Trunk Control Response to Unstable Seated Posture During Various Feedback Conditions in People with Chronic Low Back Pain

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AIMS: People with chronic low back pain (CLBP) tend to have altered postural control. Visual biofeedback may be used to restore postural control. The purpose of this pilot study was to investigate the effect of visual biofeedback on seated postural trunk control in subjects with CLBP, and to investigate the relationship between the postural control parameters and clinical tests. **METHODS**: Ten CLBP subjects (8 female, 2 male; age 40.6±5 yrs; BMI 25.06±2.93) and 10 healthy matched controls (8 female, 2 male; age 41.2±5.88 yrs; BMI 24.61±3.17) underwent seated postural assessment. Center of pressure (COP) parameters were collected under three experimental conditions: eyes-open, visual biofeedback, and eyes-closed. **RESULTS**: The results revealed that COP velocity was significantly different between healthy and CLBP subjects for each condition, both healthy and CLBP subjects had no differences in COP parameters between eyes-open and visual biofeedback conditions, and in subjects with CLBP, the straight leg raise clinical test had a strong negative correlation with all COP parameters. **CONCLUSIONS**: Our results suggest that 30-second visual biofeedback training did not improve the seated postural control of CLBP subjects, potentially due to the short duration of training, and that hamstrings muscle tightness or decreased sciatic nerve mobility was associated with worse postural control. *J Allied Health* 2019; 48(1):54–60.

PEOPLE WITH chronic low back pain (CLBP) have altered trunk and postural control.[1] The postural control impairment in people with CLBP is affected by several factors including pain intensity,[2] altered muscle recruitment,[3] and centrally mediated mechanisms.[4] By examining the neuromuscular postural control in CLBP individuals, better preventative measures and therapies may be developed.

Postural control of the spine orientation involves integrated input from multiple sensory organs, including visual, vestibular, and proprioceptive signals.[5] Visual biofeedback can provide immediate and continuous feedback about the environment and body position, with the potential to improve proprioceptive and kinesthetic awareness of posture and movement via mechanisms associated with the central nervous system.[6] Clinicians often utilize hand-held biofeedback and mirror imagery, as well as proprioceptive guidance, to stimulate muscle contraction and improve alignment of posture and movement.[7,8] In a research laboratory setting, more sensitive methods, i.e., force plate and computer graphs, can be used to display a visual representation and collect displacement data regarding center of pressure (COP). Systematic reviews suggest use of visual feedback to improve balance and postural control in frail elderly and in people after stroke.[9,10] Only one study has investigated the effect of visual feedback on postural control in people with CLBP and found an improvement in postural control.[11] However, the previous study investigated the postural control in standing only,[11] and no other studies have examined the effect of visual biofeedback on postural control during unstable seating in people with CLBP. Testing postural control in a seated condition isolates the control of the lumbar spine from the control of lower body joints,[12] and therefore is more appropriate to solely investigate the postural control of the lumbar spine.

Symptoms such as pain and lack of flexibility may alter proprioceptive input and affect the postural control in CLBP individuals. Range of motion (ROM) and straight leg raise (SLR) tests are common clinical assessments used to measure trunk and sciatic nerve flexibility, respectively.[13,14] The relationship between these clinical tests and postural control has not been examined before, but could be useful to guide clinicians in the absence of more sensitive measures, i.e., force

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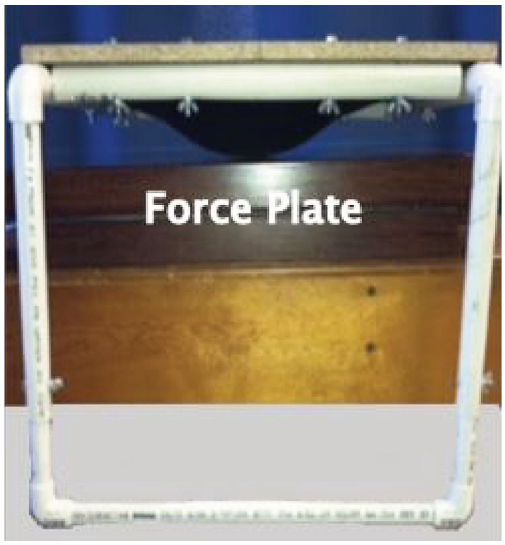

FIGURE 1. Custom-made unstable seat with adjustable footrest to ensure the subject's 90/90 hip and knee angle. The seat was placed on a force plate to assess postural control.

plates. Investigating such relationships may lead to a better understanding of postural control in people with CLBP and better interventions to target the postural control impairment in this population.

