

# A Comparison Between Performance on Selected Directions of the Star Excursion Balance Test and the Y Balance Test

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**Context:** The Star Excursion Balance Test (SEBT) is a widely accepted method of assessing dynamic postural stability. The Y Balance Test (YBT) is a commercially available device for measuring balance that uses 3 (anterior, posteromedial, and posterolateral) of the 8 SEBT directions and has been advocated as a method for assessing dynamic balance. To date, no studies have compared reach performance in these tests in a healthy population.

**Objective:** To determine whether any differences exist between reach distance performance for the anterior, posteromedial, and posterolateral directions of the SEBT and the YBT.

**Design:** Descriptive laboratory study.

**Setting:** University motion analysis laboratory.

**Patients or Other Participants:** A total of 20 healthy active male participants (age =  $22.50 \pm 3.05$  years, height =  $1.78 \pm 0.82$  m, weight =  $79.48 \pm 11.32$  kg, body mass index =  $24.96 \pm 2.56$  kg/m<sup>2</sup>).

**Intervention(s):** Participants carried out 3 trials in each reach direction on each leg on the SEBT and the YBT a minimum of 1 week apart.

**Main Outcome Measure(s):** The means of the 3 trials in each direction on each leg on both tests were calculated. Data were collected after 4 practice trials in each direction. Paired *t* tests and Bland-Altman plots were used to compare reach distances between the SEBT and the YBT.

**Results:** Participants reached farther in the anterior direction on the SEBT than on the YBT. No differences were observed in the posteromedial and posterolateral directions.

**Conclusions:** Differing postural-control strategies may be used to complete these tasks. This finding has implications for the implementation and interpretation of these dynamic balance tests.

**Key Words:** postural stability, balance, assessment, rehabilitation

## Key Points

- Differences in anterior reach distance were noted between the Star Excursion Balance Test and the Y Balance Test in a sample of healthy, active men.
- No differences were noted in posteromedial or posterolateral reach distances between the tests.
- Postural-control strategies for completing these tests may vary.

The perception and execution of musculoskeletal control and movement are mediated primarily by the central nervous system<sup>1</sup> and involve the integration of 3 main subsystems: somatosensory, vestibular, and visual.<sup>2</sup> Balance performance and its measurement are influenced by these subsystems. The Star Excursion Balance Test (SEBT) is a valid and reliable outcome measure of dynamic balance developed by Gray.<sup>3</sup> A range of indications for the clinical use of the test in athletic and pathologic populations has previously been described, including screening,<sup>4,5</sup> injury identification,<sup>6,7</sup> training,<sup>8–10</sup> and rehabilitation.<sup>11</sup> Most of the literature describes 8 reach directions using a grid formed by applying adhesive athletic tape or a tape measure to a level floor with lines spaced 45° apart. The directions are anterior (A), medial, lateral, posterior, anteromedial, anterolateral, posteromedial (PM),

and posterolateral (PL). An individual is required to move from a starting position of 2-legged stance to single-legged stance while maximally reaching along set multidirectional lines with the opposite leg and touching down lightly on the tape with the distal end of the reach foot, without compromising equilibrium. These reaching tasks are designed to challenge postural control, strength, range of motion, and proprioceptive abilities.<sup>12</sup>

A number of limitations are associated with the SEBT owing to the lack of a definitive published protocol outlining its administration. The touch-down aspect of the test allows for the individual to be supported by the ground, and the actual amount of pressure allowed through the foot is difficult to quantify and control. This may lead to variations in the administration and interpretation of the test protocol. In addition, for the test to be carried out in its

entirety (4 practice trials and 3 test trials in each of the 8 directions on each side, giving a total of 112 reach excursions)<sup>13</sup> can prove time consuming for the clinician. Hertel et al<sup>12</sup> were the first to propose redundancy in measuring all 8 directions in a sample with chronic ankle instability and purported the use of the A, medial, and PM directions in identifying functional deficits. The clinical application of the SEBT led to the development of the Y Balance Test (YBT). Plisky et al<sup>14</sup> used a Y or “peace sign,” incorporating the A, PM, and PL directions in the preseason screening of high school basketball players, which in turn led to the development of the YBT. It involves the individual standing on an elevated central plastic footplate 1 in (2.54 cm) off the ground and pushing a rectangular reach indicator block with the foot along a 1.5-m length of plastic tubing in each of the 3 directions. The *reach distance* is recorded as the point at which the reach indicator block is pushed closest to the stance leg. The purported benefits of the YBT are that it takes less time to complete and has a standard protocol and high interrater (0.99–1.00) and intrarater reliability (0.85–0.91).<sup>15</sup>

