RESEARCH ARTICLE

Efficacy of the Star Excursion Balance Test in Detecting Reach Deficits in Subjects with Chronic Low Back Pain

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Abstract

Study Design. The study design is a case control study. **Objectives.** The objective of this study is to evaluate how chronic low back pain (CLBP) affects the performance of Star Excursion Balance Test (SEBT). **Background.** Chronic low back pain is associated with paraspinal and other trunk muscle weakness and reduction in coordination of low back muscles. This reduction in muscular strength and coordination contributes to decreased postural stability, balance and neuromuscular control in subjects with CLBP. SEBT is a simple, reliable and valid method of dynamic performance and is an alternative to more sophisticated instrumented methods. However, no study has evaluated the effect of SEBT on CLBP patients. **Methods and Measures.** Ten patients with CLBP (localized back pain, lasting more than 6 months and radiating no further than the buttock with normal neurological examination) and 10 normal age and sex matched subjects (mean age 34.30 + 8.67(range 22–50) participated in this study. All participants completed the SEBT on their dominant leg, and distance measures were collected and compared between groups. **Results.** The dependant variable was analysed using independent *t*-test with $p < 0.05$. The CLBP group demonstrated significant reductions in excursion distances for all directions of the SEBT compared with the control group, except for the posterior (P) direction (0.281) **Conclusion.** Star Excursion Balance Test is an effective and simple tool to identify and measure reach deficits in patients with CLBP. We recommend using SEBT as an outcome measure to identify dynamic balance, multi-planar excursion and postural control in patients with CLBP.

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Keywords

balance; lower back pain; posture

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Introduction

Chronic low back pain (CLBP) is defined as a persistent and disabling low back pain lasting more than 3 months (Bogduk 2004). Paraspinal and other trunk muscle weakness have been documented in severe, chronic low back pain (Danneels *et al*., 2002). According to Hodges and Richardson (1999), the function and coordination of the stabilization of low back muscles are reduced in CLBP patients. This reduction in muscular strength and coordination contributes to decreased postural stability and neuromuscular control in subjects with CLBP (Gill and Callaghan, 1998; Lam *et al*., 1999; Della Volpe *et al*., 2006). According to Ershad and Kahrizi, balance impairment in CLBP patients might be due to the changes in transmitted information by mechanoreceptors, paraspinal muscle spindle dysfunction, impairment in muscle strength and coordination, delay in muscle recruitment or increased active muscle tension along with lack of postural control and changes in proprioception (Ershad and Kahrizi, 2008). Moreover, pain can also be a contributive factor for changes in postural control. Discharge from high-threshold nociceptive afferents interacts with spinal motor pathways (Decchi *et al.*, 1997; Rossi *et al.*, 1999, 1995) and primary somatosensory and motor cortex (Rossi *et al.*, 1998, 2003) leading to adaptive changes in postural control (Arendt-Nielsen *et al.*, 1996; Graven-Nielsen *et al.*, 1997). Further, Volpe *et al.* has experimentally proved that CLBP patients demonstrate dysfunction of the peripheral proprioceptive system (lower limbs) or the central integration of proprioceptive information (Della Volpe *et al.*, 2006).

The umbrella terms 'balance', 'equilibrium' and 'postural control' are used as synonyms for the same concept of the mechanism by which the human body prevents itself from loosing balance (Ragnarsdottir, 1996). The maintenance and control of balance, whether under static or dynamic conditions, is an essential requirement for physical and daily activities. In the simplest terms, balance can be defined as 'the ability to maintain the body's centre of gravity within the limits of stability as determined by the base of support' (Yim-Chiplis and Talbot, 2000). Controlling balance involves the interaction of the neurologic, musculoskeletal, proprioceptive, vestibular and visual systems. Postural control can be either dynamic or static (Winter *et al.*, 1990). Static postural control is attempting to maintain the base of support while minimizing movement of body segments and the centre of mass; dynamic postural control involves the completion of a functional task with purposeful movements without compromising an established base of support (Winter *et al.*, 1990; Gribble *et al.*, 2004). Neuromuscular control is defined as the interaction between the neurological and musculoskeletal systems to produce a desired effect or response to a stimulus (Enoka, 2002). Dynamic activities can also be described as those that cause the centre of gravity to move in response to muscular activity (Kinzey and Armstrong, 1998). Dynamic control is important in many functional tasks as it requires integration of appropriate levels of proprioception, range of motion and strength. So, assessment of dynamic balance is very much important. Very few practical and clinical tools are available for measuring dynamic balance in non-neurologically impaired adult patients.

