Variations in Star Excursion Balance Test Performance Between High School and Collegiate Football Players

Ryan S. McCann, Kyle B. Kosik, Megan Q. Beard, Masafumi Terada, Brian G. Pietrosimone, and Phillip A. Gribble

Abstract
McCann, RS, Kosik, KB, Beard, MQ, Terada, M, Pietrosimone, BG, and Gribble, PA. Variations in Star Excursion Balance Test performance between high school and collegiate football players. J Strength Cond Res 29(10): 2765–2770, 2015—The Star Excursion Balance Test (SEBT) is a reliable inexpensive tool used to assess dynamic postural control deficits and efficacy in the prediction of musculoskeletal injuries, but with little previous consideration for performance differences across age and skill levels. The purpose of this study was to examine differences in SEBT scores between high school and collegiate football players. Three-hundred eighteen high school football players and 180 National Collegiate Athletic Association Division I collegiate football players volunteered to participate. Star Excursion Balance Test scores were obtained bilaterally for anterior (ANT), posterolateral (PL), and posteromedial (PM) directions, and for an overall composite (COMP) score. The mean of 3 trials from each leg was normalized to stance leg length and presented as a percentage score. Bilaterally averaged scores were compared between high school and collegiate football players using separate independent t-tests. A multiple linear backward regression determined the amount of variance in SEBT scores explained by age, mass, and height. Compared with collegiate athletes, high school athletes had lower PL (72.8 ± 11.4% vs. 77.1 ± 10.2%; p < 0.001), PM (83.5 ± 10.2% vs. 86.7 ± 10.7%; p = 0.001), and COMP (75.4 ± 8.5% vs. 78.0 ± 7.4%; p = 0.001) scores. Anterior scores did not differ between high school (69.9 ± 7.9%) and collegiate (70.3 ± 7.1%) athletes (p = 0.545). Age, mass, and height were not meaningful contributors to ANT ($R^2 = 0.089$; $p < 0.001$), PL ($R^2 = 0.032$; $p < 0.001$), PM ($R^2 = 0.030$; $p = 0.002$), and COMP ($R^2 = 0.048$; $p < 0.001$) variances. Disparity between high school and collegiate athletes should be considered when using the SEBT to identify risk of or deficits related to lower extremity injury in football players.

Keywords: dynamic postural control, lower extremity, injury risk

Introduction
Approximately 1.1 million student athletes participate in high school football in the United States annually (17), resulting in over 500,000 injuries, 46.9% of which occur in the lower extremity (21). The National Collegiate Athletic Association (NCAA) has approximately 70,000 student athletes participating in football each year (16), and approximately 50–55% of all football injuries at that level occur in the lower extremity (6,21). The volume of injuries in the sport of football necessitates the need for prevention through identification of risk for these injuries. Previous studies indicate that risk of lower extremity injuries may be predicted by reduced dynamic postural control, as measured by the Star Excursion Balance Test (SEBT) (18) and the related Y-Balance Test (4). Plisky et al. (18) demonstrated that female high school basketball players with SEBT composite (COMP) scores less than 94% had 6.5 times greater risk of lower extremity injury, whereas Butler et al. (4) reported that collegiate football players with Y-Balance Test COMP scores less than 89.6% had 3.5 times greater risk of noncontact lower extremity injury.

Dynamic postural control is commonly assessed using the SEBT because of its strong reliability, low cost, and simplicity of clinical implementation (12). The SEBT requires an individual to maintain a single-leg stance in the center of a star pattern formed on the floor. The individual is then instructed to reach for maximum distance in 3 directions of the star pattern using the nonstance leg while maintaining the single leg base of support. Greater reach distances are associated with greater dynamic postural control of the stance limb.
The SEBT has utility in differentiating performance in injured groups, after fatigue, and between sexes (12), but we are unaware of evidence to suggest if SEBT scores vary between high school and collegiate athletes. Butler et al. (5) used a commercially available measure of dynamic postural control, the Y-Balance test, to analyze lower extremity reach scores in high school, collegiate, and professional soccer players. They found collegiate and professional athletes performed better in 2 of 3 reach directions compared with high school athletes. However, the Y-balance test cannot be directly compared with the more established SEBT, as differing ANT performance and lower extremity kinematics have been reported between the 2 tests (9). Although there is some evidence to suggest age-related variations (5), differences in dynamic postural control between high school and collegiate athletes participating in the same sport, especially assessed with the SEBT, are mostly unknown. There is a need to improve injury risk identification in sport participants using low cost, reliable testing methods. One factor that may impact the applications of these screening tests is potential differences between adolescent and collegiate levels of athletes, which could necessitate creation of separate normative values for these groups. Although evidence supporting the SEBT as an injury prediction tool is growing, age (1) and anthropometric measures, such as height and mass (23), also may be important determinants of injury risk. As age, height, and mass tend to differ between high school and collegiate football players, these factors may need to be considered when implementing injury prediction tools. Therefore, the purpose of this study was to examine variations in SEBT scores between high school and collegiate football players. We hypothesized that the high school athletes would have decreased SEBT reach scores compared with the collegiate athletes. If differences in dynamic postural control can be identified between groups, then those differences may need to be considered for developing normalized values and minimal clinically detectable differences when using the SEBT to assess lower extremity injury risk. An additional aim was to determine the amount of SEBT variance explained by age, height, and mass, all of which are possible confounders when comparing performance between these 2 levels of competitive football athletes. 

