Dynamic Postural Control Assessment with Star Excursion Balance Test among Chronic Ankle Instability and Healthy Asymptomatic Participants

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**Background:** Lateral ankle sprains (LAS) are among the most common injuries in the physically active population. The feeling of ankle “giving way” following ankle sprain and subsequent repetitive sessions of instability in several ankle sprains has been termed chronic ankle instability (CAI).

**Objectives:** To compare the dynamic postural control among CAI and healthy asymptomatic participants using star excursion balance test (SEBT) and to compare the reach distance of injured dominant and injured non-dominant limb among CAI participants.

**Materials and Methods:** Totally 60 participants (CAI=30 + Control=30) were requited for this study. CAI participants have had ankle sprain of more than two episodes on the same side and control group comprised of healthy asymptomatic participants who match in demographic details. The SEBT reach distances were measured in centimeters (cm) while the participants in standing and the score of 3 reach trials were averaged for data analysis.

**Results:** The intra group comparison of SEBT reach scores demonstrated that the reach distances of injured limb was significantly decreased in all directions compared to uninjured limb (p=0.000) of CAI participants, however the control group did not show significant difference in the inter-limb reach distances (p>0.05). No significant difference (P>0.05) was noted in reach distances between the injured dominant and injured non-dominant limb of CAI participants.

**Conclusion:** The SEBT seems to be efficient in detecting dynamic postural control in participants with or without chronic ankle instability. The reach distances of CAI participants were significantly decreased in all 8 directions when compared to that of healthy asymptomatic participants. The SEBT reach distances does not show significant difference whether the injured limb is either dominant or non-dominant.

**Keywords:** Ankle Sprain, Chronic Ankle Instability, Dynamic Postural Control, SEBT
INTRODUCTION

Lateral ankle sprains (LAS) are among the most common injuries in the physically active population. Lateral ankle sprain are also known as inversion ankle sprain or sometimes as supination ankle sprain. The previous history of a sprained ankle is the commonest predisposing factor to experiencing an ankle sprain. The feeling of ankle “giving way” following ankle sprain and subsequent repetitive sessions of instability in several ankle sprains has been termed chronic ankle instability (CAI). The frequency of residual symptoms and development of CAI after LAS has been reported as 31% and 40%. LAS, not only damages the structural integrity of ligaments, but also affects numerous mechanoreceptors, joint capsule and tendons around the ankle complex. The receptors around the joint provides feedback about the joint pressure, tension, movement and position sense. Hence, damage to the mechanoreceptors with LAS may contribute to functional impairments and chronic instability as consequence to initial injury.

The factors which are contributing to CAI are mechanical ankle instability (MAI) and functional ankle instability (FAI). The mechanical insufficiencies include pathologic laxity, impaired arthokinematics, synovial and degenerative changes. The functional insufficiencies include altered neuromuscular control, impaired proprioception, strength deficits and diminished postural control. Although mechanical and functional instability may occur in isolation, it was hypothesized that combination of both mechanical and functional instabilities were most likely to contribute in CAI.

Studies have shown postural control deficits during quiet standing or single limb stance after acute LAS and in participants with CAI; however the sensitivity of these measures has been questioned. Though postural control assessment with single limb balance is important, it may not challenge the dynamic postural control system to detect the deficits after ankle injuries. Numerous test have been developed to assess dynamic postural control in the pediatric, adult, geriatric and athletic populations. However the space and cost requirements associated with balance measuring devices are not affordable or feasible for many clinical setting or during on-field assessments. Hence, a reliable, valid and simple method of lower limb functional dynamic performance test like Star Excursion Balance Test (SEBT) can be used.

The SEBT is a simple, low-cost, reliable alternative to sophisticated instruments that measure functional performance of lower limb. The dynamic stability testing with SEBT may be a more precise assessment of lower limb function than quiet standing test. The SEBT incorporates a single limb stance with maximum reach down with opposite limb in 8 directions while maintaining balance on the stance limb. The stance limb requires ankle, knee, and hip flexion range of motion and satisfactory strength, proprioception and neuromuscular control to perform the reaching tasks.

