Evaluation of postural stability during quiet standing, step-up and step-up with lateral perturbation in subjects with and without low back pain.

Ram Prasad M, MSPT[1,2]; Shweta Shenoy D, PhD[2]; Jaspal Singh Sandhu, MS[2]; Sankara N[3], DM; Sukdeb Mahanto, MPT[1]

1 Srinivas College of Physiotherapy and Research center (SCPTRC), Mangalore, Rajiv Gandhi University of Health Sciences, Karnataka, India.
2 Department of Sports Medicine and Physiotherapy, Guru Nanak Dev University, Amritsar, Punjab, India.
3 Kasturba Medical College (KMC), Mangalore. Karnataka, India.

ABSTRACT: *The evaluation of postural stability during quiet stance, step up and step up task with perturbation using posturography could be useful in treatment and outcome monitoring in chronic low back pain rehabilitation (CLBP). The aims of this study were twofold and investigating 1) differences of postural stability measures between CLBP patients and healthy participants during above mentioned tasks. 2) postural stability characteristics between control and movement impairment groups of CLBP patients on above tasks. Fourteen CLBP and fifteen normal individuals participated and posturography outcome variables were obtained during above tasks. The low back pain subjects showed significantly different anterior-posterior (p=0 .01) as well as medio- lateral (p=0.05) postural stability characteristics during the step up task with external perturbation, whereas quiet standing and simple step up task did not show any differences. In addition to these values, in CLBP population, the maximum COP excursion (p=0.01), standard stability (p=0.02) and the stability scores (p=0.02) were also found significant in step up with perturbation task compared to healthy participants. As the task difficulty increases CLBP patients exhibited significantly different postural stability characteristics compared to healthy participants. Conversely, sub-group analysis in CLBP patients revealed significant differences only in medio-lateral COP excursions during normal standing (p=0.005). No significant differences were observed in tasks of higher difficulties such as step up and step up task with lateral perturbation in-between patients with movement and control impairment groups of CLBP. These findings have implications for assessment and optimizing postural control interventions on functional back pain rehabilitation.*

KEY WORDS: POSTURAL BALANCE; POSTUROGRAPHY; CHRONIC BACK PAIN; STEP UP TASK.

INTRODUCTION

Musculoskeletal disorders have significant influence on balance performance (Byl and Sinnott 1991; Wegener et al 1997) and limit the use of corrective movement strategies during balance perturbations (Shumway-Cook 1996). Byl and Sinnott (1991) reported that low back pain patients had a greater degree of sway, a greater use of hip strategy and a more posterior center of pressure, in erect stance when compared to healthy participants. Mok et al (2004) suggested that people with low back pain demonstrated an inability to control hip strategy for balance recovery in response to an anterior- posterior balance challenge.

COP displacements are commonly recorded using force platforms and gives major information about the postural stability characteristics of a given task, performed on the forceplate. In many studies quiet standing was commonly used for postural stability assessment despite the fact that most onset of back pain reported during dynamic activities such as day-to-day functional activities. These assessments may be helpful in evaluating and screening back pain but the clinical use of these results in back pain rehabilitation was found to be limited. On the other hand, these kinds of simple tasks particularly voluntarily generated tasks can be used as a training modality in the early functional back rehabilitation or along with other active exercise interventions such as walking and bicycling (Kerr et al 2007). The recent surge of interest in motor control issues has prompted the development and inclusion of postural stability training along with concurrent muscle (strength

Correspondence to:
Ramprasad M
Srinivas College of Physiotherapy
and Research Center,
Pandeswara,
Mangalore,
Karnataka,
India.
E-mail: mramprasad@rediffmail.com

and endurance) training for comprehensive back rehabilitation and successful functional back restoration program.

However postural stability variables for these functional tasks and their processes are not well understood in back pain rehabilitation, despite its potential as a window into functional back rehabilitation. Hence detailed kinetics, kinematics of postural stability characteristics need to be determined before applying into clinical practice. Postural control fundamentally relies on two domains, i.e., ability in maintaining a given posture and ensuring equilibrium in position change, hence in this study step up task was used to examine the postural stability. Further Sims and Brauer (2000) reported that the step up task provided a greater challenge to medio lateral (m-l) postural stability than step forward.