The goal of this study was to investigate the effects of visual biofeedback on COP parameters (measures of postural control) during unstable seating between CLBP subjects and healthy controls, and to determine correlations between clinical assessment measures and seated COP parameters. We hypothesized that subjects with CLBP will have impaired COP compared to healthy controls and that visual biofeedback would improve postural control (decrease COP parameters) during unstable seating in both healthy and CLBP subjects.

Methods

Subjects and Instrumentation

Ten subjects with CLBP (8 female, 2 male; age 40.6±5 yrs; BMI 25.06±2.93) and 10 age- and gender-matched healthy controls (8 female, 2 male; age 41.2±5.88 yrs; BMI 24.61±3.17) without any history of back pain were enrolled. CLBP subjects were included if they were 30–50 years old, had continuous or recurring back pain for more than 3 months, had a minimum weekly average pain intensity of 3 on the numeric pain rating scale (rated 0 to 10), experienced back pain at least 3 days/week on average, and were able to walk without an assistive device. CLBP and healthy subjects were excluded if they had a BMI >30, back surgery within the past year, spinal deformities, reported Meniere's disease or vertigo, neurological, or cardiovascular issues, recent head trauma, or were pregnant.

The study was approved by the Institutional Review Board at the University of Kansas Medical Center (#13393) and was performed in accordance with the ethical standards outlined in an appropriate version of the 1964 Declaration of Helsinki. All subjects signed informed consent.

Postural control was assessed using a custom-made unstable seat (Fig. 1) that was created based on the design by Cholewicki et al.[12] An adjustable footrest attached to the unstable seat ensured that the subject's hips and knees were stabilized at a 90° angle. The unstable seat was placed on top of a portable force plate (Bertec Corp., Columbus, OH) to collect forces and moments in the x, y, and z directions. The frequency of data collection from the force plate was 400 Hz. The force plate data were used to calculate the COP parameters through LabVIEW software (National Instruments Corp., Austin, TX). During the visual biofeedback condition, the COP position was displayed on the LabView user screen for the subjects to utilize.

Experimental Protocol

A clinical evaluation of ROM of the trunk in flexion and extension and SLR was obtained using inclinometers prior to COP data collection. All clinical tests were performed by the same researcher who was previously trained by an experienced registered physical therapist. The SLR test, which examines hamstring flexibility and tension on the sciatic nerve, was tested in both legs while lying down. In addition, CLBP subjects rated their back pain using the numeric pain rating scale, where 0 = no pain and 10 = the worst pain imaginable. Throughout each seated condition (eyes-open, eyes-closed, and visual biofeedback), CLBP subjects were asked to rate their pain using the same scale.

Subjects sat on the top of the unstable seat with their feet resting on the attached footrest. A stable rail was available for the subjects to hold onto between trials, and a research assistant was always standing behind the subject for safety. If the subject grabbed onto the railing at any time during a trail, the test was immediately discontinued and the trial was repeated.

Three experimental conditions were assessed and consisted of: 1) the subject looking at a visual biofeedback screen which displayed their current COP movement (red dot on the screen) and a goal target area (Fig. 2); 2) the subject looking straight ahead with eyes open (no visual biofeedback screen); and 3) the subject closing their eyes. Three trials were performed for each of the three conditions, and all of the total nine trials were completed in a randomized order to eliminate a learning effect. One practice trial was completed for each condition before the experimental trials began.