Identifying dynamic postural control in CAI may help the physiotherapist, athletic and fitness trainers to prescribe balance exercises further effectively to prevent injuries and improve functional performance. Various studies have investigated the efficacy of SEBTs in lower
limb injuries but studies comparing the dynamic postural control between injured and uninjured healthy asymptomatic participants are few and yet to determined. Many contributing factors (number of reach direction, height, body weight, gender, foot type, training effect) which may affect performance during SEBT has been discussed by a recent study, but whether the SEBT reach distances among participants with CAI with injury to dominant and non-dominant limb has any difference or not has not yet been identified. So this study aimed to compare the dynamic postural among CAI and healthy asymptomatic participants using SEBT and to compare the reach distance of injured dominant and injured non-dominant limb among CAI participants. The study hypothesized that dynamic postural control assessed using SEBT reach distances in CAI would differ from normal asymptomatic participants and that the injured dominant and injured non-dominant reach distances would be different among participants with CAI.

**Materials and Methods**

In this cross sectional comparative study, sixty participants [unilateral CAI (n=30) and healthy asymptomatic (n=30)] were enrolled through advertisement with pamphlet in local newspaper (Table 1). The participants in CAI group (9 male, 21 female; age = 22.33 ± 1.42, weight = 52.95 ± 7.90; height = 157.50 ± 4.77 cm; body mass index = 21.37 ± 2.25; limb length = 86.96 ± 3.66 cm) were selected if there were at least one acute LAS before 2 months, multiple incidences of the ankle giving way in last one year and who are willing to volunteer in the study. Participants were selected for the control group (10 male, 20 female; age = 22.23 ± 0.85; weight = 53.13 ± 8.47; height = 157.40 ± 5.22 cm; body mass index = 21.45 ± 2.50; limb length = 85.96 ± 4.00) if no history of injury to both ankle. For both the groups, the participant were excluded if they have vestibular disorders, cerebral concussions, lower limb injuries in past 3 months, ear infection and prior balance training. Prior to testing procedure all the subjects read and signed an informed consent form. The approval for this Study was obtained from the institutional scientific committee.

The SEBT for the assessment of dynamic balance was performed with the participants standing on one limb at the center point of a grid marked on floor, with 8 lines (120cm) extending at 45° increments from the center point of the grid and the distance they reached were recorded in centimetre (Figure 1). The 8 lines on the grid are labelled as per the direction of excursion relative to the stance limb: anterior (A), anterolateral (AL), lateral (L), posterolateral (PL), posterior (P), posteromedial (PM).
(PM), medial (M), and anteromedial (AM) (Figure 2). The testing procedure was demonstrated and verbally instructed to each participant by the tester. Each participant practiced 6 trials in all 8 directions for both limbs to familiarize themselves with SEBT grids, as recommended by Hertel et al.29 Soon after the practice trials, participants rode a stationary bicycle for 5 minutes at a self-selected speed followed by stretching of quadriceps, hamstrings and triceps surae muscle.

The participants maintained a single limb stance (testing limb) while reaching down with the contralateral limb along the testing direction. With the most distal part of the reaching foot the participants lightly touch the furthest point on the line while ensuring adequate neuromuscular control of the stance limb. The participants then returned to a 2-footed stance while maintaining equilibrium. The examiner measured the distance manually between the center points of the grid to touch down points in centimeters with a measuring tape. Measurements were taken after each reach by the same tester who was blinded about the groups.

Three trials in each direction were performed and recorded. They were given a 15 second rest in 2-footed stance between each reach attempts and 2 minute of rest in between the trials. The average of 3 reach trial for each limb in all the 8 directions was calculated. All trials were completed in sequential order in either the counter clock wise (right limb) or clock wise (left limb) directions. The trials were rejected and repeated if the participants (1) can’t maintain balance on the stance limb while touching the grid line with the reach foot, (2) the stance foot lifted from the center grid, (3) failed to maintain balance at any point in trial, or (4) can’t maintain start and return positions for one full second. Each reach distances were normalized to limb length (reach distance/limb length X 100 = % of limb length).

Statistical Analysis
Statistical analysis was done using SPSS 16.0 version software for windows. The descriptive analysis was used to find the mean and standard deviation. Intra group analysis of injured and uninjured limb reach distances of the CAI group and right and left limb reach distances of the control group were done using pair t-test. ANOVA (post hoc Tukey test) was further performed for comparison of injured, uninjured and control averaged SEBT reach distances. Independent t-test was used to compare the reach distances of injured dominant and injured non-dominant. The level of