Methods

Experimental Approach to the Problem

There are little data comparing differences in dynamic postural control between athletes of high school and collegiate athletic teams, especially football. Using a cross-sectional design, we compared participants of a sport with a high rate of lower extremity injuries using a simple assessment tool to make the results transferrable to clinical settings. Potential differences in dynamic postural control between groups may be valuable in the future for developing standards of injury risk across high school and collegiate athletics.

Subjects

A sample of convenience included 318 male high school football players (15.91 ± 1.14 years; age: 14–23 years, 177.62 ± 10.18 cm; 81.89 ± 17.44 kg) and 180 male NCAA Division I collegiate football players (19.79 ± 1.38 years;
186.76 ± 6.66 cm; 102.29 ± 18.93 kg) recruited to participate in this study. All participants were cleared for full sport participation at the time of the study. Participants older than 18 years read and signed an informed consent document. For participants younger than 18 years, we acquired assent directly from the participants and written informed consent from a parent or legal guardian. All methods used were approved by a university institutional review board.

**Procedures**

On arrival for testing, each participant’s total leg length was measured in centimeters bilaterally in a supine position, from the anterior superior iliac spine to the most distal portion of the medial malleolus. Using tape measures secured to the floor with clear packing tape, SEBT reach distances were assessed bilaterally in each direction by marking the distance reached on the clear tape. The order of dominant and non-dominant limb assessments for leg length and SEBT performance was randomized. Dominant limb was determined by asking each participant which leg is preferentially used to kick a ball. The SEBT was originally designed as a lower extremity reach test performed on an 8-directional star pattern formed by metric tape measures adhered to the floor (10). The test has been suggested to be simplified to include just 3 directions, such as anterior (ANT), posterolateral (PL), and posteromedial (PM) (12).

The SEBT required an unshod participant to maintain a single-limb base of support in the intersection of the star pattern while reaching for maximum distance in each direction with the nonstance limb (Figure 1). The ANT reach was tested with the most distal portion of the participant’s first toe placed at the center of the intersection. The PL and PM reaches were tested with the participant’s heel placed at the center of the intersection. Throughout each trial, the participant was required to keep the stance heel in contact with the floor and keep his hands on his hips. The participant was instructed to make a gentle tap on the tape measure with the most distal portion of the reaching foot. Before completing 3 recorded test trials in each direction, participants were provided a brief demonstration of how to perform the SEBT by an experienced investigator and were required to perform 4 practice trials in each direction (20). If the participant shifted weight into the reaching limb, lifted the stance heel, or removed his hands from his hips, the trial was rejected and repeated. In the event of a rejected trial, participants were given verbal feedback so that the participant could attempt to correct the performance error(s) on the next trial. All reach distances were measured and recorded in centimeters. The SEBT assessments were performed by a team of multiple investigators at the testing sites. However, each rater had undergone previously described reliability training to establish consistency across the assessors, from which strong reliability has been reported (ICC: 0.86–0.92) (13).

After data collection, the following formula was used to normalize the 3 trials (T) of each reach direction to stance leg length (LL): \([T_1 + T_2 + T_3]/3 \times 100 = \%\text{LL}\) (11). All normalized scores were presented as a percentage of stance LL (%LL). The normalized ANT, PL, and PM scores were then averaged together to find a composite (COMP) score. The 4 normalized measures from the right limb (ANT\(_R\), PL\(_R\), PM\(_R\), and COMP\(_R\)) were then averaged with the same measures of the left limb (ANT\(_L\), PL\(_L\), PM\(_L\), and COMP\(_L\)) to get an overall composite measure (COMP) (19).