Each subject was instructed to cross their arms over their chest and maintain balance for 30 seconds during each trial (the practice trial and testing trials). During the visual biofeedback condition, the subject was instructed to try to keep the red dot directly in the

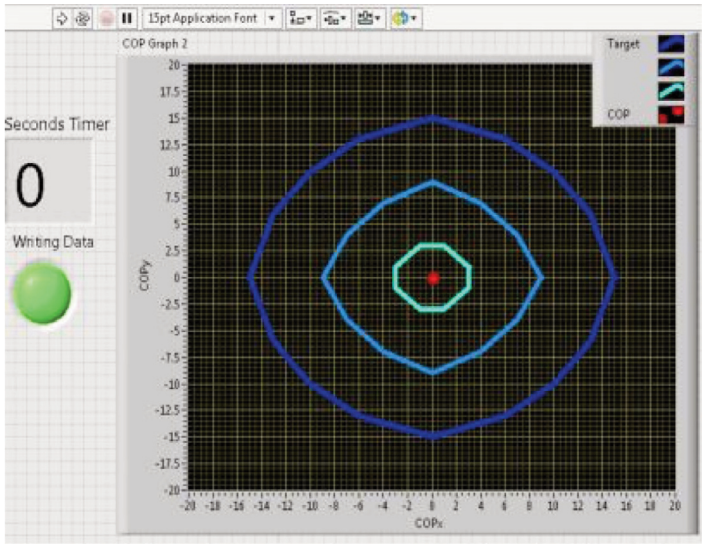

FIGURE 2. Visual feedback screen displaying a subject's COP position on the LabView user screen.

center of the target area on the screen in front of them. Before data collection began, the current COP of each subject was centered within the goal target area on the screen after the subject had crossed their arms over their chest to ensure that each trial for every subject began in the same location. CLBP subjects rated their back pain before and after each trial.

Data Analysis

The force plate data were analyzed using Matlab Software (MathWorks, Natick, MA). The forces in the x and y directions were plotted on an x-y graph and used to calculate COP displacement in millimeters (mm) for the three trials in each condition. Initially, the raw force data were converted into meters using the following equation and then multiplied by 1,000 to convert into mm. The COP values for the x-axis and y-axis were calculated using the force along the *z*-axis (F_z), moment around the y-axis (M_y), and moment around the x-axis (M_x):

$$COP_x = \frac{-M_y}{F_z}, COP_y = \frac{M_x}{F_z}$$

The following COP parameters were calculated: distance traveled in the x direction (mm), distance traveled in the y direction (mm), total distance traveled (mm), and average velocity of movement (mm/s), with the x-axis being the medial/lateral movement and the y-axis being the anterior/posterior movement. Examples of one healthy subject's and one CLBP subject's COP trajectory per condition are displayed in Figure 3.

Different COP parameters were calculated from three averaged trials, which included width (medial/lateral motion defined as maximum deviation in x-axis), length (anterior/posterior motion defined as maximum deviation in y-axis), and velocity calculated as distance divided by time (identified at each time point and averaged to yield total velocity of the trial). These values for three trials for each condition (eyes-open, eyes-closed, and visual biofeedback) were averaged together.

IBM SPSS Statistics ver. 22 (IBM SPSS, Armonk, NY) was used for statistical analysis. A two-way, mixed-measures ANOVA was used to test the difference between groups and conditions for the dependent variables of COP parameters (width, length, and velocity). Student's *t*-test was used for post hoc analysis. For the clinical tests, group differences for SLR and trunk ROM were calculated with the independent sample *t*-test. The correlations between the clinical values for CLBP subjects and COP parameters were calculated using a Pearson correlation. All statistical analyses were considered significant with p=0.05. Due to the pilot nature of the study and small sample size, we did not adjust the significance level for multiple comparisons/correlations.

Results

Subjects with CLBP reported baseline pain intensity 3.7±1.9 on a 0–10 scale with mean duration of pain of 8.1±3.6 yrs. Out of 10 subjects with CLBP, only 2 were taking pain medications of ibuprofen and meloxicam, respectively, on an as-needed basis, and 5 subjects were receiving chiropractic care. Seven subjects with CLBP experienced a slight non-statistically significant and non-clinically relevant increase in back pain (0.65±0.9, <1 on 0-10 pain scale) or reported muscle fatigue during testing. Two of these subjects took a 1-minute standing break during testing. None of the healthy subjects reported back pain or muscle fatigue.

For the COP parameters, velocity was the only one that showed a significant difference between groups (Fig.