| Table 1 Demographic Data of the Participants |
|---------------------------------------------|
| Characteristics                             | Total (N=60) | CAI Group (N=30) | Control Group (N=30) | p-value* |
| Age (Years)                                 | 22.28 ± 1.16 | 22.33 ± 1.42     | 22.23 ± 0.85         | 0.743^   |
| Gender (M/F)                                | 19 /41       | 9 /21             | 10 /20                | 0.845^   |
| Weight (kg)                                 | 53.05 ± 8.12 | 52.96 ± 7.90     | 53.13 ± 8.47         | 0.937^   |
| Height (cm)                                 | 157.45 ± 4.96 | 157.50 ± 4.77   | 157.40 ± 5.22        | 0.939^   |
| BMI ^                                       | 21.41 ± 2.36 | 21.37 ± 2.25     | 21.45 ± 2.50         | 0.895^   |
| Limb Length (cm)                            | 86.46 ± 3.83 | 86.96 ± 3.66     | 85.96 ± 4.00         | 0.317^   |

Sub-types of Foot

| Sub-types of Foot   | Total (% of Total) | CAI Group (% of CAI) | Control Group (% of Control) |
|---------------------|--------------------|-----------------------|-------------------------------|
| Normal Foot         | 33 (66.7%)         | 15 (50%)              | 18 (60%)                      |
| Flat Foot           | 19 (26.7%)         | 10 (33.3%)            | 9 (30%)                       |
| High Arch           | 8 (6.7%)           | 5 (16.66%)            | 3 (10%)                       |
| Injured             | 30                 | D = 18, ND = 12       | NA                            |
| No of LAS*          | 1.43 ± 0.62        | 1.43 ± 0.62           | NA                            |
| Duration of LAS*    | 5.43 ± 2.04        | 5.43 ± 2.04           | NA                            |

* - Mean ± SD, ^ - Independent t tests, ^ - Chisquare Test, * - Not significant - p>0.05, BMI - Body mass index, LAS - Lateral ankle sprain, D – Dominant, ND - Non-dominant
**RESULTS**

The groups were homogenous in their demographic details at baseline, with p>0.05 (Table 1). The intra group comparison of injured and uninjured limb of CAI participants shows significant difference (p=0.000) in all the 8 directions whereas in control participants there were no significant different difference (p>0.05) between the right and left limb reach distances (Table 2). So, the reach distances of right and left limb in control group were averaged as they didn’t show significant changes to reduce the number of analysis. Comparison between the injured, uninjured and averaged control SEBT reach distances using one way ANOVA shows significant difference (p=0.000) (Figure 3, Table 3a). Further analysis of ANOVA post hoc Tukey test result shows that the SEBT reach scores were significantly different between injured and uninjured (p=0.000), between injured and control group (p=0.000), however the uninjured and control group did not show significant difference (p>0.05) (Table 3b).

Additionally, it was found that the lateral and anterolateral reach distances of the injured limb were shortest when compared to the uninjured (20.92% and 20.27% respectively) and control (23.08% and 21.21% respectively). The comparison of dominant injured and non-dominant injured limb reach distances of CAI group did not show significant difference (p>0.05) for all directions (Table 4, Figure 4). Effect size of significant changes are listed in Table 2, 3a and 4. The largest effect sizes were evident for the variables lateral, anteromedial and anterolateral reach distances respectively and the least were noted in medial and posterior for the injured limb when compared with uninjured limb as well as with the control participants.

**DISCUSSION**

Balance (static and dynamic) and sensory motor deficits are found to be associated with acute as well as chronic ankle instability. The present study attempts to compare the dynamic postural control among chronic ankle instability and healthy asymptomatic participants and to investigate the reach distance differences in injured dominant and injured non-dominant limb in participants with CAI. The finding of the study shows that participants with CAI has significantly shorter SEBT reach distances while standing on the injured limb compared with uninjured limb and when compared with age, gender, height, weight and body mass index match healthy

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**Table 2 Intra Group Comparison of SEBT Reach Distance**