Both the SEBT and YBT involve similar movements that are deemed to measure and challenge dynamic balance. Despite the similarity between the tests, no researchers to date have evaluated performance in both tests in the same group of participants. The increasing popularity of the YBT in the clinical setting for diagnosis, screening, and rehabilitation means that it is imperative to establish if any differences exist in its application and performance when compared with performance on the similar reach directions of the SEBT. Therefore, the purpose of our study was to compare the A, PM, and PL reach distance performance of healthy participants in these 2 dynamic balance tests. We hypothesized that participants would attain the same reach distance in the respective directions of the SEBT and YBT.

## METHODS

### Participants

Ethical approval was obtained from the University College Dublin Human Research Ethics Committee. We recruited 20 healthy male participants (age =  $22.50 \pm 3.05$  years, height =  $1.78 \pm 0.82$  m, weight =  $79.48 \pm 11.32$  kg, body mass index =  $24.96 \pm 2.56$  kg/m<sup>2</sup>) from the local university population. Inclusion criteria for the study required volunteers to be between 18 and 30 years of age and active participants in sporting activity 3 or more times per week with no history of lower limb injury in the past 3 months, neurologic or balance disorder, or lower limb fracture. Before formal testing began, each participant read an information leaflet and signed a consent form.

### Protocol

Participants reported to the laboratory in shorts and T-shirts for 2 test sessions spaced a minimum of 7 days apart. Their height, weight, and limb length in supine lying (anterosuperior iliac spine to the center of the ipsilateral medial malleolus) were measured. They were then randomized to conduct either the SEBT or YBT at the initial session and undertook the other test at the second session. The SEBT reach directions were evaluated by

affixing 3 tape measures to the laboratory floor, 1 oriented anterior to the apex and 2 aligned at 135° to this in the PM and PL directions (Figure 1).<sup>16</sup> The YBT was evaluated using a commercially available device (Y Balance Test, Move2Perform, Evansville, IN; Figure 2). In order to ensure comparison between the tests, the A, PM, and PL directions of the SEBT were used. Order of the test leg and direction were also randomized at each test session. All testing was conducted barefoot to eliminate additional balance and stability from the shoes.<sup>17</sup> As in the YBT, the anterior borders of the participant's feet were placed at the convergence of the reach direction lines of the SEBT at the second toe. The test was demonstrated by a member of the research team before the participant completed 4 practice trials in each direction on each leg. Completing these practice trials has previously been reported to decrease the learning effect without hindering an individual's ability to perform the test.<sup>13</sup> After the test trials were completed, each participant was given a 2-minute rest period and then conducted 3 test trials in each direction. Test sessions were undertaken at the same time of day to minimize diurnal variation in postural stability.<sup>18</sup> A trial was classified as *invalid* if the participant removed his hands from his hips, did not return to the starting position, applied sufficient weight through the reach foot so as to gain an increase in reach distance (SEBT), placed the reach foot on the ground on either side of the line or tube, raised or moved the stance foot during the test, or kicked the plate with the reach foot to gain more distance (YBT). If an invalid trial occurred,