A sub-grouping approach i.e., classifying CLBP patients into homogenous groups i.e., movement and control impairment, was performed to differentially analyze postural stability characteristics of complex heterogeneous CLBP population. An external perturbation during mid of step-up task was introduced to examine the effect of external perturbation on step-up mediated postural control responses in CLBP and healthy participants. The direction of perturbation was kept to the lateral side to examine the influence of laterally induced postural adjustments during step-up rather than sagittal fashion commonly used in many studies. The primary aim of this study was to investigate differences in postural stability characteristics of patients with and without low back pain during quiet standing, voluntary step up and step up with externally induced lateral perturbation. Several studies have reported larger COP displacements (Della-volpe et al 2006; Popa et al 2007) with narrow and self-selected natural stance widths. We therefore hypothesize that wider stance width may reduce the likelihood of greater resultant COP displacements in CLBP population. Further as stated above an attempt was made to investigate whether a difference exist between movement and control impairment groups of CLBP subjects (O'Sullivan 2005) on postural stability characteristics.

METHODOLOGY

Selection of the participants:

Chronic low back pain participants were recruited from the affiliated hospitals and rehabilitation centers of SCPTRC Mangalore, Karnataka, India. Informed consent was obtained from all the subjects, which was approved by the university ethical committee.

Patients with chronic localized low back pain lasting more than 6 months and radiating no further than the buttock with normal neurological examination were included in this study; of these none had neurological disorders (sciatica or radicular involvement), major musculoskeletal disorders, or previous lumbar or abdominal surgery. An orthopedic surgeon performed the examination. All CLBP subjects were instructed to avoid medication 24 hours before the test. Prior to the experiment, the CLBP patients completed visual analog scale for pain (VAS), Ronald Morris Disability Questionnaire (RMDQ) and Fear Avoidance Belief Questionnaire (FABQ).

A musculoskeletal assessment to identify movement impairment or control impairment based on guidelines provided by O'Sullivan (2005) was performed by a sports physiotherapist trained from Curtin University, Australia and had 6 years of clinical experience in back rehabilitation. This classification system was based on set of substantially reliable essential characteristics proposed by Dankaerts and O'Sullivan et al (2006). The control impairment group were identified by the presence of "pain with minimal radiation and absence of impaired movement of the symptomatic segment in the painful direction of movement or loading (based on clinical joint motion palpation examination)". If hypomobility or the presence of impaired movement was found in involved segment, the subject was categorised into movement impairment group.

A BERTEC force plate with Balance Screener Setup (Columbus, U.S.A.) was used to record the COP displacements during normal quiet standing, voluntary step-up, and step-up with perturbation as described below. For step-up with lateral perturbation task, initially Digital Acquire setup of forceplate was used to determine the weight shift on the stepping leg. The following outcome variables were computed: COP-medial-lateral and anterior-posterior excursions, Maximum and minimum COP excursions, Percentages of maximum standard stability and stability scores, Minimum/maximum COP excursion ratio and Minimum stability. Based on the COP displacements postural stability outcomes variables were computed using screener setup and their calibration procedures reported in Annexure 1 (Parker 1973; http://bertec.com/uploads/pdfs/manuals/BalanceCheck% 20Screener.pdf).

Normal Quiet Standing:

A marked foot chart with the intermalleolar distance of 25-cm placed on the force plate was used as a reference. While standing 30 seconds on the foot chart, participants were instructed to fix their gaze at a point on the wall to their eye level to minimize head tilting.

Voluntary Step- Up:

The subjects were asked to stand 10 cm away from the force plate, which height was kept at 10 cm. The subjects were informed to step-up on the force plate using natural speed. A metronome was used to coordinate the step-up task for 5 consequent beeps to complete the entire step-up task. The entire step up task was completed within 10 seconds and data was stored.

Step- Up Task with Lateral Perturbation:

All participants were informed to achieve and maintain half of their body weight on the force plate monitor using their stepping leg while maintaining the stance foot on the ground. Once the participants achieved the necessary weight level on the force plate, an external perturbation was provided at the stepping leg's side through pendulum setup. COP excursion of above 2 standard deviations for 50 milliseconds obtained from the quiet standing position in medio-lateral direction was kept as minimal requirement of perturbation and weight on the pendulum was calculated as reference weight. This was determined by 'Digital Acquire' setup of the force plate. Perturbations which triggered stumbling reactions were excluded and weights on the pendulum were readjusted to identify the exact reference weight through maximum of three trial tasks.