| Reach Direction | Chronic Ankle Instability Group | Control Group |
|-----------------|---------------------------------|---------------|
|                 | Injured<sup>y</sup> | Uninjured<sup>y</sup> | P value<sup>e</sup> | Effect size | Left<sup>y</sup> | Right<sup>y</sup> | P value<sup>f</sup> | Effect size |
| Ant             | 76.40 ± 6.46 | 91.02 ± 5.15 | 0.000** | 2.50 | 91.58 ± 7.03 | 92.77 ± 5.97 | 0.169* | 0.18 |
| Ant-lat         | 72.69 ± 6.03 | 91.18 ± 5.50 |            | 3.20 | 92.03 ± 8.34 | 92.48 ± 5.47 | 0.634* | 0.06 |
| Lat             | 69.67 ± 5.12 | 88.11 ± 5.20 |            | 3.57 | 89.80 ± 8.84 | 91.37 ± 8.84 | 0.087* | 0.17 |
| Post-lat        | 76.78 ± 7.46 | 92.51 ± 5.20 |            | 2.44 | 92.45 ± 7.22 | 93.75 ± 7.50 | 0.217* | 0.17 |
| Post            | 77.20 ± 7.20 | 90.52 ± 6.90 |            | 1.88 | 94.06 ± 9.46 | 94.10 ± 9.33 | 0.983* | 0.00 |
| Post-med        | 75.11 ± 6.57 | 90.92 ± 5.43 |            | 2.62 | 90.64 ± 9.76 | 92.31 ± 8.28 | 0.275* | 0.18 |
| Med             | 76.62 ± 8.76 | 89.60 ± 8.17 |            | 1.53 | 90.51 ± 10.05 | 91.46 ± 6.90 | 0.520* | 0.11 |
| Ant-med         | 72.43 ± 5.81 | 89.82 ± 4.51 |            | 3.34 | 90.40 ± 7.72 | 91.43 ± 9.33 | 0.334* | 0.12 |

<sup>y</sup>- Mean ± SD of SEBT Reach Distance in cm, <sup>e</sup>- Paired t-test, <sup>f</sup>- Not significant - p>0.05, **- Significant difference – p<0.05. Effect Size (Cohen’s d) = 0.2-Small, 0.5-Medium, >0.8-Large
Previous studies have emphasized on reliability which is similar to the previous finding. The study also found that there is no significant difference between the injured and uninjured dominant limb SEBT reach distances among participants with CAI. 

Moreover the test required minimal cost and it is understandable and easy to administer. The procedure of the test is easily understandable and easy to administer with minimal requirement of equipment and space. Moreover the test required minimal cost and it is capable to use for mass screenings without consuming much time.

The dynamic balance assessment must be considered along with the static balance test in determining the postural control ability in participants with CAI. The static balance impairment among the CAI after LAS is thought to be caused by the impaired neuromuscular deficits in lower limb reach distance in CAI and healthy asymptomatic participants. Apart from positive reporting about the reliability, the SEBT seems to be valid, consistent and efficient in detecting dynamic postural control in CAI after LAS as well as in healthy asymptomatic participants. The procedure of the test is easily understandable and easy to administer with minimal requirement of equipment and space. Moreover the test required minimal cost and it is capable to use for mass screenings without consuming much time.

The study also found that there is no significant difference between the injured dominant and injured non-dominant limb SEBT reach distances among participants with CAI. Additionally, the lateral and anteromedial reach distances were shortest and most affected while the medial and posterior reach direction were least affected among the participants with CAI, which is similar to the previous finding. 

Table 3a Inter Group Comparison of SEBT Reach Distance

| Reach Direction | Chronic Ankle Instability Group | Control Group Averaged | P value | Effect Size |
|-----------------|---------------------------------|------------------------|---------|-------------|
|                 | Injured Y | Uninjured Y |                |                 |             |
| Ant             | 76.04±5.46 | 91.02±5.15 | 92.18±6.09 | 0.000** |            |
| Ant-lat         | 72.69±6.03 | 91.65±4.80 | 92.26±6.56 | 0.71     |            |
| Lat             | 69.67±5.12 | 88.11±5.20 | 90.58±8.07 | 0.69     |            |
| Post-lat        | 76.78±7.46 | 92.51±5.20 | 93.10±6.79 | 0.57     |            |
| Post            | 77.20±7.20 | 90.52±6.90 | 93.10±7.81 | 0.50     |            |
| Post-med        | 75.11±6.57 | 90.92±5.43 | 91.48±8.07 | 0.56     |            |
| Med             | 76.62±8.76 | 89.60±8.17 | 90.98±7.63 | 0.39     |            |
| Ant-med         | 72.43±5.81 | 89.89±4.38 | 90.91±6.22 | 0.70     |            |

