RESEARCH ARTICLE

Immediate Effects of Lumbosacral Orthosis on Postural Stability in Patients with Low Back Pain: A Preliminary Study

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Abstract

Background: Lumbosacral orthosis (LSO) is commonly used for the treatment of back pain. The clinical and mechanical effectiveness of this device has been repeatedly investigated in several studies; however, its sensorimotor effectiveness has been rarely considered. Regarding this, the aim of the current study was to investigate the effect of a non-extensible LSO on postural stability (as a construct of sensorimotor function) in patients with nonspecific chronic low back pain (LBP).

Methods: This preliminary study was conducted on 17 patients with nonspecific chronic LBP using a single-group quasi-experimental design. Postural stability was measured while the participants were placed in a quiet standing position, under the combined conditions of base of support (rigid and foam surface), visual input (open eyes and closed eyes), and LSO (with and without orthosis).

Results: The findings demonstrated that wearing orthosis during the most challenging postural task (i.e., blindfolded while standing on a foam surface) significantly reduced postural sway parameters related to the position and displacement of the center of pressure (COP; the sway area and sway amplitude in the anteroposterior direction; $P<0.001$). However, the use of this device had no significant effect on COP velocity.

Conclusion: As the findings of the present study indicated, the use of a non-extensible LSO decreased the COP displacement; however, it did not affect the COP velocity. Therefore, our data could not utterly support the effectiveness of non-extensible LSO on postural stability as a construct of sensorimotor function. Postural control is an appropriate indicator for assessing the global functioning of the sensorimotor system due to its dependence upon the interaction between the neural and musculoskeletal systems. Consequently, further studies are needed to elucidate the positive effects of LSO on the aspects of sensorimotor function.

Level of evidence: III

Keywords: LBP, Orthotic device, Postural balance

Introduction

Lumbosacral orthoses (LSOs) are commonly used for the treatment of low back pain (LBP) (1). Despite the great amount of disagreement on the clinical efficacy of orthoses, these devices have been reported to reduce pain and disability in recent clinical trials (2-4). However, the mechanism of these devices in the improvement of

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LBP symptoms is unclear yet. Different hypotheses have been proposed to justify the clinical effectiveness of orthoses and their relevant mechanism of action (5). For example, these devices have been found to restrict the gross trunk motion (5). The inhibition of the lumbar spine movements near the limits of the range of motion is effective in relieving pain (5).

On the other hand, some researchers believe that an orthosis does not physically restricts the trunk motion. They assume that this device improves the patients' sense of lumbar position and prevents them from performing vigorous motions, thereby helping to alleviate back pain (6). A couple of studies investigating the mechanisms of LSO proposed that this kind of support can reduce the trunk muscle co-contraction by providing passive stiffness (7, 8).

The decreased activity of the trunk muscles induces as a result of wearing a LSO occurs at only approximately 1-2% of the maximum voluntary activation (7). This rate of decline in the muscle activity is not enough to reduce the demand for the muscle work and the need for an extension moment through the trunk extensor muscles. However, it is able to lower the trunk muscle activity level below the 5% maximum voluntary action threshold to prevent the muscle fatigue and subsequent pain (7).

Several studies have investigated various types of LSOs in terms of their clinical (e.g., alleviation of pain and disability and improvement of quality of life) (2, 3, 9, 10) and mechanical effectiveness (e.g., modification of the muscle activity, intra-abdominal pressure, muscle strength, and spinal load moment) (5, 11). Nonetheless, few studies have evaluated the effectiveness of these devices in sensorimotor function.

Postural control is a level of sensorimotor control system that has been considered frequently in the current literature with regard to LBP. The dependence of postural control on the interaction of musculoskeletal and neural systems may suggest it as an appropriate indicator of the efficiency of whole-body performance (12). There is ample evidence regarding the impaired postural control in patients with LBP, compared to healthy individuals (13-17).