The pendulum weights were adjusted to produce similar perturbation on the Bertec screener setup. To minimize the amount of measurement error, particularly to achieve 50% body weight on force plate, up to three trials were provided to become fully comfortable and familiar with the testing protocol. The pendulum setup was suspended from the ceiling and the resting position of pendulum was positioned at midpoint of base of support on the foot chart on the force plate. The perturbation was given at shoulder level by moving the pendulum laterally and released manually by the operator. Their weights were adjusted based on above minimal COP M-L shift excursion criteria. Mean values of three trials of each task were taken for statistical analysis. Up to four trials were performed to achieve valid recordings from the force plate during step-up with lateral perturbation. Independent t-test was used to analyze the difference between CLBP and normal participants. A p-value of less than 0.05 was used to determine significance.

RESULTS

Data were collected from fourteen individuals with chronic non-specific low back pain and fifteen healthy individuals. CLBP subjects had a mean age of 36.8(2.8(SD)) years, mean height of 165.7(8.8) centimeters, mean body mass index (BMI) of 22.3(3.3) and healthy participants had a mean age of (SD) 32.7(1.2) years, mean height of 163.8(9.0) centimeters and BMI of 20.9(3.6). CLBP patients had a mean(SD) score of 4.72(2.5) for actual pain intensity (0= no pain, 10= most severe pain), a disability level of 7.7(4.7) measured by the RMDQ (0= no disabilities, 24= severe disabilities), Fear Avoidance Belief for Work score component of 19.8(1.2) (0 = minimal score, 42 = maximum score) and Fear Avoidance Belief for Physical activity score component of 14(4.5) (0 = minimal score, 24 = maximum score), as measured by the FABQ.

Our study revealed significantly different postural sway characteristics in the directions of medio-lateral and anterior-posterior COP excursions, maximal COP amplitudes, percentages of maximum standard stability, and stability scores only in the step-up with lateral displacement task between CLBP and healthy participants ($p<0.05$) (Figure 1,2,3,4 and 5). CLBP and healthy participants did not demonstrated significant difference in quiet standing as well as step-up task. Further significant differences were observed between groups of movement and control impairment CLBP patients only during quiet standing on COP (Medio-lateral) excursions ($p<0.05$), however no significant COP (Medio-lateral) excursions observed during step-up and step-up with lateral perturbation tasks (Figure 6).

DISCUSSION

Analysis of quiet standing and step-up task:

This study found no differences in COP excursions on medio-lateral and anterior-posterior directions, maximal COP excursions and maximum standard stability scores during step-up and quiet standing between healthy participants and CLBP subjects (Figure 1, 2 and 3). In our study CLBP patients reported COP sway characteristics particularly excursion amplitudes similar to healthy participants contrary to smaller or larger postural sway commonly reported in CLBP population while comparing to healthy participants during usual standing and sitting tasks (Byl and Sinnott 1991; Van Dieen 2010; Van Daele 2010). These non-significant changes in COP excursions (Medio-lateral, anterior-posterior), maximum COP excursions and standard stability scores during quiet standing and stepping up task of CLBP patients might have resulted from wider base of support used in the study. Hence we postulate that with an optimal wider base of support such as used in this study, abnormal postural strategies can be minimized in CLBP population.

The results support the hypothesis that abnormal propensities of COP oscillations can be reduced by widen the stance of foot in CLBP population. Non-significant larger stability score also support this notion, 93.3% and 94.3% respectively in CLBP and healthy participants indicates that the patient population was also able to main perfect stillness as close to healthy participants in wider stance width (Fig 4).

Some aspects of our methodology warrant attention. Step-up task and the resultant non-significant COP excursions between CLBP and healthy participants could have been affected by the height and length of step-up (10cm) used in this study. This height was relatively lower compared to exigencies of day-to-day activities. Hence, step height alterations can be varied in future studies to evaluate the postural stability and COP displacements in CLBP patients during the step-up task.

Analysis of step-up with lateral perturbation:

During step-up with lateral destabilization postural responses, CLBP subjects exhibited significant increase in COP excursions on medio-lateral as well as anterior-posterior directions (Fig 1 and 2).