- Mean ± SD of SEBT Reach Distance in cm. *- One Way ANOVA,

**- Significant difference – p<0.05, Effect size (Eta squared) = Small - 0.01, Medium - 0.059, Large - 0.138

Table 3b Multiple Comparisons of Injured, Uninjured and Averaged Control

| Reach Direction | Group | P value | Group | P value | Group | P value |
|-----------------|-------|---------|-------|---------|-------|---------|
|                 | Injured Y | Uninjured Y | Injured Y | Control Y | Uninjured Y | Control Y | Uninjured Y | Control Y |
| Ant             | 76.40±6.46 | 91.02±5.15 | 76.40±6.46 | 92.18±6.09 | 91.02±5.15 | 92.18±6.09 | 0.730** |
| Ant-lat         | 72.69±6.03 | 91.18±5.50 | 72.69±6.03 | 92.26±6.56 | 91.18±5.50 | 92.26±6.56 | 0.915** |
| Lat             | 69.67±5.12 | 88.11±5.20 | 69.67±5.12 | 90.58±8.07 | 88.11±5.20 | 90.58±8.07 | 0.285** |
| Post-lat        | 76.78±7.46 | 92.51±5.20 | 76.78±7.46 | 93.10±6.79 | 92.51±5.20 | 93.10±6.79 | 0.936** |
| Post            | 77.20±7.20 | 90.52±6.90 | 77.20±7.20 | 93.10±7.81 | 90.52±6.90 | 93.10±7.81 | 0.149** |
| Post-med        | 75.11±6.57 | 90.92±5.43 | 75.11±6.57 | 91.48±8.07 | 90.92±5.43 | 91.48±8.07 | 0.946** |
| Med             | 76.62±8.76 | 89.60±8.17 | 76.62±8.76 | 90.98±7.63 | 89.60±8.17 | 90.98±7.63 | 0.790** |
| Ant-med         | 72.43±5.81 | 89.82±4.51 | 72.43±5.81 | 90.91±6.22 | 89.82±4.51 | 90.91±6.22 | 0.752** |

- Mean ± SD of SEBT Reach Distance in cm. *- Post hoc (Tukey HSD)test, *- Not significant - p>0.05, **- Significant difference – p<0.05
control and proprioception.\textsuperscript{7,14,16} In a sprain or torn ligaments, the receptors around the joint may be damaged and contributing to noticeable postural control deficits.\textsuperscript{7,10} The dynamic postural control during movements, as in SEBT, required the ability to maintain the COG over the stable base of support without compromising the balance.\textsuperscript{22} The maximum reach down during SEBT challenged the subject’s stability limits, hence, indicating the dynamic postural control ability. Likewise in static balance, the dynamic postural control also may be influenced by the impaired neuromuscular control and proprioception along with the other contributing factors including muscle strength and range of motion of hip, knee and ankle joints.

The predominance of female participants (68.33%), dominant limb injury (60%) with age group (22.28 ± 1.16) and who live an active lifestyle as reflected in this study reveals the characteristics of the population that are likely to experience recurrent LAS. This may be an additional finding of this study which has not yet been documented by the earlier studies. Taking this finding positively, the clinicians may have to give more emphasis on balance training in individuals with LAS as a measure to prevent recurrence. The current study cannot comment on injury with respect to limb dominancy within the same gender. It is also observed that the number of participants with normal foot types (66.7%) was more than those with flat foot (27.7%) as well as high arch (6.7%). The study
did not analyze the reach distances among different foot types, however a previous study has shown difference in the SEBT reach distances among different sub-types of foot.

The study has certain limitations like it did not analyze the other contributing factors which may have affect the performance of SEBT. Muscle strength, range of motion and joint proprioception of the ankle and other lower limb joints have not been taken into account in this current study, which might have given some additional understanding about the dynamic reach deficits in CAI using SEBT. The correlation of injured ligaments and its relative deficit in reach distance was not established in this study. Further studies can be conducted by considering the other contributing factors like muscle strength, range of motion, joint proprioception, injured ligament and different durations of CAI after different types of sprained ankle. Studies also can be conducted with different age and with different severity of the ligament injuries. The result of this study can be implicated for identifying dynamic postural control in participants with or without CAI after LAS and to plan early balance training strategies.

**CONCLUSION**

It may be concluded that dynamic postural control in CAI and healthy asymptomatic participants are significantly different and SEBT is efficient in detecting it. The participants with CAI demonstrate shorter SEBT reach distance in all 8 directions when compared with healthy asymptomatic participants. The lateral and anteromedial reach distance were the shortest however the medical and posterior were least affected. There is no difference in the reach distances whether the injury is in dominant or non-dominant limb in participants with CAI.

**CONFLICTS OF INTEREST**

None declared

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