The Star Excursion Balance Test (SEBT), introduced by Grey as cited by Earl and Hertel (2001), evaluates the postural control system, and the outcomes to SEBT are mixed. SEBT has been found to be a reliable functional test that quantifies lower extremity reach while challenging an individual's limits of stability (Olmstead *et al.*, 2002). SEBT is found to have good inter-rater reliability and measures dynamic balance well while detecting performance deficits in musculoskeletal injuries (Gribble, 2003) such as chronic ankle ligament instability (Olmsted *et al.*, 2002), anterior cruciate ligament reconstruction (Hertel *et al.*, 2006) and fatigue (Winter *et al.*, 1990; Denegar *et al.*, 2001). Hertel *et al.* (2000) found high intra-tester (0.78–0.96, 0.82–0.96) and inter-tester reliability (0.35–0.84, 0.81–0.93), with significant learning effects. Raty *et al.* (2002) and Olmsted *et al.*, 2002 in their studies concluded that the SEBT is a simple, cheap, rapid, reliable and valid tool that does not require special equipment and is effective in measuring multi-planar excursion and postural control. The SEBT has also been found to be a valid tool in determining the effectiveness of reach deficits and postural control in patients with ankle stability (Kinzey and Armstrong, 1998; Olmsted *et al.*, 2002). However, Kinzy and Armstrong have claimed that the SEBT uses quasi-static equilibrium and that the movement patterns tested are not similar to movements found in activities of daily living or sports. Learning effects, body height, leg length and gender are found to be limiting factors that may affect the outcome of SEBT (Kinzey and Armstrong, 1998).

Although studies have looked in to the effects of SEBT on lower limb musculoskeletal injuries, no study has evaluated the effect of SEBT on CLBP patients, in whom the neuromuscular control has been impaired. Hence, the purpose of this study is to evaluate how CLBP affects the performance of SEBT.

Methodology

Subjects

Ten CLBP and 10 age matched control subjects participated in this study ($n = 20$). There were 10 men and 10 women. The mean age group of the patients was 34.30 (standard deviation 8.67, range 22–50). Inclusion criteria were 1) localized back pain, lasting more than 6 months and radiating no further than the buttock, 2) no previous history of sciatica or other radicular involvement, 3) normal neurological examination, 4) no dysfunction of nerve roots (changes in muscle strength, sensory changes and problems with bladder or bowel function) and 5) no hip/knee/ankle/foot problems. The patients with CLBP recruited for the study had no complaints of vestibular and neurological diseases.

Control subjects had not experienced any low back pain 6 months prior to testing and had no evidence of gait, postural or musculoskeletal abnormalities. Informed consent was obtained from each subject, and the experimental procedure was approved by the Institute Ethics Committee.

As Olmsted *et al*., 2002 has reported that there is no test that is considered a gold standard for validation of the SEBT, no other tests were warranted.

Star Excursion Balance Test description

This functional test requires subjects to maintain balance on a single limb (stance leg) while trying to reach as far as possible with the opposite leg. The SEBT is a series of eight unilateral balance tests. In the test, the participants stood at the centre of a grid laid on the floor with eight lines extending at 45° increments from the centre of the grid. Each of the eight lines extending represents the specified directions to which each subject was required to reach out with the most distal part of their reach foot and touch as lightly as possible to ensure they are not using that leg for support. The eight directions are anterolateral (AL), anterior (A), anteromedial (AM), medial (M), posteromedial (PM), posterior (P), posterolateral (PL) and lateral (L) . The subject then returned to bilateral stance while maintaining balance. The reach distance was measured in centimetres using a standard measuring tape from the centre of the grid to the point that the subject had managed to reach in the specified diagonal line.

Procedure

The test was explained to each patient by verbal instruction and visual demonstration. The test was performed with the subject maintaining a single leg stance with his dominant leg while reaching with the contra lateral leg. Leg dominance was asked by asking subjects what leg they would use to kick a soccer ball (Greenberger and Paterno, 1995). The subjects were instructed to reach as far along the eight directions as possible to touch the farthest point on the line as lightly as possible so as to avoid using the reach leg for support. The subjects then returned to the centre of grid on both feet while maintaining balance. Six practice trials in each direction were given to decrease any learning effects (Gribble, 2003), and a randomized order of testing was followed to avoid potential learning effects and fatigue (Gribble and Hertel, 2003). Subjects were given a five second rest between each reach. Reach distances were recorded by one of the authors placing a mark on the touchdown point (Figure 1). The trials were discarded 1) if the subject lifted the stance foot from the centre of the grid, 2) if the subject lost his or her balance and 3) if the subject did not touch the line with the reach foot while continuing to fully weight bear in the stance leg. The patients and their matched controls were measured on the same day and session to minimize the effect of temperature and environment.