### Table 1. Mean SEBT scores and SDs for high school and collegiate football players.*

<table>
<thead>
<tr>
<th>Score</th>
<th>High school</th>
<th>Collegiate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANT (%)</td>
<td>69.9 ± 7.9</td>
<td>70.3 ± 7.1</td>
</tr>
<tr>
<td>PM (%)†</td>
<td>83.5 ± 10.2</td>
<td>86.7 ± 10.7</td>
</tr>
<tr>
<td>PL (%)†</td>
<td>72.8 ± 11.4</td>
<td>77.1 ± 10.2</td>
</tr>
<tr>
<td>COMP (%)†</td>
<td>75.4 ± 8.5</td>
<td>78.0 ± 7.4</td>
</tr>
</tbody>
</table>

*ANT = anterior; PM = posteromedial; PL = posterolateral; COMP = composite.
†Statistically significant difference between groups (p ≤ 0.05).

### Table 2. Regression models examining influence of age, height, and mass on SEBT scores.*

<table>
<thead>
<tr>
<th>COMP</th>
<th>Covariates included</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANT</td>
<td>Age, height, mass</td>
<td>0.09†</td>
</tr>
<tr>
<td></td>
<td>Age, mass</td>
<td>0.089†</td>
</tr>
<tr>
<td>PM</td>
<td>Age, height, mass</td>
<td>0.03†</td>
</tr>
<tr>
<td></td>
<td>Age, mass</td>
<td>0.03†</td>
</tr>
<tr>
<td>PL</td>
<td>Age, height, mass</td>
<td>0.035†</td>
</tr>
<tr>
<td></td>
<td>Age, mass</td>
<td>0.032†</td>
</tr>
<tr>
<td>COMP</td>
<td>Age, height, mass</td>
<td>0.049†</td>
</tr>
<tr>
<td></td>
<td>Age, mass</td>
<td>0.048†</td>
</tr>
</tbody>
</table>

*ANT = anterior; PM = posteromedial; PL = posterolateral; COMP = composite.
†Statistically significant regression model (p ≤ 0.05).
left limb (ANT<sub>L</sub>, PL<sub>L</sub>, PM<sub>L</sub>, and COMP<sub>L</sub>) to obtain the 4 outcome measures used for statistical analyses (ANT, PL, PM, and COMP).

**Statistical Analyses**
Separate independent t-tests were used to compare differences in ANT, PL, PM, and COMP scores of the SEBT between high school and collegiate football players. Separate multiple linear backward regression models were performed to determine the amount of variance in each reach direction explained by age, mass, and height of the participants on each of the 4 dependent variables. All significance levels were set a priori at \( p \leq 0.05 \). All statistical analyses were performed using IBM SPSS Statistics, version 21 (IBM, Corp., Armonk, NY, USA).

**RESULTS**
Differences in SEBT scores between high school and collegiate football players are presented in Table 1. High school football players had significantly lower normalized reach distances in the PM, PL, and COMP measures compared with the collegiate football players. There were no significant group differences for the normalized ANT reach scores.

The regression models examined the influence of the variance of age, height, and mass on the variances of the SEBT scores. For all 4 SEBT outcome variables, the contribution of height was almost nonexistent and was removed from the models. The remaining models using the variances in age and height were very weak, explaining only 3–9% of the variances in SEBT scores (Table 2).

**DISCUSSION**
This study’s primary finding was that high school football players had lower reach distances in 2 of 3 reach directions, as well as in COMP scores of the SEBT when compared with collegiate football players. Therefore, despite participation in a common sport at the highest level of organization and competition for their respective age groups, these cohorts differed in their ability to perform selected tests of dynamic postural control. Differences in postural control between age groups have been widely explored by studies analyzing changes through growth and development (2,8,14,22,24). Expensive laboratory equipment and static postural control tasks are commonly used to measure these changes. This study was able to detect dynamic postural control differences using low-cost materials and time efficiency, making the test accessible to clinicians and coaches, regardless of budgetary limitations.

The results of this study in the PL and PM directions were similar to findings in a study comparing high school, collegiate, and professional soccer players that reported high school athletes to have diminished performance compared with the older age groups (5). Robinson and Gribble (19) previously reported that hip flexion motion accounted for 94.5 and 88.6% of the variance in PL and PM scores, respectively. The collegiate football players may have had greater exposure to hip strengthening exercises, such as squats and Olympic lifts, which may improve performance on the PL and PM reach directions. In addition, the collegiate athletes were likely among the highest performing athletes when they played high school football. Therefore, those who excel in their sport and advance to higher levels of competition may have greater neuromuscular control, which could be demonstrated in PL and PM reach performance. However, no additional measures of strength or neuromuscular control were assessed in this study.