The LBP is frequently reported to be accompanied by reduced postural strategy variability, disability to use a hip strategy, difficulty in equilibrium maintenance after perturbation, and increased center of pressure (COP) movement during quiet stance (18-23). However, the underlying mechanism of postural control impairment is still unknown in the LBP patients. Based on a number of reports, poor postural stability is associated with neuromuscular deficiencies, such as impaired lumbar proprioception and increased trunk muscle co-contraction (stiffness) (24, 25). The improvement of position sense and reduction of trunk muscle co-contraction are the most commonly suggested hypotheses about the mechanism of action of LSO, arising this question whether LSO can affect postural control in the LBP patients (6, 7).

Extensible and non-extensible LSOs are commonly prescribed for the conservative management of back pain. Evidence suggests that only non-extensible orthoses are capable of providing passive stiffness and reducing the trunk muscle co-contraction (26). It has been also revealed that the non-extensible orthoses are clinically superior to the extensible ones (2). Regarding this, the aim of the present study was to investigate the effect of a non-extensible LSO on postural stability in patients with nonspecific chronic LBP.

The postural stability is often evaluated by recording postural sway (center of pressure movement) during quiet standing. Two recently published systematic reviews reported the increased postural sway magnitude (the rate of COP fluctuations) in the LBP patients (15, 27). Accordingly, in the current study, it was hypothesized that an LSO may reduce postural sway magnitude in patients with LBP.

Materials and Methods

Study population

This preliminary study was conducted on 17 patients with nonspecific chronic LBP using a single-group quasi-experimental design. The participants consisted of 8 males and 9 females with the mean age of 27.47±5.70 years, mean weight of 68.91±13.19 kg, and mean height of 172.29±10.14 cm. They were recruited through either poster advertisements or word of mouth, and some of them were referred by general practitioners [Table 1]. An experienced physical therapist screened all patients before enrollment.

The inclusion criteria were: 1) age of 20-55 years, 2) a minimum 1-year history of LBP, 3) incidence of at least one recurrent episode of pain in the last 6 months that lasted at least 1 week and needed treatment or sick leave, 4) pain of a semi-continuous nature and various severity depending on the situation, and 5) a minimum score of 6 in the Oswestry Disability Index.

On the other hand, the exclusion criteria were: 1) non-musculoskeletal back pain, 2) neurological symptoms due to nerve root compression, 3) a history of vestibular

Table 1. Baseline demographic and clinical characteristics of patients

	LBP patients (n= 17) Mean ± SD
Sex (Male/Female)	8/9
Age (year)	27.47 ± 5.70
Height (cm)	172.29 ± 10.14
Weight (kg)	68.91 ± 13.19
LBP duration (year)	4.13 ± 3.46
Pain intensity on test day (/10)	3.77 ± 1.97
Pain intensity in last week (/10)	5.12 ± 1.75
ODI (%)	22.95 ± 6.58

LBP= Low Back Pain; SD= Standard Deviation; Pain intensity was according to 10 cm visual analog scale;
ODI= Oswestry Disability Index

disorders, diabetes, and an observable spinal deformity as confirmed by the Adam's Forward Bend Test, 3) lower limb length discrepancy, and 4) consumption of sedatives or substances affecting the central nervous system 24 h prior to the test. The Human Ethics Committee of the Iran University of Medical Sciences approved the protocol of this study (Committee No. 9211503211), and all participants signed an informed consent form.

Lumbosacral orthosis

A non-extensible LSO (QuikDraw Brace, Aspen Medical Products, Inc., Irvine, CA) was used in the current study. The orthosis was made of polyester and nylon and had a posterior panel that can be heat-molded and shaped according to the anatomy of the patient's lumbar region to accurately match the patient's lordosis. The LSO was fitted at an identical tension in all patients by an experienced licensed orthotist following the manufacturer's instructions.