During step-up with perturbation task, CLBP patients further demonstrated significant increase in maximum COP excursions (*p=0.01*) and maximum standard stability (*p=0.02*) (Fig 4). Maximum COP excursion indicates the magnitude of the movement in the direction of maximum movement. The smaller value in healthy participants clearly demonstrated the better postural adjustments during step-up with perturbation compared to CLBP population.

Maximum standard stability scores represented how much of the standard limit of stability was used during the test in the direction of maximum movement. A higher score of CLBP (41%) compared to the group of the healthy participants (28%) indicated a larger standard limit of stability used by CLBP patents during step-up with perturbation task. This indicates the inability of the CLBP population to prepare and resist the pre-informed lateral displacement applied and tendency to lean larger in medio-lateral direction for lateral displacement, predisposing them to fall laterally in this study. However healthy participants were well prepared to counter the suddenly applied lateral displacement and demonstrated significantly smaller lean in medio-lateral direction during step-up with lateral perturbation.

Stability scores represent the ability to maintain balance during the test. 100% indicates that the patient was able to maintain perfect stillness. 0% indicates that the patient used all the standard efforts to maintain the stability during the test. The obtained stability scores of CLBP patients (58%) compared to healthy participants (71%) during step-up with lateral perturbation task, was significantly lower ($p<0.02$, Figure 5) indicating CLBP patients were unable to maintain balance during the step-up with lateral perturbation. However, CLBP subjects demonstrated no significant changes compared to healthy participants in minimum COP excursion, minimum/ maximum COP excursion ratio, minimum stability, and direction of instability parameters during step-up with perturbation task, step-up and quiet standing. The above results clearly revealed the frontal and sagittal plane movement execution dysfunction in CLBP subjects, while encountering demanding postural task during this study.

The findings of this study support the previous literatures reporting relation between COP displacements and stance width. Larger medial-lateral sway and COP oscillations were reported with narrow stance width in healthy participants (Kirby et al 1987; Henry et al 2001). Henry et al (2001) also reported more trunk displacements in narrow stance due to larger changes in COP oscillations in response to lateral perturbations. They further reported during wide stance, equilibrium control relied on passive stiffness resulting from changes in limb geometry, whereas narrow stance relied on active postural strategy regulating loading and unloading of the limbs.

Further studies have reported increased stiffness of legs-pelvis and the hip-ankle coupling (Day et al 1993), and hip abductor/ adductor muscles mediated stiffness control for frontal plane motion with wider stance width (Winter et al. 1996; 1998).The frontal and sagittal plane control execution dysfunction found in our study may be

Figure 1: COP (Medio-lateral) excursions during step-up with perturbation, step-up and quiet standing task in CLBP and healthy participants with independent 't' test results.

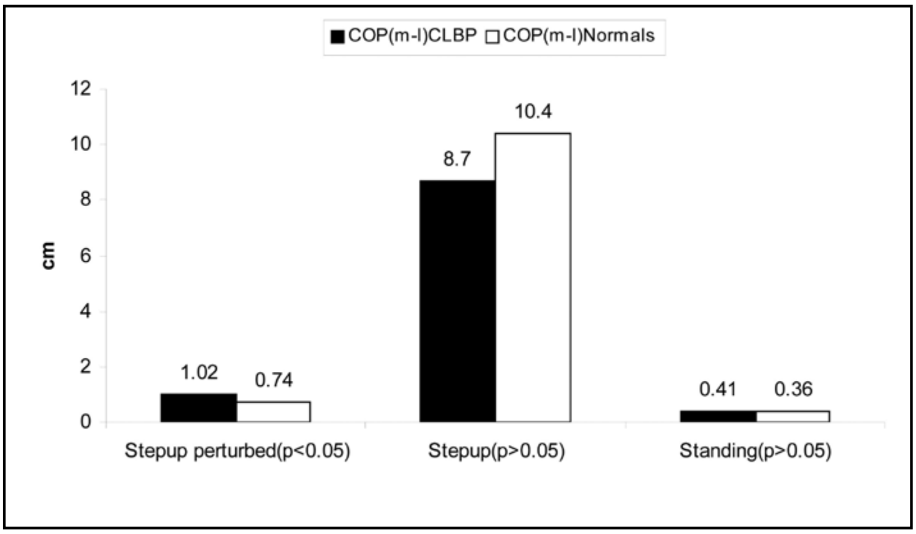


Figure 2: COP (Antero-posterior) excursions during step-up with perturbation, step-up and quiet standing task in CLBP and healthy participants with independent 't' test results.