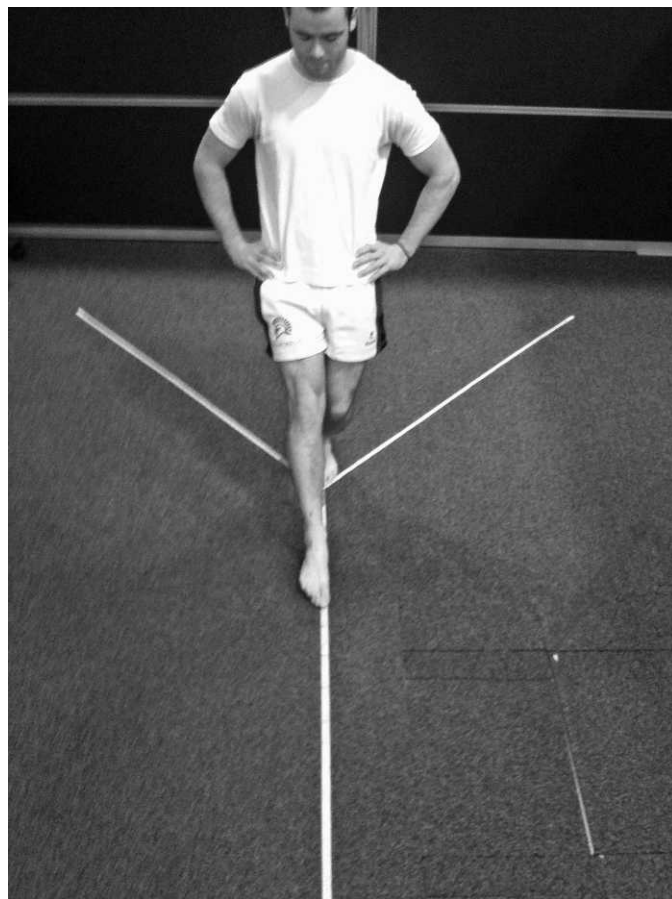


Figure 1. Star Excursion Balance Test anterior reach direction.

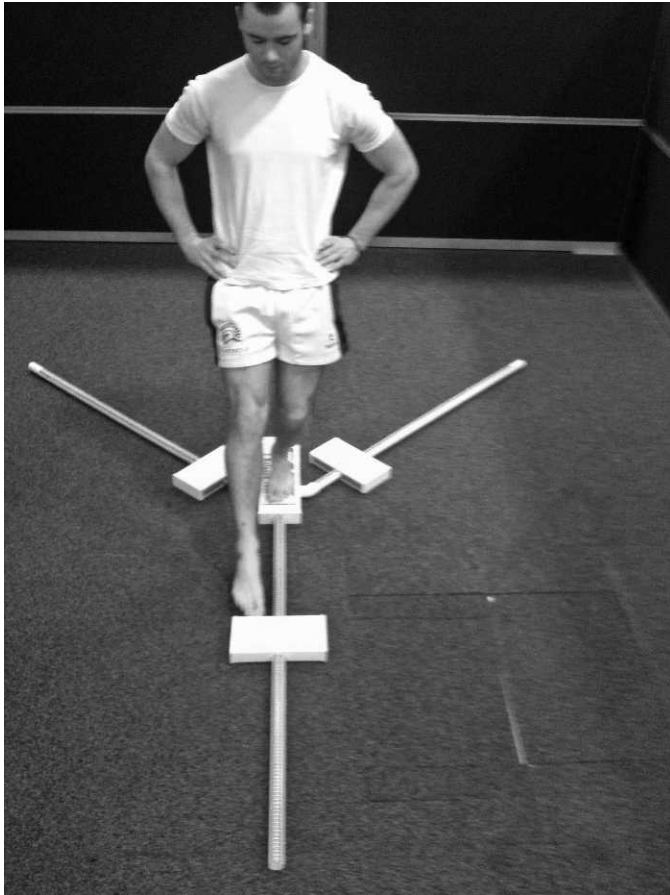


Figure 2. Y Balance Test anterior reach direction.

the data were discarded, and the participant repeated the trial.

### Statistical Analysis

Reach distances were normalized to limb length by calculating the maximized reach distance (%MAXD) using the formula (excursion distance/limb length)  $\times$  100 = % MAXD.<sup>13</sup> This normalization method accounts for limb-length differences in individuals and allows comparisons between the right and left limbs and between participants. Means and standard deviations were calculated for both legs. Paired-samples *t* tests were conducted to compare the reach distances for each leg and between tests (version 18.0; PASW Statistics, IBM Corporation, Armonk, NY). Because 6 *t* tests were calculated, a Bonferroni correction was used (0.05/12), and therefore, an  $\alpha$  level of  $P < .004$  was set for all comparisons. Effect sizes for test differences were calculated by obtaining the difference between mean SEBT and YBT values and dividing by the pooled standard deviation. The strength of the effect sizes was interpreted using guidelines described by Cohen,<sup>19</sup> with values less than 0.2 interpreted as weak, 0.21 to 0.79 as moderate, and greater than 0.8 as strong. Pearson correlations and Bland-Altman assessments for agreement were used to compare SEBT and YBT performance.<sup>20</sup> Where heteroscedasticity (increasing differences with increasing mean difference) was observed, the data were log transformed.