Equipment and measurement

The participant's postural sway was evaluated by means of a force platform (9260 AA, Kistler Instruments, Winterthur, Switzerland). The force platform data were sampled at 100 Hz and filtered with a second-order Butterworth filter at a cutoff frequency of 10 Hz. The COP parameters to measure the amount of postural sway, including sway area (95% confidence ellipse), mean total velocity, and sway amplitude (standard deviation of the COP position in the anteroposterior [AP] and medial-lateral directions), were calculated using MATLAB software (Mathworks, Natick, MA).

The postural stability was evaluated while the patients were placed in a quiet standing position. To this end, the participants stood barefoot on the center of the force platform so that their body weight was distributed equally on both feet, with their feet close together and their arms placed beside their body. The position of the feet was drawn on a paper sheet that was pasted onto the force platform to homogenize the position of the feet in all trials.

Each person was tested in six experimental conditions, including standing on a rigid surface with open eyes without an orthosis, standing on a rigid surface with closed eyes without an orthosis, standing on a foam surface with closed eyes without an orthosis, standing on a rigid surface with open eyes and an orthosis, standing on a rigid surface with closed eyes and an orthosis, and standing on a foam surface with closed eyes and an orthosis.

In the open-eyes experiments, the patients were asked to stare at a paper mounted on a wall at a distance of 4 m that was level with the patients' eyes. A blindfold was used in the blindfolded experiments. In the positions in which the participant stood on a foam surface, a piece of foam with a thickness of 10 cm and a density of 35 kg/m^3 was placed on the force platform. To familiarize the participants with the test and reduce the learning effect, they were allowed to practice each of the test conditions twice prior to the initiation of the main test.

The participants stood on the force platform for 5 sec in each trial before recording the data. The data entry for each trial required 60 sec. During the test, the participants were asked to relax, breathe normally, and stay as still as possible. The order of the experimental conditions was completely randomized. Each condition was repeated three times with a 1-minute rest period between the trials. The order of the test conditions (with or without the orthosis) was also completely randomized. There was a 5-minute interval between the orthosis and without-orthosis trails.

Statistical analysis

The mean score of the three trials for each experimental condition was used for statistical analysis. The Kolmogorov-Smirnov test was run to assess the normality of the variables. A separate two-way repeated measures analysis of variance was employed to determine the main effects and interaction of wearing the orthosis and postural task difficulty (as within-group factors) for each of the postural stability variables. Furthermore, Bonferroni corrections were made for multiple comparisons. A paired-sample t-test was also used for the post hoc pairwise comparison. Data analysis was performed in SPSS software, version 16 (SPSS Inc., IL, USA). A p-value less than 0.05 was considered statistically significant for all analyses.

Results

Table 2 shows the changes in COP parameters while wearing the orthosis with a 95% confidence interval. The results of two-way analysis of variance test are summarized in Table 3. The interaction between orthosis and postural task difficulty was statistically significant for the sway area and sway amplitude ($P<0.001$). A further analysis using the paired sample t-test showed that wearing orthosis reduced postural sway in terms of area and amplitude in the AP direction in the most difficult postural task (i.e., blindfolded while standing on a foam surface) [Table 4]. Neither the two-way interaction orthosis by postural task difficulty nor the main effect of orthosis was significant for the COP velocity.

Discussion

This study was targeted toward investigating the effect of a non-extensible LSO on the postural stability of patients with nonspecific chronic LBP. Our findings demonstrated that wearing orthosis during the most challenging posture (i.e., blindfolded while standing on a foam surface) reduced the postural sway parameters that were related to the displacement and position of the COP (i.e., sway area and sway amplitude in the AP direction). However, it had no significant effect on the mean total velocity.

