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systematic review

Using the Star Excursion Balance Test to Assess Dynamic Postural-Control Deficits and Outcomes in Lower Extremity Injury: A Literature and Systematic Review

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Context: A dynamic postural-control task that has gained notoriety in the clinical and research settings is the Star Excursion Balance Test (SEBT). Researchers have suggested that, with appropriate instruction and practice by the individual and normalization of the reaching distances, the SEBT can be used to provide objective measures to differentiate deficits and improvements in dynamic postural-control related to lower extremity injury and induced fatigue, and it has the potential to predict lower extremity injury. However, no one has reviewed this body of literature to determine the usefulness of the SEBT in clinical applications.

Objective: To provide a narrative review of the SEBT and its implementation and the known contributions to task performance and to systematically review the associated literature to address the SEBT's usefulness as a clinical tool for the quantification of dynamic postural-control deficits from lower extremity impairment.

Data Sources: Databases used to locate peer-reviewed articles published from 1980 and 2010 included Derwent Innovations Index, BIOSIS Previews, Journal Citation Reports, and MEDLINE.

Study Selection: The criteria for article selection were (1) The study was original research. (2) The study was written in English. (3) The SEBT was used as a measurement tool.

Data Extraction: Specific data extracted from the articles included the ability of the SEBT to differentiate pathologic conditions of the lower extremity, the effects of external influences and interventions, and outcomes from exercise intervention and to predict lower extremity injury.

Data Synthesis: More than a decade of research findings has established a comprehensive portfolio of validity for the SEBT, and it should be considered a highly representative, noninstrumented dynamic balance test for physically active individuals. The SEBT has been shown to be a reliable measure and has validity as a dynamic test to predict risk of lower extremity injury, to identify dynamic balance deficits in patients with a variety of lower extremity conditions, and to be responsive to training programs in both healthy people and people with injuries to the lower extremity. Clinicians and researchers should be confident in employing the SEBT as a lower extremity functional test.

Key Words: clinical balance, functional tests, dynamic balance tests, dynamic postural-control tasks

Key Points

- The Star Excursion Balance Test should be considered a highly representative noninstrumented dynamic balance test for physically active people.
- The Star Excursion Balance Test is a reliable measure and a valid dynamic test to predict risk of lower extremity injury, to identify dynamic balance deficits in patients with lower extremity conditions, and to be responsive to training programs in healthy participants and those with lower extremity conditions.

Clinicians often use postural-control assessments to evaluate risk of injury, initial deficits resulting from injury, and level of improvement after intervention for an injury. Postural-control and balance can be grouped into static and dynamic categories.[1–6] Static postural-control tasks require the individual to establish a stable base of support and maintain this position while minimizing segment and body movement during the assessment. These assessments can be conducted with instrumented equipment, such as a force platform, or valid, reliable clinical scales, such as the Balance Error Scoring System[1–3,5,7–20] or Berg Balance Scale.[1,21] Whereas static measures of postural-control provide useful clinical information, the underlying task of standing as still as possible might not translate necessarily to movement tasks during physical activity.

Conversely, dynamic postural-control involves some level of expected movement around a base of support. This might involve tasks, such as jumping or hopping to a new location and immediately attempting to remain as motionless as possible or attempting to create purposeful segment movements (reaching) without compromising the established base of support. Although these dynamic measures of postural stability do not exactly replicate