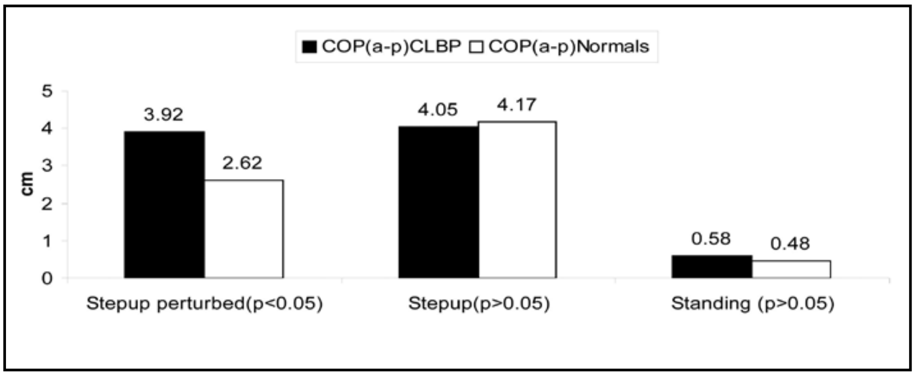


Figure 3: Maximum COP excursions during step-up with perturbation, step-up and quiet standing task in CLBP and healthy participants with independent 't' test results.

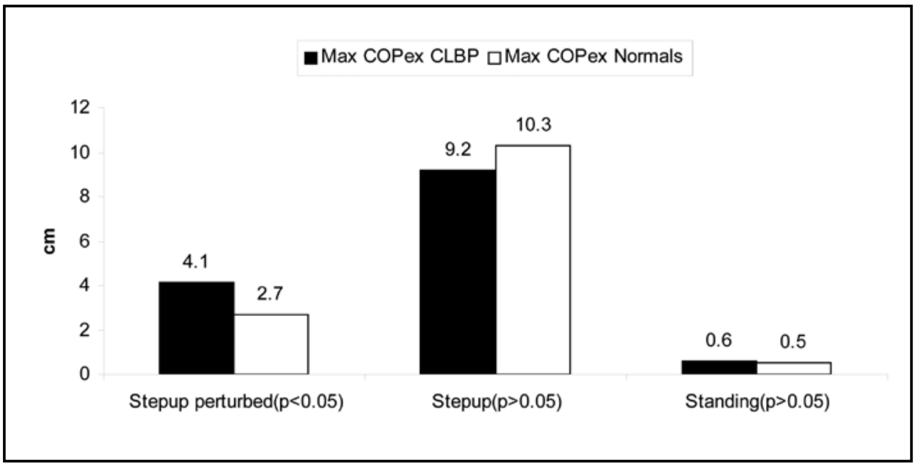


Figure 4: **Maximum Standard Stability % during step-up with perturbation, step-up and quiet standing task in CLBP and healthy participants with independent 't' test results.**

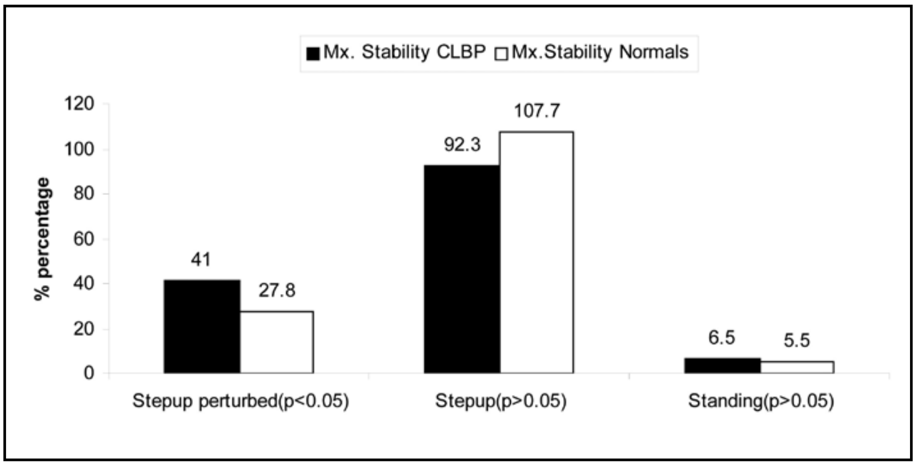


Figure 5: Stability scores (%) during step-up with perturbation, step-up and quiet standing task in CLBP and healthy participants with independent 't' test results.