Table 1. Reach Distances for Star Excursion Balance Test (SEBT) and Y Balance Test (YBT) and Effect-Size (ES) Calculations

Reach Direction	Test	Reach Distance as % of Limb Length (Mean $\pm$ SD)	
		Left Leg	Right Leg
Anterior	SEBT	69.92 $\pm$ 7.29	69.49 $\pm$ 7.14
	YBT	64.84 $\pm$ 7.47	64.90 $\pm$ 6.96
	ES	1.04	0.76
Posteromedial	SEBT	111.51 $\pm$ 5.76	110.82 $\pm$ 7.23
	YBT	110.58 $\pm$ 7.56	110.48 $\pm$ 7.31
	ES	0.15	0.07
Posterolateral	SEBT	104.00 $\pm$ 6.42	104.03 $\pm$ 6.89
	YBT	103.97 $\pm$ 6.42	104.79 $\pm$ 7.61
	ES	0.00	-0.13
Composite	SEBT	108.98 $\pm$ 5.54	90.72 $\pm$ 5.33
	YBT	90.89 $\pm$ 4.91	89.74 $\pm$ 5.43
	ES	2.55	0.3

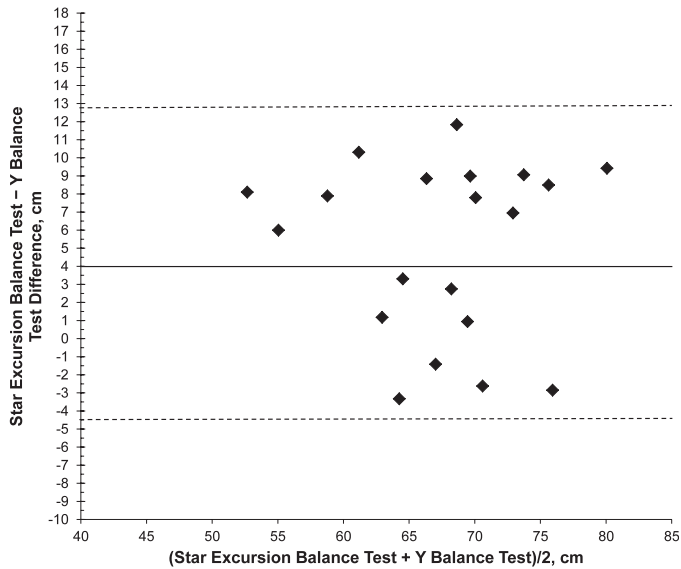
### RESULTS

Differences were observed between the SEBT and YBT in the A reach direction on both legs (Table 1). Participants reached further in the SEBT than in the YBT on both the left ( $P = .0002$ ) and right legs ( $P = .003$ ). No other differences were noted in the PM and PL reach directions or between left and right legs in either test. Effect size calculations indicated that results were strong for the left leg and moderate for the right leg in the A direction and weak for both legs in the PM and PL directions. The Bland-Altman analysis showed that the 95% limit of agreement between SEBT and YBT performance in the anterior direction was 5.08 (% limb length) for the left leg (5.08 [-4.69 to 14.85]), demonstrating that SEBT reach excursions were, on average, greater than YBT values (Figure 3). Log-transformed anterior-direction reaches on the right leg (4.59 [-7.41 to 16.60]) showed good agreement, with an SEBT score 3% higher than the YBT score (Figure 4). Posteromedial excursions for both left (0.93 [-11.55 to 13.42]) and right (0.34 [-9.09 to 9.78]) displayed a slight bias, with SEBT scores slightly higher and scores for the right leg having less bias and variability (Figures 5 and 6). Posterolateral excursions for both left (0.03 [-10.88 to 10.94]) and right (log transformed -0.76 [-12.70 to 11.18]) legs indicated minimal bias (Figures 7 and 8). Paired-samples correlations are presented in Table 2.