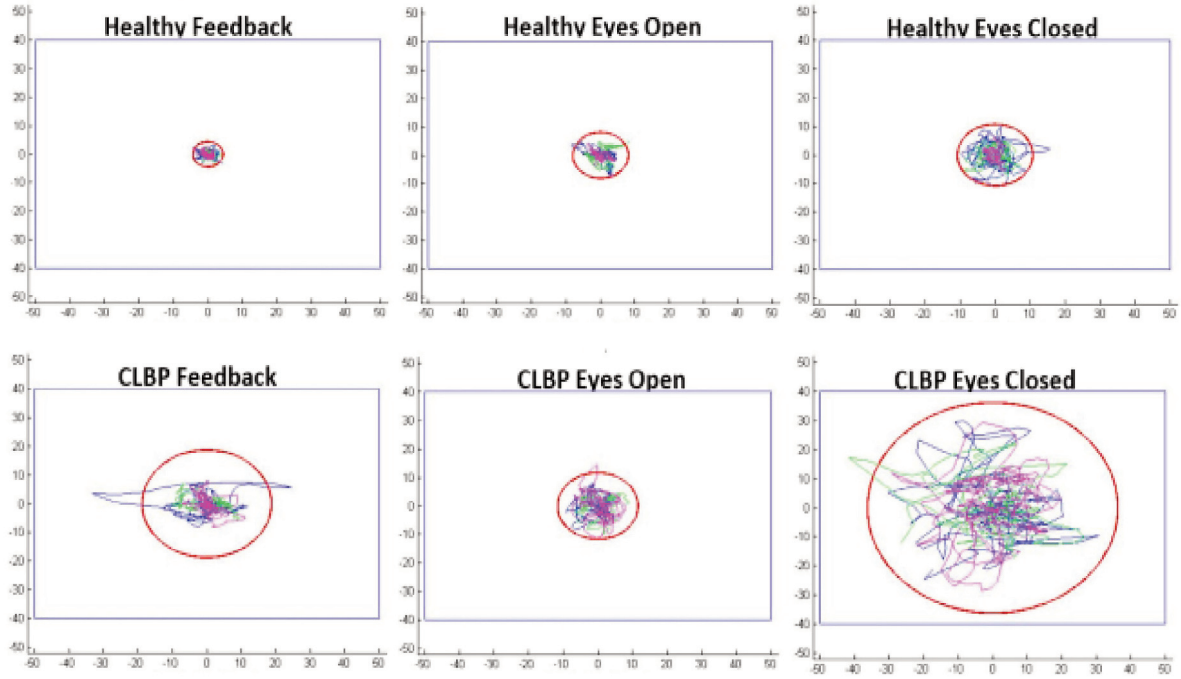

FIGURE 3. Example of COP trajectory per condition for one healthy subject and one CLBP subject. The 3 trials per condition were plotted in different colors, and the average COP circle was drawn in red around the 3 trials. X-axis = medial/lateral movement; y-axis = anterior/posterior movement.

4). For COP velocity, the ANOVA revealed a significant difference between groups (p=0.042), between conditions (p<0.001), and a significant interaction between condition and group (p=0.05). Further analysis using t-test demonstrated significant differences between the two groups in each condition: eyes open (p=0.045), visual biofeedback (p=0.049), and eyes closed (p=0.046). For the COP width and length parameters, there was no significant difference between groups (width, p=0.09; length, p=0.13), but there was a significant difference between conditions (width, p<0.001; length, p<0.001). Furthermore, there was no significant interaction between condition and group (width, p=0.12; length, p=0.26); however, CLBP subjects had consistently higher COP values and standard deviations compared to healthy controls.

Between the three conditions, the values for all COP parameters were significantly higher in the eyes-closed condition than both the eyes-open and visual biofeedback conditions (Fig. 4). There was no significant difference in COP parameters between eyes-open and visual biofeedback conditions.

Comparing the clinical tests between the two groups, trunk extension was the only test that was significantly different (p=0.02, Table 1). There was no statistically significant difference in trunk flexion or SLR between the healthy and CLBP subjects.

