity using the VAS scale, a horizontal line containing verbal indicators on the extreme ends was used for this purpose. The VAS is a valid and reliable tool for measuring musculoskeletal pain[6]. The Biodex balance system instrument (Biodex Medical Systems Inc., Shirley, New York, USA) was used to assess PSIs and LOS. The system is characterised by a freely movable platform of up to 20° horizontal planes. A computer connected to the platform enables the device to process and save the evaluation[19,20]. The validity and reliability of the measurements performed by the Biodex device have been investigated previously[21].

Postural stability indices

The process began by entering the necessary data, such as the subjects' demographic data, into the Biodex software. Then, the detailed parameters of the test were set. The following test details were used: bare feet, double leg-standing, medium difficulty (level 5 with open eyes), 30-s trial time, 10-s rest interval, and one familiarisation trial was allowed before each actual test. As the test commenced, the subject was instructed to avoid using hands for support and to keep the platform as horizontal as possible by controlling a cursor on the Biodex screen grid using visual feedback. After pressing the start key, the platform was released free (after a 5-s delay)[19,20].

The measured PSIs were the anterior-posterior stability index (APSI), the mediolateral stability index (MLSI) and the overall stability index (OASI). According to Aydog et al.[22], the OASI is the best indicator of the overall ability of the patient to maintain balance of the platform. These indices have been designed to calculate the amount of deviation from the baseline position. Poorer postural stability results in higher PSI scores[10].

Limits of stability

The LOS was expressed as direction control (DC) and time (T) required for completing the task. The decline in dynamic LOS results was visible in lower DC value and prolonged timing[10]. LOS is among the indicators of motor control skills.

During the actual tests, each subject was instructed to assume the same foot position used for PSIs assessment. A 2-minute rest interval was allowed after completing PSI assessment to minimise errors from adaptation.

The stability level of the platform was set to level 7. At this stage, the participant was instructed to shift and move the cursor over a target box located on the screen. This cursor was maintained over the target box for a minimum of 5 s and then returned to the centre of the screen. Little deviation and quick movement were needed before the next target box emerged. This was achieved by un-leveling the platform to reach the target box. The test ended when 8 target boxes were completed, and the cursor was repositioned in the central box. Touching the device handle was permitted to avoid falling, but grasping it was not allowed. When the test was completed, the DC (%) and time (s) were recorded and printed[10,20].

Methods of analysis

Means, *SD* and percentages were used to describe subject characteristics. Unpaired *t*-tests were used to compare characteristics for both groups. Before data analysis, the Shapiro–Wilk test was used to test data normality, and Levene's test was applied to detect homogeneity of variance. One-way multivariate analysis of variance was implemented to compare the study and control groups. Bonferroni correction was conducted to compensate for multiple analyses of variance. Cohen's *d* calculator (www.socscistatistics.com/effectsize/default3.aspx) was used to determine the effect size. The following cutoff points were used to interpret the results of Cohen's d effect size: $d \leq 0.2$ was considered small, $d \leq 0.8$ represents medium effect size, while $d \geq 0.8$ indicates large effect size[23]. *P* values <0.05 were considered statistically significant. Statistical analysis was conducted via SPSS, version 23 (SPSS Inc., Chicago, Illinois, USA).

RESULTS

The participants from both groups were similar regarding age, height, weight and body mass index (Table 1).

Regarding PSIs, the comparisons between all outcome measures revealed that the LBP group demonstrated a statistically significant decline in overall stability index (OSI) and anteroposterior stability index (APSI) compared to the healthy control. This observation was manifested as increased values of these indices in favour of the LBP group. On the other hand, the mediolateral stability index (MLSI) values were almost similar in both groups (Table 2).

Regarding LOS, the LBP group showed a statistically significant reduction in DC values and increase in the time required to perform the task ($p=0.001$, and 0.01, respectively), which means that the LBP group has poorer LOS compared to the healthy control.

Clinically-wise, all outcome measures demonstrating statistically significant results also showed high effect size, as represented by Cohen's *d* values.