### DISCUSSION

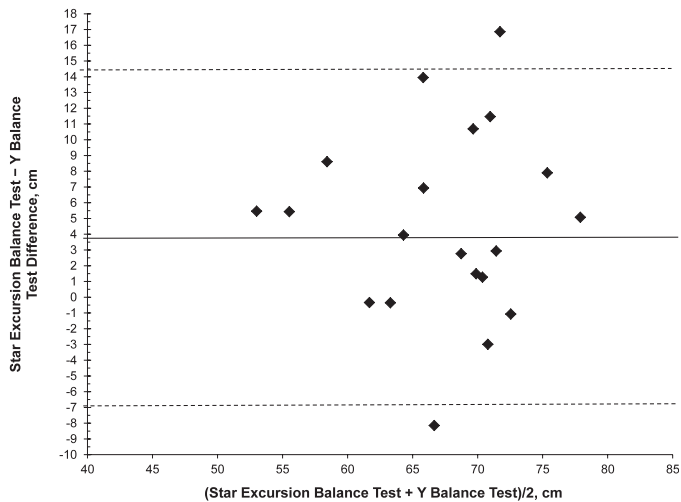
The principle finding in this investigation was that healthy participants achieved a longer reach distance in the A direction of the SEBT compared with the YBT. Previous authors have reported differences in SEBT reach distances similar to those of the balance tasks we observed after neuromuscular training<sup>8,9</sup> and fatigue protocols<sup>21</sup> and in injured groups.<sup>7,21</sup> These differences have implications for the implementation and interpretation of the YBT. We observed no differences in the other 2 reach directions. These findings may be due to differences in postural-control strategies in completing the dynamic balance tasks.

Postural control may be classified as either static (attempting to maintain a base of support with minimal movement) or dynamic (attempting to maintain a stable base of support while completing a prescribed movement).<sup>21</sup> This is a complex process that requires central

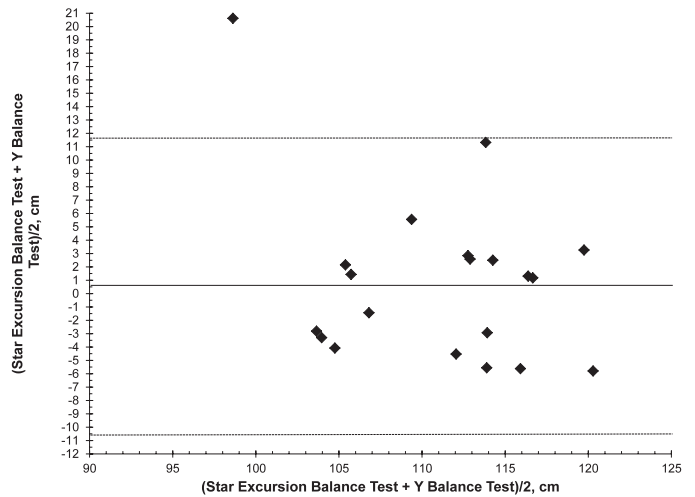


**Figure 3. Ninety-five percent limits of agreement for anterior reach with left leg (5.08 [-4.69 to 14.85]).**

processing of sensory inputs from visual, vestibular, and somatosensory pathways, as well as a resultant efferent response that controls the precise recruitment of specific motor units.<sup>22</sup> The central nervous system generates a “blueprint for movement,” which is delivered to pattern generators at a spinal level, resulting in the patterned activation of  $\alpha$  and  $\gamma$  motoneuron systems.<sup>23</sup> Feedback and feed-forward control mechanisms play vital roles in the control of movement and the execution of tasks such as the SEBT and YBT. The stimulation of mechanoreceptors located in the periphery (ie, skin, ligaments, muscles, and joints) provides afferent feedback via spinal pathways regarding joint movement and position in various body segments during movement.<sup>24,25</sup> The pattern of motoneuron activation is fine tuned by feedback from these mechanoreceptors, which act either monosynaptically or via inhibitory interneurons and provide a corrective response to the action.<sup>26</sup> In contrast, feed-forward controls have previously been described as anticipatory actions occurring