In healthy subjects, there was no single clinical test that had a significant correlation with any COP parameter in all conditions (Table 2). There were no significant correlations between left SLR and any of the COP

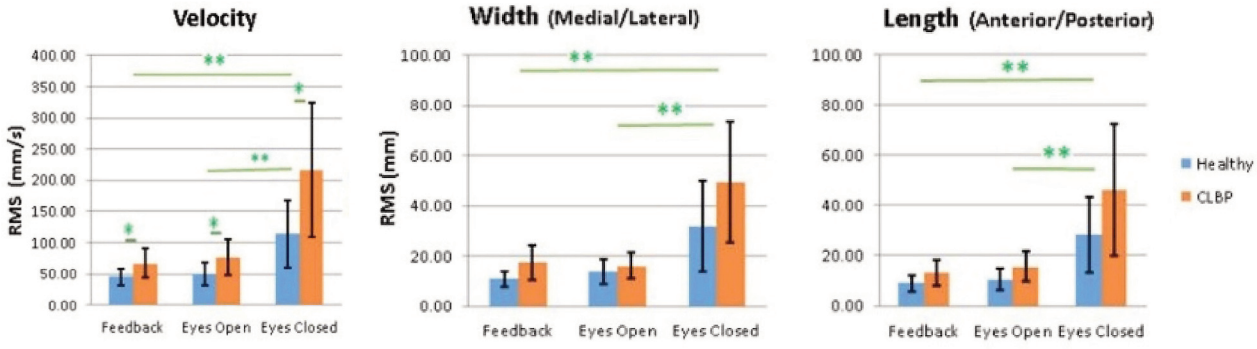

FIGURE 4. Average velocity, width, and length of COP movement for CLBP subjects vs healthy controls. Asterisks indicate statistical significance (p<0.05).

TABLE 1. Differences in Clinical Measures Between Healthy and CLBP Groups

Clinical Tests	Healthy	CLBP	p-Value
Lumbar flexion (deg)	52.3±12.7	41.6±17.1	0.14
Lumbar extension (deg)	19.2±6	13±4.8	0.02*
Right SLR (deg)	71.9±7.6	70.5±11.4	0.75
Left SLR (deg)	72.3±7.5	69.5±11	0.51

*Significant at $p<0.05$.

TABLE 2. Clinical Tests Correlation with COP Parameters*

	Healthy COP Parameters			CLBP COP Parameters		
	Velocity	Width	Length	Velocity	Width	Length
Eyes open						
SLR right	–0.68			–0.81†	–0.74	–0.76
SLR left				–0.70		–0.65
Flexion ROM						
Extension ROM						
Baseline pain						
Visual biofeedback						
SLR right				–0.84†	–0.85†	–0.78†
SLR left				–0.72	–0.86†	
Flexion ROM						
Extension ROM		0.70				
Baseline pain					0.65	
Eyes closed						
SLR right				–0.84†	–0.90†	–0.85†
SLR left				–0.74	–0.75	–0.70
Flexion ROM	–0.67	–0.70				
Extension ROM						
Baseline pain					0.65	

*Correlation coefficient r values for the significant correlations between COP parameters and clinical test values. COP, center of pressure; SLR, straight leg raise; ROM, range of motion.All shown values significant at 0.05 level, except † significant at 0.01 level. Non-significant values are not shown.

parameters. Right SLR had a significant correlation with COP velocity only during the eyes-open condition. Trunk flexion had a significant correlation with both the width and velocity of COP during the eyes-closed condition, while trunk extension had a significant correlation with only COP length during the visual biofeedback condition.

In CLBP subjects, SLR was the only clinical test that had significant and high correlation with all COP parameters in all conditions (Table 2). Trunk flexion or extension did not have a significant correlation with any of the COP parameters in any of the conditions. Baseline back pain had a significant correlation only with COP width and only during the visual biofeedback condition.

Discussion

The primary goal of this pilot study was to examine unstable seated postural control in people with CLBP under various conditions (eyes-open, visual biofeedback, and eyes-closed) and to examine the relationship between seated sway postural control and clinical measures. This approach provided insight into the effects of visual biofeedback during a pure trunk balance control task. The results showed that CLBP subjects had significantly higher velocity of COP than healthy subjects. There was no significant difference between eyes-open and visual biofeedback conditions in both healthy and CLBP subjects. Finally, SLR had a significant correlation with all COP parameters in CLBP subjects.

CLBP subjects had significantly higher values for COP velocity but not for COP length or width, relative to healthy controls. Previous studies reported higher COP velocity in subjects with low back pain (LBP) compared to healthy subjects during balance challenging conditions (e.g., low base of support, unstable balance) in both standing[15–17] and sitting.[18] This increase in COP velocity indicates impaired postural control in people with LBP during unstable conditions. This impairment may be a result of delayed muscle activation[18] and altered muscle activation patterns[19] in people with LBP.