Data analysis

The independent '*t*' test was used to determine the statistical differences in reaching distances of eight directions between groups. Reach distances were normalized to subjects' leg length. Leg length was measured from the anterior superior iliac spine to the distal tip of the medial malleolus. Normalization was performed by dividing each excursion distance by the participant's leg length and then multiplying by hundred. Normalized values can thus be viewed as a percentage of excursions distance in relation to a participant's leg length (Gribble and Hertel, 2003). The significant level for

Figure 1. Measurement of reach distance

all analyses was set at $p < 0.05$. All statistical analyses were performed using SPSS (SPSS Inc., Chicago, USA) 10.0 computer programme.

Results

The results of the study (Table 1) showed that after normalizing the values to the leg length, all directions but posterior (P) demonstrated a great mean distance in the control group compared to the CLBP group. The posterior direction showed the lowest standard deviation range in the CLBP but was one of the highest ranges in the control group.

Discussion

The main result of the present study showed that there was statistically significant difference in performance between the control and CLBP groups in all directions except P.

In normal human movement, postural reflexes are organized well ahead in anticipation of movement or perturbation to balance. Effective postural control during a dynamic task such as SEBT involves the generation and application of forces and controlling the body in space. The human postural system operates on the basis of the integrated information from somatosensory, vestibular and visual inputs. In a task such as SEBT, this information is constantly reweighted so as to generate the appropriate forces to control and maintain balance in a wide range of situations (Massion, 1992). The amalgamation of afferent and efferent signals either within the central or peripheral nervous systems provides a feedback control circuit between the brain and the musculoskeletal system (Guskiewicz and Perrin, 1996) (Lephart *et al*., 2000). Optimal performance of SEBT may not be possible if there is no accurate afferent input. The integration of all afferent information provides more accurate conscious awareness of body, joint position and movement that is useful for controlled movement/tasks or in corrective strategies (Guskiewicz and Perrin, 1996). This may be the reason why the control subjects performed well in directions where all the three systems were available (Table 1).

Table 1. Mean normalized excursion distance in centimetre

Direction	CLBP (mean and SD)	Control (mean and SD)	Significance ($p < 0.05$)
AL	64.27 ± 4.31	72.21 ± 5.35	0.002
A	72.61 ± 6.91	82.38 ± 5.11	0.002
AM	74.31 ± 6.88	88.88 ± 6.00	0.000
M	71.36 ± 5.17	87.47 ± 1.21	0.001
PM	74.19 ± 8.50	83.06 ± 1.02	0.049
P	71.59 ± 1.09	76.22 ± 7.35	0.281
PL	63.19 ± 1.18	76.30 ± 9.32	0.000
L	50.80 ± 6.32	70.04 ± 5.76	0.013

AL = anterolateral; A = anterior; AM = anteromedial; M = medial; PM = posteromedial, P = posterior; PL = posterolateral; L = lateral; SD = standard deviation; CLBP = chronic low back pain.

In a dynamic task such as SEBT, the visual and vestibular inputs are important for perception of external cues and dynamic movements. The vestibular sensory apparatus is linked closely with the visual system, influencing eye movement patterns, and it individually affects postural control through postural reflexes (Guskiewicz and Perrin, 1996; Lephart *et al*., 2000), (Goldberg and Hudspeth, 2000; Honrubia and Hoffman, 2011). Visual cues tend to be the most reliable, and individuals tend to trust this information more in situations of conflicting inputs (Latash, 1998). When visual cues are conflicting or when support surface is unstable, the vestibular sense becomes more predominant (Guskiewicz and Perrin, 1996). As the participants recruited for the study had no documented evidence of visual or vestibular dysfunction, it is highly possible that the difference in excursion distance in CLBP group may be attributed to the reduced proprioceptive feedback from mechanoreceptors.