The LSOs are commonly used for the treatment of back pain. Accordingly, the clinical and mechanical effects of these devices have been repeatedly investigated in different studies (2-5, 9). However, there are limited investigations addressing the sensorimotor effectiveness of these tools (28, 29). Additinally, few studies have

Table 2. Mean ± standard deviation of COP parameters, and changes in postural stability variables (95% confidence interval) following orthosis wearing in different postural task conditions

Postural conditions and COP parameters		Without orthosis	With orthosis	Changes (95% confidence interval)
Rigid surface – open eyes				
Area (95% confidence ellipse)		5.10 ± 2.37	5.55 ± 3.22	0.44 (-0.25 – 1.15)
Mean total velocity		1.03 ± 0.28	1.06 ± 0.28	0.02 (-0.05 – 0.10)
S.D amplitude	AP	0.49 ± 0.17	0.53 ± 0.18	0.03 (0 – 0.08)
S.D amplitude	ML	0.53 ± 0.11	0.51 ± 0.14	-0.01 (-0.07 – 0.04)
Rigid surface – closed eyes				
Area (95% confidence ellipse)		7.21 ± 3.43	7.30 ± 4.15	0.09 (-0.86 – 1.05)
Mean total velocity		1.45 ± 0.36	1.45 ± 0.38	0 (-0.06 – 0.06)
S.D amplitude	AP	0.57 ± 0.16	0.55 ± 0.17	-0.01 (-0.07 – 0.04)
S.D amplitude	ML	0.64 ± 0.20	0.65 ± 0.20	0.01 (-0.02 – 0.04)
Foam surface – closed eyes				
Area (95% confidence ellipse)		23.69 ± 9.33	20.74 ± 8.17	-2.95 (-4.25 – (-1.65))
Mean total velocity		3.33 ± 0.67	3.13 ± 0.54	-0.19 (-0.40 – 0.01)
S.D amplitude	AP	1.15 ± 0.19	1.02 ± 0.18	-0.13 (-0.19 – (-0.07))
S.D amplitude	ML	1.08 ± 0.25	1.04 ± 0.21	-0.03 (-0.09 – 0.01)

SD: Standard Deviation; AP: Anteroposterior; ML: Mediolateral;
Unit of area is cm^2; unit of mean total velocity is cm/s; unit of S.D amplitude is cm

Table 3. Summary of the analysis of variance for postural stability variables

Independent variable	Sway area		Mean total velocity		S.D amplitude (AP)		S.D amplitude (ML)	
	F ratio	*P-value*	F ratio	*P-value*	F ratio	*P-value*	F ratio	*P-value*
Orthosis	6.15	0.02*	2.14	0.16	4.93	0.04*	0.78	0.39
Postural task difficulty	96.89	< 0.001*	414.48	< 0.001*	146.79	< 0.001*	168.17	< 0.001*
Orthosis × postural task difficulty	18.66	< 0.001*	4.14	0.02*	13.25	< 0.001*	1.26	0.29

*The difference is significant at the 0.05 level
SD: Standard Deviation; AP: Anteroposterior; ML: Mediolateral

evaluated the effect of LSOs on postural stability.

Munoz *et al.* (29) reported a decrease in COP displacement immediately after wearing a lumbar belt in 11 patients with herniated discs. In another study, Munoz *et al.* (28) examined the effect of a kind of lumbar support, called lordactive lumbar belt, on postural control in 12 healthy participants in the sitting position. In the mentioned study, the postural difficulty of each task was adjusted by changing the radius of the hemisphere upon which the patient was asked to sit, and the tests were repeated for each of the postural tasks by adjusting the posterior panel of the orthosis in the flat and lordotic conditions. Their findings suggested that a lordactive lumbar belt may have harmful, neutral, or beneficial effects on postural stability, depending on the degree of lordosis that is determined by the orthosis and the difficulty of the posture (28).

Similar to the results of our study, they showed that orthosis did not affect postural stability during the simplest postural task. However, in contrast to our study, they showed that orthosis impaired postural stability during the most challenging postural task conditions. However, the comparison of our results with those obtained by Munoz *et al.* should be made with caution due to differences in the participants' health status, types of orthoses, postural tasks, and postural stability variables (28).