Both healthy and CLBP subjects showed no difference in COP parameters between the visual biofeedback and eyes-open conditions. These results are in line with the findings of Mousa et al.,[11] in which the improvement in postural control after an extended visual feedback training program (2 months) was found with eyes closed but not with eyes opened in people with LBP.[11] This suggests that visual feedback might not provide added value to already acquired vison input for postural control in either healthy people or people with LBP. Alternately, the resolution of the visual biofeedback display used in our study may have not been sufficient to enhance visual input. In a previous study, a scale display of 5 or 10 times the magnitude, but not 2 times larger than the actual displacement of COP, was found to decrease COP parameters in healthy and elderly subjects.[20] We did not magnify the size of the scale of the visual biofeedback display. Therefore, the small scale display in our study might have resulted in no changes between eyes-open and visual biofeedback conditions.

Our study findings cannot be easily compared to the findings from previous studies about the efficacy of visual biofeedback training on balance control because of differences in the feedback protocols. Mousa et al.[11] found an improvement in postural control after 2 months of visual feedback training in people with LBP. Karimi et al.[21] also reported improvement in postural balance after 10 days consecutively training targeting specific trunk muscles with biofeedback in people with chronic LBP. A systematic review[10] and a randomized control trial[22] found that visual biofeedback training programs improved the COP parameters and balance in frail older adults.[10] However, Mousa et al.,[11] Karimi et al.,[21] Hagedorn et al.,[22] and the studies included in the systematic review[10] used long-term visual biofeed-

back training (10 days to 15 weeks, 240–960 min of training), while in our study the visual biofeedback was applied for a short duration (1 session, 3 trials of 30 sec each). Therefore, it is possible that the short duration of the visual biofeedback training (30-sec trials) in our study was not sufficient to improve the postural control. This is an important finding to consider when implementing visual feedback training to improve postural control and balance in rehabilitation programs. Although evidence for the effects of visual feedback training on postural control in the LBP population is lacking, a longer duration or more challenging training, as used for improving postural control in older adults or patients with peripheral joint pain,[23] could improve postural control in people with LBP also. Rehabilitation training based on verbal, visual, and tactile cues can normalize neuromuscular control,[24] anticipatory or feedforward postural adjustment,[25] and perhaps reduce pain as pain and postural control are associated in LBP.[26–28] Visual feedback training has been shown to compensate sensorimotor disturbance[29] and can be used to readjust proprioceptive input[30] that gets disrupted in people with CLBP.

We found that both healthy and CLBP groups had an increase in COP parameters with eyes-closed, confirming that neuromuscular postural control was challenged when vision is removed. This result was also seen by Radebold et al.,[18] who found significant correlations between muscle response time and balance control during eyes-closed tasks but not during eyes-open tasks.

The significant and strong negative correlation between SLR and all COP parameters in CLBP subjects indicates that increased flexibility leads to better postural control in people with CLBP. The SLR test causes tension on the hamstring muscles and lower lumbar nerve roots, and therefore reduced SLR measures could be caused by increased nerve root tension,[31] which could alter balance and postural control. If these results are confirmed with larger clinical trials, SLR could be used in future research and clinical programs to predict balance control deficits in people with CLBP. Future studies should utilize an intervention (e.g., stretching exercises, nerve glide techniques) to increase SLR and investigate its effect on postural control.

The main limitation of this study is the small sample size. Therefore, results should be considered with caution. However, the findings from this pilot study could guide future studies investigating the use of visual biofeedback on seated balance control training with longer duration in CLBP populations. The results also highlight the importance of investigating the effects of visual feedback on clinical tests, as clinicians do not have access to laboratory equipment or training to conduct seated postural sway testing. Further correlations between other clinical values should also be examined, which could play an important role in CLBP therapy programs.

Conclusion

Seated postural control is altered in people with CLBP. Closing eyes decreased postural control in both healthy and CLBP subjects, yet the addition of short-duration 30-second visual biofeedback did not improve the unbalanced-seated postural control in healthy and CLBP subjects. More studies using a larger sample size and longer visual biofeedback training are needed to confirm this finding. The SLR test had significant and strong negative correlation with COP parameters. Further studies are needed to investigate if improving the hamstring flexibility and sciatic nerve glide can improve the balance /postural control in CLBP.

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