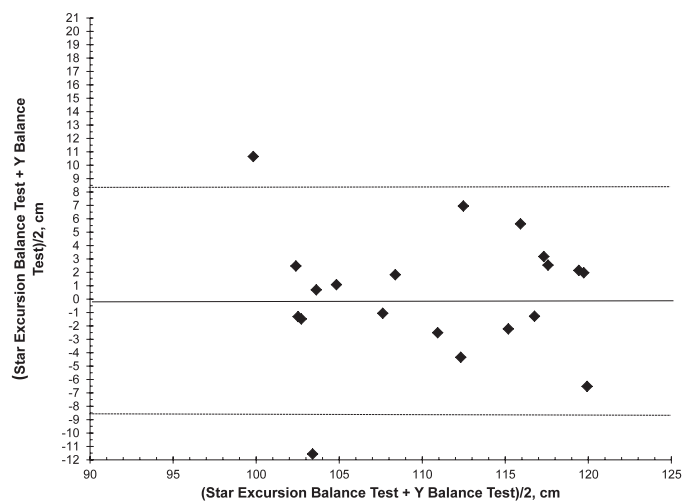


**Figure 4. Log-transformed 95% limits of agreement for anterior reach with right leg (4.59 [-7.41 to 16.60]).**



**Figure 5. Ninety-five percent limits of agreement for posteromedial reach with left leg (0.93 [-11.55 to 13.42]).**

before the sensory detection occurs.<sup>27,28</sup> The mechanism of feedback and feed-forward control may vary between the SEBT and YBT, resulting in differences in reach distances in the A direction. The YBT requires the participant to stand in an elevated position on a central footplate while pushing a sliding block. He or she receives constant proprioceptive feedback throughout the reach excursion from the plantar surface of the reach foot. In the SEBT, the participant places downward pressure through the reach foot only at the end of the reach excursion and, therefore, does not receive a similar level of afferent information throughout the movement, potentially relying on a feed-forward control strategy until contact is made with the tape measure. The postural-control strategy used during the SEBT may mean that the individual does not have the same level of inhibition throughout the movement and, thus, reaches further. An external focus of attention facilitates automaticity in motor control and promotes movement efficiency compared with an internal focus.<sup>29</sup> Contact with the sliding block may have induced a more internal focus, thereby resulting in a negative influence on the A direction. In addition, pressure is allowed with the ground by the



**Figure 6. Ninety-five percent limits of agreement for posteromedial reach with right leg (0.34 [-9.09 to 9.78]).**

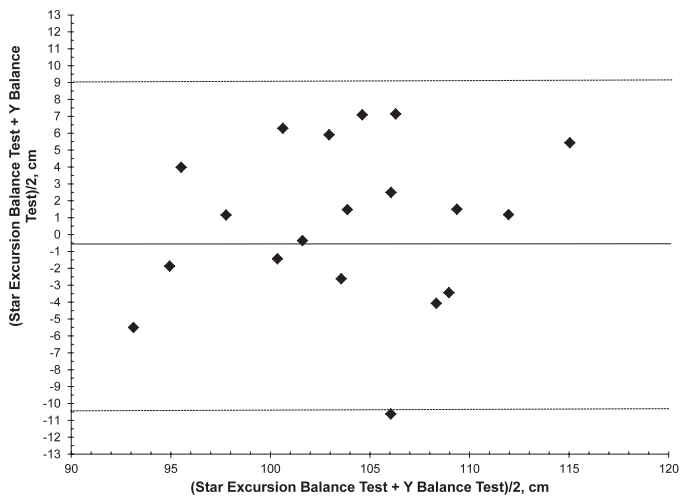


Figure 7. Ninety-five percent limits of agreement for posterolateral reach with left leg (0.03 [-10.88 to 10.94]).

reach leg, albeit minimally, and actually provides a point of support. In the YBT, the individual may remain in a narrower stance as a result of the feedback received throughout the movement and therefore not reach as far. In upright stance, a stiffening strategy, characterized by decreased amplitude and increased frequency of postural adjustments and leaning back away from the direction of the postural threat, has previously been reported,<sup>30,31</sup> resulting in a feeling of less stability when standing on an elevated surface.<sup>32</sup> Sabin et al<sup>33</sup> recently reported reduced reach distances when performing the SEBT on an unstable surface. The elevated stance-leg position of the YBT, although at a relatively low height, may be perceived as a barrier to reaching further.