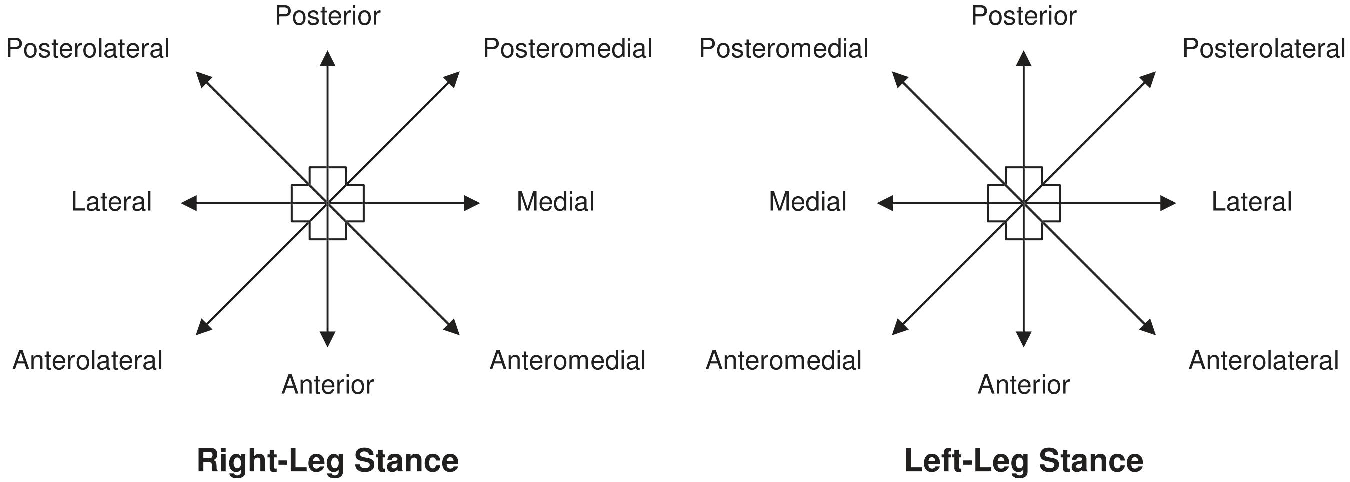

Figure 1. Reaching directions for the Star Excursion Balance Test.

sport participation, they more closely mimic demands of physical activity than assessments of static postural stability. Therefore, discovering assessment techniques that can provide reliable, sensitive, and, if possible, cost-effective information about dynamic movement is important.

One such task that has gained notoriety in the clinical and research settings is the Star Excursion Balance Test (SEBT). Originally described by Gray[22] as a rehabilitative tool, the SEBT is a series of single-limb squats using the nonstance limb to reach maximally to touch a point along 1 of 8 designated lines on the ground.[23] The lines are arranged in a grid that extends from a center point and are 45° from one another (Figure 1). Each reaching direction offers different challenges and requires combinations of sagittal, frontal, and transverse movements. The reaching directions are named in orientation to the stance limb as anterior, anteromedial, anterolateral, medial, lateral, posterior, posteromedial, and posterolateral (Figure 1). The goal of the task is to have the individual establish a stable base of support on the stance limb in the middle of the testing grid and maintain it through a maximal reach excursion in 1 of the prescribed directions.[22,23] While standing on a single limb, the participant reaches as far as possible with the reaching limb along each reaching line; lightly touches the line with the most distal portion of the reaching foot without shifting weight to or coming to rest on this foot of the reaching limb; and then returns the reaching limb to the beginning position in the center of the grid, reassuming a bilateral stance (Figure 2). If the individual touches heavily or comes to rest at the touch-down point, has to make contact with the ground with the reaching foot to maintain balance, or lifts or shifts any part of the foot of the stance limb during the trial, the trial is not considered complete.[23,24] These stipulations should be applied during rehabilitation, injury evaluation, and research applications of the SEBT.

The measurement or outcome from the SEBT performance is how far the participant can reach without violating any of the described stipulations. The reach distance values are used as an index of dynamic postural-control (ie, a farther distance reached indicates better dynamic postural-control). These assessments can be compared between injured and uninjured limbs or before and after an intervention to quantify deficits or improvements in dynamic postural-control. The body of literature that exists suggests that, with appropriate instruction and practice by the participant and normalization of the reaching distances, the SEBT can provide objective measures to differentiate deficits and improvements in dynamic postural-control related to lower extremity injury and induced fatigue, and it has the potential to predict injury to the lower extremity. However, no one has reviewed this body of literature to determine the usefulness of the SEBT in clinical applications. Therefore, the 2 purposes of our study were to (1) provide a narrative review of the SEBT and its implementation and the known contributions to task performance and (2) systematically review the associated literature to address the usefulness of the SEBT as a clinical tool for the quantification of dynamic postural-control deficits from lower extremity impairment.