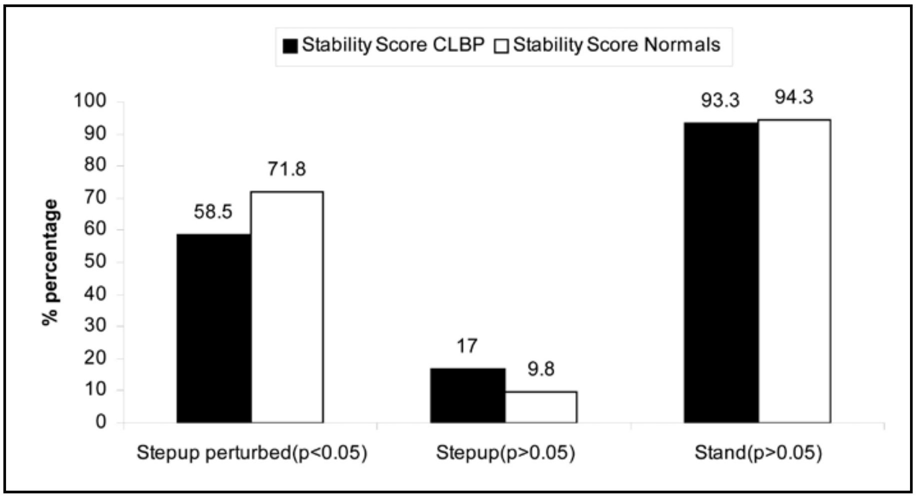
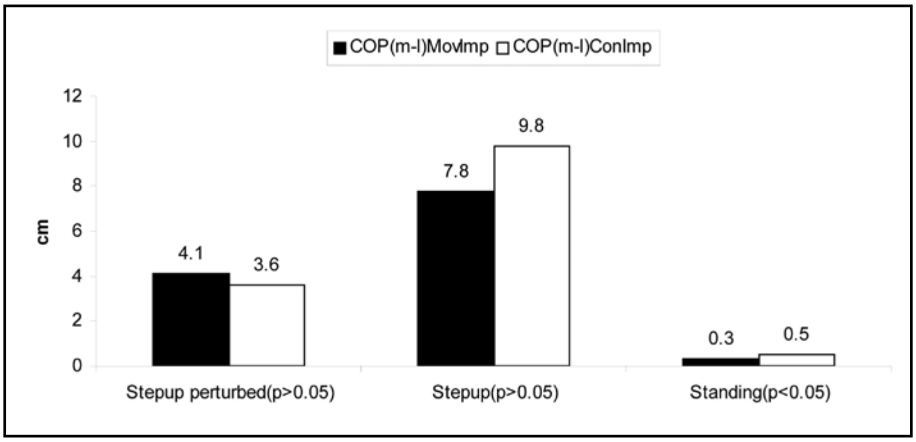


Figure 6: Sub-group analysis of COP (Medio-lateral) excursions during step-up with perturbation, step-up and quiet standing task between movement impairment and control impairment CLBP groups with paired 't' test results.



attributed to dysfunction in hip strategy (Mok et al 2004) and corrosion of postural control of above-mentioned mechanisms during exigent situations in CLBP patients.

The value of COP excursions on medio-lateral direction was analyzed to study the differences in movement and control impairment groups of CLBP participants. Statistical analysis revealed significant differences between groups of movement and control impairment during quiet standing ($p<0.05$), but not during the step-up and step-up with lateral perturbation tasks (Figure 6). The control impairment group (n=6) demonstrated significantly higher mean COP (Medio-lateral) oscillations than the movement impairment group (n = 8). These results provide preliminary evidence for the importance of sub-grouping in CLBP patients for functional specific exercise interventions. Inclusion of more subgroups as specified by O'Sullivan (2005) such as 'flexion pattern', 'active extension pattern' and 'multiple pattern' could have provided more distinct information on postural control characteristics pertaining to the groups during perturbation, rather than generally classifying them into movement and control impairment.