Several possible explanations for A reach differences are based on feedback mechanisms. The visual system provides the body with visual cues for use as reference points in orienting the body in space. It is generally agreed that, under normal conditions, the somatosensory and visual subsystems are the primary mediators of balance and postural awareness.<sup>25</sup> In the A reach direction, participants receive visual feedback from the reach leg as they move

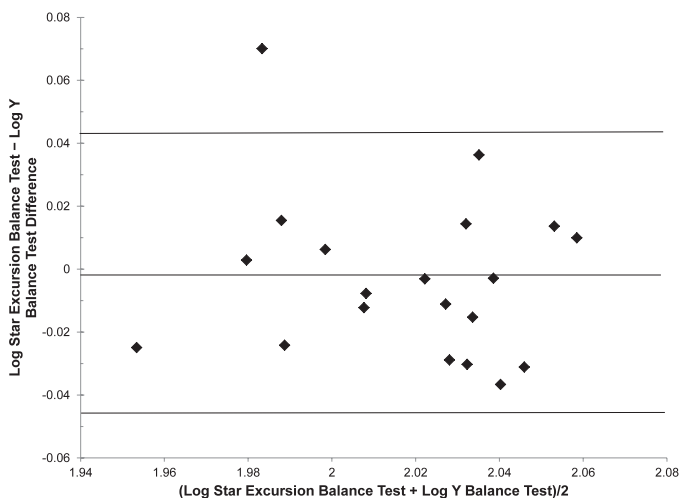


Figure 8. Log-transformed 95% limits of agreement for posteromedial reach with right leg (-0.76 [-12.70 to 11.18]).

Table 2. Star Excursion Balance Test and Y Balance Test: Paired-Samples Correlations (N = 20)

	Direction, Leg	Correlation	P Value
Pair 1	Anterior, left	0.781	.000
Pair 2	Anterior, right	0.638	.002
Pair 3	Posteromedial, left	0.572	.008
Pair 4	Posteromedial, right	0.781	.000
Pair 5	Posterolateral, left	0.624	.003
Pair 6	Posterolateral, right	0.651	.002

and can observe the scored reach distance on each trial. In the PM and PL directions, visual awareness is reduced, and therefore, the inability of the participants to see their scores may not limit their reach as in the A direction. However, this places an increased demand on somatosensory feedback strategies, meaning that, during the YBT, participants were able to reach similar distances as on the SEBT owing to their contact with the sliding block. Another potential reason for similar reach distances observed in the PM and PL directions relates to the placement of the reach foot on the sliding block of the YBT. Participants were instructed to not place the foot on top of the tubing and in all cases placed the plantar surface of the reach foot on the medial side of the sliding block. This may have resulted in their maintaining support closer to their center of gravity during the YBT than when they reached along the tape measures of the SEBT, again allowing them to reach similar distances in the PM and PL directions. In the A direction, the foot was placed on the lateral side of the sliding block, thus displacing the center of gravity and subsequently reducing reach distances compared with the SEBT.

These factors may also account for the significant differences and relatively large limits of agreement in the A direction, which indicate poor agreement between the tests in this study. Although this poor agreement would have practical implications for the use of these tests together as part of a screening protocol or clinical assessment outcome, it is unlikely that the tests would be used concurrently in these situations. Similarly, previous investigators measuring SEBT performance have indicated that side-to-side differences like those we observed between the SEBT and YBT in the A direction predict lower limb injury<sup>4</sup> and indicate deficiency in conditions such as chronic ankle instability<sup>6</sup> and anterior cruciate ligament injury.<sup>7</sup> Therefore, caution should be exerted when interpreting reach distances from both tests in the A direction in the same individual or group. Based on our findings, the posterolateral direction is the test with the least bias, which may make it more feasible for comparison between the tests. There is a paucity in the literature of studies investigating the relationship between the YBT and injury screening and assessment. Owing to its practicality and ease of use in a clinical setting, further research is warranted.

Finally, the differentiation between the levels of the elevated stance foot on the central footplate and the lower reach foot during the YBT compared with the level base for the SEBT may influence the individual's postural-control strategy. However, the former may be more applicable to everyday situations in which postural control is required on uneven surfaces. The role this strategy may have in the completion of these tests warrants further investigation.

## CONCLUSIONS

A difference in A reach-direction distance was observed between the SEBT and YBT, with no differences noted in the PM and PL directions. Postural-control strategies used in completing the tests appear to influence reach performance. The results of this study have implications for both researchers and clinicians in interpreting and implementing these dynamic balance tests. Reach values and research established for the SEBT in athletic, healthy, and injured populations may not be transferrable to YBT performance. We are also the first to report on such values for the YBT in a healthy athletic male group. It is important to note that differences exist between these assessment tools; however, we did not establish if one test is more clinically appropriate than the other. Further research on the postural-control strategies and kinematic demands associated with these tests may indicate which conditions may be best screened or diagnosed using which test and therefore have implications for assessment and rehabilitation.

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