PART I: IMPLEMENTATION OF THE SEBT AND KNOWN CONTRIBUTIONS TO PERFORMANCE—A NARRATIVE REVIEW

Development of Measurement Properties

The first report of the SEBT in the research literature was a reliability study published in 1998.[25] Test-retest reliability estimates were reported for the 4 diagonal reach directions of the test (anteromedial, anterolateral, posteromedial, and posterolateral). Intratester reliability estimates (intraclass correlation coefficients [ICC]) for the different directions ranged from 0.67 to 0.87.[25] In another reliability study,[26] the intratester and intertester reliability of all 8 reach directions of the SEBT in healthy young adults were established. These included anterior, posterior, medial, and lateral reach directions in addition to the 4 diagonal directions previously mentioned.[22] Participants performed 12 trials in each direction on 2 days: 3 trials in each direction while 1 examiner measured reaching distance as the performance variable. Intratester reliability estimates (ICCs) for the different directions ranged from 0.78 to 0.96, and the intertester reliability ranged from 0.35 to 0.84 on day 1 and from 0.81 to 0.93 on day 2. The relatively poor intertester reliability reported on day 1 was likely an

[redacted]

Figure 2. Performance of the Star Excursion Balance Test using the right leg as the stance limb in the, A, anterior, B, posterolateral, and C, posteromedial directions.

artifact of a practice effect. The investigators found a practice effect, with participants reaching farther as they performed more trials until a plateau occurred during trials 7 through 9. Therefore, they recommended having participants perform 6 practice trials in each direction before recording reaching distances for clinical or research purposes.[26]

More recently, Robinson and Gribble[27] demonstrated that, in most reach directions, the maximum reaching distances and associated kinematic displacement values of the stance limb stabilized by the fourth trial. Thus, they recommended that only 4 practice trials need to be performed before measuring reaching distances for clinical or research purposes.[27] Similarly, Munro and Herrington[28] found that performance on the SEBT stabilized after 4 trials among healthy participants. Furthermore, those authors examined the test-retest reliability among 3 additional trials and found strong reliability (ICC = 0.84–0.92),[28] which was consistent with previous reliability studies.[25,26]

Based on the results of a factor analysis study,[29] great redundancy has been found in participant performance in the 8 reach directions. A tremendous amount of shared variance was present across the 8 reach directions. In other words, an individual's reaching distance in a given direction was highly correlated with his or her reaching distance in the other 7 directions.[29] This has led to the recommendation that only 3 reach directions (anterior, posteromedial, and posterolateral) should be performed (Figure 2).[30] This modification substantially reduces the time necessary to perform the SEBT.

Building on the reduction in the number of reach directions, Plisky et al[31] proposed a commercially available product, the Y Balance Test (functionalmovement.com, Danville, VA), to further improve the efficiency of SEBT measures. This device comprises a stance platform from which 3 pieces of polyvinylchloride pipe extend in the anterior, posteromedial, and posterolateral reach directions. Each pipe is marked in 5-mm increments. The participant pushes a target (reach indicator) along the pipe with the foot of his or her reach limb, and the target remains over the tape measure after performance of the test to allow for easy measurement. Intratester reliability (ICC) using this device ranged from 0.85 to 0.89, whereas intertester reliability was nearly perfect, ranging from 0.97 to 1.00.[31]

To compare performance within limbs of an individual, comparisons in the absolute reaching distance can be made between reaching distances attained on each limb. However, to make valid comparisons of SEBT reaching distances among individuals or groups, reaching distances need to be normalized to each participant's limb length.[24] This recommendation is based on limb length, as measured from the anterosuperior iliac spine to the medial malleolus, being correlated with reach performance.[24] Whereas overall body height also was correlated with reaching distance, limb length was more strongly correlated.[24] When normalizing reaching distances to limb length, performance typically is expressed as a percentage of limb length.