Table 1

Participant characteristics

Characteristic	Mean ± *SD*		MD	T	*p* value	95% CI	
	LBP group	Control group				Lower	Upper
Age	22.00 ± 1.38	22.73 ± 1.62	-0.733	-1.57	0.12	-1.67	0.20
Height	169.03 ± 6.98	167.93 ± 5.49	1.10	0.53	0.59	-3.06	5.26
Weight	71.29 ± 9.29	70.36 ± 9.48	1.55	0.52	0.68	-4.41	7.52
BMI	25.07 ± 2.06	25.20 ± 2.36	-0.12	-0.18	0.86	-1.50	1.25

SD – standard deviation; MD – mean difference; T – *t*-test value; *p* – significance; CI –confidence interval; BMI – body mass index

Table 2

Comparison between outcomes in both groups

Outcomes	**Mean ± *SD***		**Univariate test**		
	LBP group	**Control group**	**F**	***p***	**Cohen's *d***
PSIs					
- OASI	2.23 ± 0.82	0.52 ± 0.17	62.59	**0.000**	2.88
- APSI	2.93 ± 0.98	0.78 ± 0.44	64.33	**0.000**	2.83
- MLSI	0.35 ± 0.28	0.28 ± 0.14	0.93	0.33	0.31
LOS					
- DC	36.50 ± 10.51	50.26 ± 13.76	13.91	**0.001**	1.12
- T	2.22 ± 1.47	1.17 ± 0.36	7.26	**0.01**	0.98

SD – standard deviation; F – F value; *p* – significance; PSIs – Postural stability indices; OASI– overall stability index; APSI– anteroposterior stability index; MLSI – mediolateral stability index; LOS – limit of stability; DC – directional control; T – time required to complete the task

DISCUSSION

The presented study was conducted to assess PSIs and LOS in subjects having chronic LBP versus healthy controls. The current results demonstrated that all outcome measures, except for MLSI, were better in the healthy group when compared to those having LBP.

Due to the variation in outcome measures representing balance and postural stability, different outcomes have been investigated in different studies among literature on the subject. For example, George et al. 2011[3] evaluated proprioception in the form of repositioning error among subjects having different LBP problems versus healthy subjects. Similar to the current study, the authors of other studies were interested in PSIs and LOS among subjects having radiculopathy secondary to low back dysfunction[8,10,20]. Automatic postural responses[9] and postural sway[12] were also investigated on other occasions.

Two previous studies were conducted on chronic LBP populations. In both, detecting the influence of pain severity on PSIs and LOS was of interest. Soliman et al.[10] subdivided the LBP participants into 2 groups according to pain severity and compared the results with the asymptomatic subject. The results supported those obtained in the current study, where both LBP groups manifested poorer PSIs and LOS compared to the asymptomatic comparators. In the other study[8], the values of LOS were reported to be lower in LBP subjects, regardless of pain severity. Additionally, it has been found that forward-leaning tasks were compromised when the task was performed only with closed eyes.

Further support to the current findings came from a recently conducted study[20]. However, it was conducted on a different category of LBP including radiculopathy, similar findings were reported. According to Takla, subjects having lumbar radiculopathy demonstrated poorer values of PSI and DC.

On the other hand, Soliman et al., found that MLSI was compromised in subjects experiencing severe LBP. This finding contradicts what has been concluded in the presented study. The explanation for these findings might be attributed to the fact that in the current study, the severity of LBP was not assessed as a contributing factor. Additionally, MLSI could be easier to control compared to other indices because the nature of the human support base provides more mediolateral stability.

The current findings allow to suggest that LBP demonstrates a change in the activation pattern of trunk musculatures, which could be a strategy limiting spinal mobility and hence, reducing LBP associated with movement[10]. In addition, the impairment in proprioception associated with LBP[3] might also play a role in the decline of PSI and LOS values.

LBP can also affect upright posture and increase muscle stiffness[24]. These compensatory changes in posture and trunk muscles may further hinder spinal flexibility and avoid provocation of pain (kinesiophobia), consequently, leading to deterioration in PSIs and LOS[12].

The subjective nature of pain perception and rating its intensity may have influenced the inclusion of the subjects into the LBP group. Being part of a previous study, the appropriate sample size was not calculated for the current study. This could have led to a type-2 error. Although Cohen's *d* formula was used to clarify the effect size, there is little agreement about the criteria for clinical significance in posturography. Depending on the subjects' characteristics and the purpose of the study, even small improvement in postural control may significantly contribute to the actual functional performance being examined. Therefore, the values of PSIs should be clinically interpreted with caution.

CONCLUSIONS

Postural stability indices and limits of stability are abnormal in subjects with chronic low back pain.

Competing interests

The authors declare no competing interests.

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Address for correspondence

Hisham Mohamed Hussein
4009 Sababah, Ha'il City, Saudi Arabia
e-mail: drhisham3000@yahoo.com / drhisham3000@cu.edu.eg / hm.hussein@uoh.edu.sa
Mobile Phone No.: +966543704108