Implications:

Specific muscle training can be achieved through simple functional tasks such as stepping, if these tasks practiced repeatedly and cyclical in manner for functional specific back rehabilitation. This may facilitate the desired functional task specific outcome with minimal abnormal postural strategies in CLBP patients (for e.g. recumbent cycling for the sit-to-stand and step-up tasks). Further, the use of these robust, highly flexible cyclic movements such as stepping and step-up can benefit from the advantage of sequentially stretching and shortening of the muscles involved to produce more work (force) and use of spinal neural oscillators that optimize the postural control strategies related to locomotion (Kerr et al 2007; Smits-engelsman et al 2006). The assessment of postural stability characteristics of these simple functional tasks may help clinicians to quantify the impairments associated with these tasks, may provide effective intervention strategies aimed at optimizing abnormal postural control variables and may help in assessing the efficacy of treatment strategies for the training of the particular task. Our findings suggest that use of optimal wider stance width during exercise sessions of early functional and motor/postural control specific back rehabilitation can be helpful in reducing abnormal postural sways contrary to commonly reported patients selected or narrow stance width and associated abnormal postural sways during functional tasks.

Limitations:

Perturbation was induced by manual method and adjusted accordingly with the postural responses produced during familiarization trials. It may be possible that some participants might have developed rapid adaptation to the test situations. Larger step length, step height, maximum foot width and foot length with narrow to wider base of support combinations should be considered in future studies to examine the postural stability related parameters in back pain patients. More precise sub-grouping of CLBP patients could have resulted in significant different postural responses during tested tasks in this study. Larger sub-group sample size with improved research methods are needed to substantiate the results.

CONCLUSION

CLBP population demonstrated frontal and sagittal plane control dysfunction while encountering demanding postural task during this study. No significant difference was observed in subgroups of CLBP population while encountering difficult postural adjustments. Using wider stance width and adequate monitoring of postural stability responses during early functional specific back rehabilitation can curtail the problem of inducing abnormal postural strategies in CLBP patients as poor stability and control may influence abnormal spinal loading and sustain the production of peripheral nociception.

ACKNOWLEDGEMENTS

Our thanks to Selvamani K, Joseley SP, Narayanan V of SCPTRC and Srinivas Hospital, Raguveera KMC, Manipal for their assistance in force plate data analysis process; Trupti Metha, Abhisk, Pranav and Sruthi for countless assistance in mining data and assisting in each part of the overall study; Ramprabhu, Balasubramanian, John Varghese for their assistance during the revision of this manuscript; and A Shama Rao Foundation office and participated hospitals and our research center staffs for their overall assistance. This project was funded in part with an internal grant from SCPTRC, Mangalore, Karnataka, India.

REFERENCES

Byl N , Sinnott P 1991 Variations in balance and body sway in middle- aged adults: subjects with healthy backs compared with subjects with low back dysfunction. Spine 16: 325-30.

Dankaerts W, O'Sullivan PB, Straker LM, Burnett AF, Skouen JS 2006 The inter-examiner reliability of a classification method for non-specific chronic low back pain patients with motor control impairment. Manual therapy 111:28-39.

Day BL, Steiger MJ, Thompson PD, Marsden CD 1993 Effect of vision and stance width on human body motion when standing: Implications for afferent control of lateral sway. Journal of physiology 469: 479–499.

Della Volpe R , Popa T, Ginanneschi F, Spidalieri R, Mazzocchio R , Rossi A 2006 Changes in coordination of postural control during dynamic stance in chronic low back pain patients. Gait & posture 24:349-355.

Henry SM, Fung J, Horak FB 2001 Effect of stance width on multidirectional postural responses. Journal of neurophysiology 85:559–570.

http://bertec.com/uploads/pdfs/manuals/BalanceCheck%20Screener.pdf (accessed 29 April 2010).

Kerr A, Rafferty D, Moffat F, Morlan G 2007 Specificity of recumbent cycling as a training modality for the functional movements; sit-to-stand and step-up. Clinical biomechanics 22:1104-11.

Kirby RL, Price NA, Macleod DA 1987 The influence of foot position on standing balance. Journal of biomechanics 20: 423–427.