According to the literature, the patients suffering from chronic LBP due to lumbar proprioception defects are more dependent on visual input and afferent information from the foot mechanoreceptors for balance control than healthy subjects (30). This may be a probable explanation for our observation in the present study confirming the effectiveness of LSO in postural stability only in the most challenging postural task condition (i.e., blindfolded while standing on a foam surface).

Standing on a foam surface with closed eyes may increase the demand on the lumbar proprioception due to the lack of visual input and variation of somatosensory information. The LSO might promote the patient's awareness of the trunk position by increasing the activity of the lumbar spine mechanoreceptors, and subsequently reducing COP displacement under this test condition.

Since COP velocity is always considered to be directly related to the muscle activity level, the orthosis is expected to reduce the COP velocity by decreasing the trunk muscle co-contraction and signal-dependent noise (24, 31). However, this expectation was not met in the present study since wearing an orthosis did not significantly change the COP velocity. The electromyography activity of the trunk muscles was not investigated in the present study. Therefore, it is unclear whether the unchanged level of the trunk muscle co-contraction is responsible for these results.

However, the simultaneous recording of electromyography and COP signals in the studies carried out by Reeves et al. and Cholewicki et al. showed that the use of LSO could result in a decrease in the trunk muscle activity without any change in COP velocity (7, 25). The participants in the two mentioned studies were healthy people with ideal balance control. However, the present study included people with LBP and impaired balance control. Nevertheless, our findings regarding COP velocity were in line with those reported in the two aforementioned studies.

The reduction of COP displacement and unchanged COP velocity as a result of wearing LSO may be interpreted based on the feedback control approach. According to this approach, the controller (in this case, the central nervous system) needs to get enough information regarding the state of the system to stabilize the system. Recent studies have shown that the controller requires at least two variables, namely stiffness (position-related feedback) and damping (velocity-related feedback), to detect the state of the system (32).

It is likely that external supports, including LSO, are unable to provide enough sensory information for the central nervous system to detect the state of the body. In other words, the orthosis may affect the participants' sense of trunk position rather than velocity-related sensitivity (damping). However, this is a hypothetical interpretation that was not tested directly in our study. The results of recent studies also indicated that stiffness (position-related feedback) alone is not enough to maintain the stability of the system. In this regard, the damping property (velocity-related feedback) also plays an important role in maintaining the system's stability; therefore, it should not be overlooked (33, 34).

The use of an LSO has been repeatedly reported to increase stiffness. However, only two studies have focused on the effect of an orthosis on damping (8, 26). One of these reports indicated an increase in damping, while the other found no significant changes in this parameter (8, 26). The LSO had a significant effect on postural sway parameters related to the displacement and position of COP. Nonetheless, caution should be exercised when interpreting the clinical significance of this finding because the changes in both parameters were lower than the previously reported minimal detectable changes (35). Therefore, the reduction in the sway area and amplitude does not seem to have clinical value as these changes are below the potential errors associated with the measurement and cannot be considered as true changes.

Some limitations of our preliminary study are the investigation of the immediate effect of LSO, examination of a small number of participants, and adoption of a single-group quasi-experimental design. Regarding this, it is required to perform randomized clinical trials with large sample size and a long-term follow-up to evaluate the effect of LSO on postural control. Future studies are also suggested to examine the effect of LSO on the structure and amount of COP fluctuations in more challenging postural task conditions, compared to quiet standing.

In conclusion, the findings obtained from the present study showed that the use of a non-extensible LSO decreased COP displacement; however, it had no effect on COP velocity. Therefore, our findings could not utterly support the effectiveness of non-extensible LSO in terms of postural stability, as a construct of sensorimotor function. Postural control is an appropriate indicator for assessing the global functioning of the sensorimotor system due to its dependence upon the interaction between the neural and musculoskeletal systems. Consequently, further studies are needed to elucidate the positive effects of LSOs on the aspects of sensorimotor function.

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