The current results for the ANT reach differ from Butler et al. (5), who reported greater reach distances in high school athletes, where this study found no difference between groups on the performance of that reach direction. Those authors (5) postulated that the older athletes may have had longer playing careers, and possibly a greater injury history, particularly involving the ankle, which may have created the deficits on the ANT reach performance. Previous literature has suggested that deficits exist in selected directions among participants with chronic ankle instability (12); however, Butler et al. (5) nor our current study documented injury history, so we cannot conclude the strength of this influence between cohorts of different age groups. Another reason for conflicting results in the ANT reach may be the differences between the SEBT used in this study and the Y-Balance test used by Butler et al. (5). Despite being similar, the SEBT and Y-Balance test have been shown to elicit significantly different reach scores and kinematic data in subjects during the ANT reach (9), indicating the 2 tests are likely not interchangeable.

Although the initial comparisons of SEBT performance were made between 2 distinct groups of football athletes, there was uncertainty as to whether the differences could be attributed to grouping or to other confounding variables. There are expected differences in age, mass, and height between high school and college football players, and it was important to examine if this is why SEBT scores may have differed. However, the regression analyses demonstrated that less than 10% of the variance in SEBT performance was explained by variances in age, mass, and height. In 3 of the 4 dependent measures (PL, PM, and COMP), less than 5% of the variance was explained by the covariates. Not surprisingly, the contribution of height to these models was almost zero. We followed previously published procedures for proper normalization to leg length (11), which can be partially related to height, likely removing any influence of this demographic variable.

Although we are able to conclude that high school and collegiate football players differ in selected aspects of the SEBT, most of the variance remains unexplained. As mentioned above, one aspect that needs future consideration is previous history of lower extremity injury. In addition, the group differences in SEBT performance may be explained by
differences in neuromuscular and skeletal variances, such as static joint range of motion (3,15), functional joint motion (19), and muscle activation (7). Unfortunately, these measures were not included in this database, so we are unable to conclude which factors could explain the remaining 90–95% of the variances in SEBT performance in this sample of football players. Future studies should continue to analyze these and other specific factors contributing to variations in SEBT performance between cohorts, which may then become targets for performance improvement and injury prevention.

The findings of this study support the idea that the level of player should be considered when interpreting SEBT scores, which could have implications when implementing the SEBT for injury risk prediction. Other investigators have previously used tests of dynamic postural control to determine injury risk cutoff scores for specific groups of athletes. Piskly et al. (18) reported that female high school basketball players with SEBT COMP scores less than 94% were 6.5 times more likely to sustain a lower extremity injury. In addition, female and male high school basketball players with left-right ANT reach differences greater than or equal to 4 cm were 2.5 times more likely to sustain a lower extremity injury. Butler et al. (4) found that collegiate football players with Y-Balance COMP scores less than 89.6% were 3.5 times more likely to sustain a noncontact lower extremity injury. Although dynamic lower extremity reaching tests, such as the SEBT, show promise for clinical screening of athletes’ dynamic postural control, our data suggest that clinicians using these tools may need to consider age and concomitant performance level when determining values that will denote injury risk.

Our posterior reaching directions yielded group differences, whereas the ANT reaching direction did not. One possible application to consider is that posterior reaches may be able to separate performance deficits and possible targets for intervention between a high school and a collegiate athlete. However, because the ANT reach did yield group differences, perhaps the ANT reaching direction is more universally applicable to this group of athletes, regardless of the cohort that is being assessed. Future research on which specific directions of the SEBT may be have more utility for screening of injury risk vs. identification of deficit will be needed to adequately address these questions.

Our study is not without limitations. We have documented group differences, but only among football players. Additional work is needed to examine if these differences are consistent in other groups of athletes. Our sample of football players was one of convenience based on teams from university and high school teams from the surrounding community that were willing to participate. Expansion of this work into larger samples may be warranted. As we mentioned above, future additions to the screening process to include static and dynamic joint motion analysis, strength, and muscle activations may provide insight to the source of these differences in the cohorts. Finally, while a team of multiple raters, rather than a single rater, acquired the data, as mentioned in the methods, reliability of this design has been shown previously to be strong.

Prospective postural control testing and subsequent injury tracking should continue to be performed with the goal of establishing cutoff scores for identifying individuals at higher or lower risk of lower extremity injuries. This could be done for various groups across multiple sports as well as the positions played. Researchers, clinicians, and coaches should be aware of variations that exist in assessment tools for dynamic postural control, such as the SEBT and Y-Balance, as the results may not be directly comparable between tests.

**Practical Applications**

When using the SEBT as an assessment tool for lower extremity injury risk, clinicians and coaches should be aware that variations between high school and collegiate athletes may affect the athletes’ scores. In particular, high school athletes may be expected to have lower normalized scores compared with collegiate athletes of the same sport. Thus, they likely have different standards for what is considered “at risk.” As research in this area progresses, quantitative cutoff values may further help delineate higher- and lower-risk athletes, which should lead to better allocation of injury prevention resources.

**References**