Mok NW, Brauer SG, Hodges PW 2004 Hip strategy for balance control in quiet standing is reduced in people with low back pain. Spine 29: e107-112.

O'Sullivan PB 2005 Diagnosis and classification of chronic low back pain disorders: maladapitve movement and motor control impairments as underlying mechanism. Manual therapy 10: 242-255.

Parker JF, Vita WR 1973 Bioastronautics Data Book, 2nd edn. Scientific and technical information office, National aeronautics and space administration, Washington, D.C.

Popa T, Bonifazi M, Della Volpe R, Rossi A, Mazzocchio R 2007 Adaptive changes in postural strategy selection in chronic low back pain. Experimental brain research 177:411-8.

Shumway-Cook A 1996 Control of posture and balance. In: Shumway-Cook A, Wollacott M (eds) Motor control. Theory and practical applications, pp119-142. Williams and Wilkins, Bethesda.

Sims KJ, Brauer SG 2000 A rapid upward step challenges medio-lateral postural stability. Gait & posture 12:217-224.

Smits-Engelsman BC, Swinnen SP, Duysens J 2006 The advantage of cyclic over discrete movements remains evident following changes in load and amplitude. Neuroscience letters 20:28-32.

Van Daele U, Hagman F, Truijen S, Vorlat P, Van Gheluwe B, Vaes P 2010 Decrease in postural sway and trunk stiffness during cognitive dual-task in nonspecific chronic low back pain patients, performance compared to healthy control subjects. Spine 35:583-9.

Van Dieen JH, Koppes LL, Twisk JW 2010 Low back pain history and postural sway in unstable sitting. Spine 35:812-7.

Wegener L, Kisner C, Nichols D 1997 Static and dynamic balance responses in persons with bilateral knee osteoarthritis. The journal of orthopaedic and sports physical therapy 25:13-18.

Winter DA, Patla AE, Prince F, Ishac M, And Gielo-Perczak K 1998 Stiffness control of balance in quiet standing. Journal of neurophysiology 80: 1211–1221.

Winter DA, Prince F, Frank JS, Powell C, Zabjek KF 1996 Unified theory regarding A/P and M/L balance in quiet stance. Journal of neurophysiology 75: 2334–2343

ANNEXURE 1:

COP (m-l) excursions: The amount of movement of the Center of Pressure in the lateral plane. It is calculated as the projection of the 95% confidence ellipse on the lateral axis. (95% Confidence Ellipse - The ellipse containing 95% of the Center of Pressure points. It is determined by multiplying the standard deviation of the coordinates of the Center of Pressure points by 1.96).

COP (a-p) excursions: The amount of movement of the Center of Pressure in the sagittal plane. It is calculated as the projection of the 95% confidence ellipse on the sagittal axis.

Maximum COP excursions: The maximum movement of the Center of Pressure in the Direction of Maximum Instability. (Direction of Max Instability - The direction in which the patient is less stable, and therefore most likely to fall. It corresponds to the angle between the patient's postero-anterior (forward) direction and the major axis of the ellipse. Angles to the left are indicated as negative numbers)

Maximum Standard Stability%: How much of the Standard Limits of Stability was used in the patient's Direction of Maximum Instability.

Stability scores%: is a score of the patient's ability to maintain balance during the test. It is calculated as percentage of $S_{standard} - A_{max} / S_{standard}$, where A_{max} is the major semi-axis of the 95% confidence ellipse and $S_{standard}$ represents the Standard Limits of Stability, calculated as $S_{standard} = 0.55\ H \sin 6.25^0$. H is the patient's height.

Minimum COP excursion: The maximum movement of the Center of Pressure in the direction of minimum instability (Direction of Min Instability - The direction in which the patient is more stable, and therefore less likely to fall).

Minimum/maximum COP excursion ratio: Min/Max CoP Excursion Ratio - The ratio between the Minimum CoP Excursion and the Maximum CoP Excursion.

Minimum stability: This is an evaluation of the patient's ability to maintain balance. It is calculated as min $[R_{NS-EO} / R_{LoS}]$ % where R_{NS-EO} is the distance from the origin of any point of the 95% confidence ellipse for the normal stability - Eyes Open test and R_{LoS} is the corresponding distance on the ellipse representing the patient's Limits of Stability.