Other Contributing Factors to SEBT Performance

In addition to limb length and height, several other anthropometric and physiologic characteristics have been studied to assess their association with SEBT performance. Several researchers have investigated if SEBT performance is different among individuals with different foot types. In 2 studies, researchers[4,24] reported no differences in reaching distances among groups with pes cavus, pes rectus, and pes planus feet. However, in another study, researchers[32] found several differences in reaching distance across foot-type groups. A group of participants with pronated feet reached farther in the anterior and anteromedial directions than did a group with neutral foot alignment. Interestingly, a group with supinated feet reached farther in the posterior and posterolateral directions than did a group with neutral feet. In the lateral direction, the group with supinated feet reached farther than the group with pronated feet but not farther than the group with neutral feet. Because consistent differences in reaching distances have not been identified in groups with different foot types, we do not recommend controlling foot type in studies in which the SEBT is used as an outcome measure.

Earl and Hertel[33] found that muscle activation, as assessed with surface electromyography, was substantially different across the various reach directions. Vastus medialis activity was greater during the anterior excursion than all other directions. Vastus lateralis activity was less during the lateral excursion than all other directions. Medial hamstring activity was higher during the anterolateral reach direction than during the anterior, anteromedial, and medial excursions. Biceps femoris electromyographic (EMG) activity was higher during the posterior, posterolateral, and lateral excursions than during the anterior and anteromedial excursions.[33] The EMG differences across specific reach differences might be helpful to clinicians deciding which reach directions to employ as outcome measures in patients with specific impairments in muscle strength.

Sex Differences. The existence of differences between men and women in a variety of dynamic and functional measures related to physical performance is well established. Therefore, an important factor to consider when using the SEBT for outcome measures is the potential for sex differences. One of the first comparisons between men and women was made by Gribble and Hertel.[24] When the raw scores for reaching distances were compared in a sample of healthy participants, men were able to reach farther than women in all 8 directions of the SEBT. The authors considered that because men on average are taller and have longer limbs than women, perhaps a normalizing procedure should be implemented. When the raw reaching distances were normalized by height and by limb length of the stance leg, the differences between men and women no longer existed. Therefore, they concluded that because of anthropometric discrepancies, performance differences could be negated through this normalization process, with stronger agreement using limb length as the normalizing factor.[24]

Many investigators have examined SEBT performance differences between men and women using the normalized scores. Gribble et al[34] compared the performance of healthy men and women in the anterior, medial, and posterior directions before and after various fatigue protocols to determine if sex differences exist in dynamic postural-control and if fatigue exacerbates these potential differences. They found that women performed better than men in all 3 directions, which contradicted the notion of no difference in performance between sexes. However, whereas some differences exist before the inducement of fatigue, the discrepancy in performance became more consistent and pronounced after fatigue.[34] Interestingly, similar sex differences in knee flexion angle were observed in conjunction with the dynamic postural-control differences in the study, which were hypothesized to be a key factor in explaining optimal performance of the SEBT. These kinematic patterns will be discussed further in the next section.

Although Gribble et al[34] reported performance differences in men and women, the influence of fatigue prevents one from directly examining the potential for sex differences. In another study from the same laboratory, researchers used the SEBT as an outcome measure before and after a 6-week exercise intervention period among healthy men and women.[5] Looking at the baseline/pre-exercise data allows potential differences in performance by men and women to be examined. In the 3 reaching directions that were used in this study, the investigators found no sex differences in the anteromedial, medial, or posteromedial directions for normalized reaching distances. Consistent with findings in a previous study,[24] men and women did not have dynamic postural-control differences when the raw scores were normalized to the limb length of the stance limb.[5]

In another investigation in which men and women were compared, researchers[35] evaluated healthy National Collegiate Athletic Association Division I basketball athletes and recreationally active participants. For the anterior and medial directions, normalized reaching distances did not differ between sexes. However, men performed 5% better than women in the posterior reaching direction. When the performances of all 3 directions used in this study were averaged, men and women did not demonstrate differences, suggesting that the differences in the posterior reach might not be enough to separate the sexes when overall performance is being evaluated using multiple directions.