It was a surprising finding that the control subjects performed this test as well as the CLBP subjects in P direction, when the vision input was not available. This may be hypothesized to both the role of vision and proactive strategies employed. Vision plays a major role in studying the environment, and prediction is used to estimate the potential de-stabilizing effects of simultaneously performing another task, such as posterior reach, leading to either avoidance or accommodation. As avoiding is not possible in SEBT due to the nature of the test, the participants might have opted for the accommodation strategy such as reducing the extent of posterior reach (Shumway-Cook and Woollacott, 2001).

During posterior reach, the brain could not cognitively process visual information of any kind as both central and peripheral visions were not available. Vickers (2009) postulated this as the quiet eye period, which represents the time needed to cognitively process information, an indicator of optimal focus and attention. As central vision is not available during P direction, no visual fixation was framed, and the higher command might have chosen stability over mobility by reducing the reach to within safe limits. These findings are in contradiction with previous work showing the largest differences between CLBP patients and healthy subjects in tasks in the absence of visual input. This may be attributed to the peculiar nature of SEBT, than to any other factors.

The excursion distances have been found to be reduced in CLBP group (Table 1). Neuro imaging studies have revealed numerous structural and functional changes within the brains of people with chronic musculoskeletal pain contributing to the development and maintenance of the chronic pain state (Apkarian *et al.*, 2009; Tracey and Bushnell, 2009). It has been hypothesized that disruption of cortical representations of the body will disrupt body perception. CLBP patients exhibit deficits in proprioception and tactile acuity (Gill and Callaghan, 1998; Taimela *et al.*, 1999) (Brumagne *et al.*, 2000; O'Sullivan *et al.*, 2003) (Moseley, 2008; Luomajoki and Moseley, 2009; Wand *et al.*, 2010) and perform poorly on tasks that require judgements on the direction of trunk rotation (Bray and Moseley, 2009). Balance dysfunction in CLBP patients may be due to altered proprioceptive feedback from the lumbar spine (Gill and Callaghan, 1998; Mok *et al.*, 2004) resulting in dysfunction of the central integration of proprioceptive information. As the accurate information from mechanoreceptors is impaired, the corrections necessary for task completion and the maintenance of dynamic balance (Nashner, 1987; Schmidt and Lee, 2005) might have been affected. This stress in proprioceptive system might have lead to differences in sensory discrimination in the CLBP group, as compared with the healthy subjects, which might have resulted in the inferior reach in this group.

Silfies *et al.* (2009) have demonstrated experimentally that there is lack of feedforward activation of core musculature in CLBP patients leading to motor control dysfunction of posture during movement. This activation of core muscles is a general response to postural challenge and is independent of the direction of the extremity movement (Aruin and Latash, 1995; Hodges and Richardson, 1997). Because the perturbation in SEBT is self-initiated, it is expected that the central nervous system can predict the changes and preprogramme itself to the dynamic challenges posed by SEBT. The reduced excursion distance in CLBP group as seen in this study may add to the literature of articles showing weakness or impaired activation timing in CLBP subjects.

However, there are limitations with this study. The small sample size might not be sufficient enough to generalize the results of the study to the whole CLBP population. Proprioception and core muscle strength was not evaluated, and it was assumed to be impaired in patients with CLBP. It is possible that other factors such as apprehension, fatigue, reduced exercise tolerance and impaired cortical functions might have played a role.

Conclusion

The SEBT is effective as an outcome measure in identifying functional deficits in patients with CLBP. The CLBP group demonstrated a significant reduction in excursion lengths for all directions, except P, when compared with a control group. The SEBT is a dynamic and low cost tool that may successfully identify functional reach deficits in CLBP patients using measures of lower extremity reach. Future studies may evaluate if lower extremity reach improves with rehabilitation in CLBP. Further research is required to understand the cause of this reduction (e.g. strength, proprioceptive deficits, pain and perception changes associated with chronic pain states).

Implications for practice and research

The results of the study showed that CLBP patients have limited excursion distances in SEBT. As it is assumed that reduction in SEBT is associated with impairment in proprioception and muscle strength, we may hypothesize that SEBT, when used as a rehabilitation tool, may help in the improvement of strength and proprioception in patients with CLBP. Further, the effect of strengthening of core muscles and proprioception training on SEBT reach distances in patients with CLBP is a future area of study. Another interesting area of future research is to measure the muscle activation patterns in tasks that involve trunk and lower limb movements such as SEBT.

Key points

- Patients with CLBP have significant reduced excursion distance in all directions.
- The results demonstrate no significant finding for the posterior direction.

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