Finally, using the SEBT as a screening tool for lower extremity injuries among adolescent boys and girls, Plisky et al[36] described the importance of this test for helping to understand discrepancies in risk of injury between the sexes. The focus of this study was not to examine performance differences between male and female athletes on the SEBT and, subsequently, no results are available to contribute to this question. However, an important finding was that female basketball players, with a lower composite SEBT score than their male cohorts, were 6 times more likely to sustain a lower extremity injury during the season. Conversely, this predictive relationship for overall reach performance did not exist for the male athletes. The authors believed this demonstrated the usefulness of the SEBT to detect neuromuscular control differences between males and females.

Whereas it appears that, with appropriate normalization, performance of healthy men and women on the SEBT should be relatively consistent, researchers potentially can use the SEBT to describe differences between the sexes in the presence of neuromuscular control alteration, such as injury or fatigue. Because a consistent finding is not available in the existing literature, we believe that the SEBT should not be the only outcome measure to assess sex differences, but because of its strong reliability, it should be considered as part of a battery of screening and assessment tools.

Movement Pattern Differences. Although the primary measure during performance of the SEBT is the reaching distance, some factors are believed to contribute to one's ability to maximize the achievable reaching distance. The evaluator should impose only a few movement restrictions on an individual (eg, keep the foot fixed to the floor). Otherwise, the individual should determine his or her optimal movement patterns to perform this task. In a few studies, investigators have examined the patterns that exist in men and women[34] and in participants with and without chronic ankle instability[1,2] and patellofemoral pain.[9] Collectively, information from these studies has suggested that knee and hip movements in the sagittal plane strongly influence SEBT performance.

In an initial investigation, the available lower extremity range of motion (ROM) for ankle dorsiflexion and hip internal and external range of motion that participants exhibited did not influence reaching distance.[37] However, in a more recent investigation, available dorsiflexion motion in the ankle was correlated strongly with anterior reaching distance.[38] A closed chain measure of dorsiflexion was applied in both studies, but Hoch et al[38] used a weight-bearing lunge test, whereas Gribble and Hertel[24] used an open chain measure of dorsiflexion and found that dorsiflexion accounted for 28% of the variance in the anterior reach performance.

Differences in sagittal-plane knee ROM have been demonstrated among the different reach directions.[1] The greatest amount of knee flexion ROM occurred during performance of the anteromedial reach. The anterior, anteromedial, medial, and posteromedial directions produced more knee flexion than did the anterolateral direction. Knee flexion was less in the posterolateral and lateral directions than all other directions except the anterolateral direction. The anterior, anteromedial, and medial directions produced greater ankle dorsiflexion than all other directions except that the medial and lateral excursions were not different.[1] This kinematic information might be helpful to clinicians when deciding which reach directions to use in patients with specific ROM impairments.

Looking at healthy participants, Gribble et al[34] compared performances between men and women. Women demonstrated better dynamic postural-control, which was illustrated by longer normalized reaching distances than men had. Simultaneously, women used an average of more than 4° additional knee flexion in the anterior direction and more than 5° additional knee flexion in the posterior direction than men, both of which were significant findings.

In 2 additional studies, Gribble et al[1,2] considered how kinematic contributions can affect SEBT performance between participants with and without chronic ankle instability (CAI). In an initial investigation, 2-dimensional kinematics of the sagittal-plane positions of the ankle, knee, and hip of the stance leg were quantified at the point of maximum reach during the SEBT between participants with and without CAI.[2] The authors found that the amount of knee and hip flexion used by participants with CAI was less than that of the matched control participants. These reduced joint motions were theorized to contribute to the decreased dynamic postural-control that was demonstrated simultaneously by the participants with CAI. In a follow-up analysis, regression analyses were employed to determine the influence that CAI and these same kinematic patterns might have had on the reaching distances during the SEBT performance.[1] In the anterior direction, knee flexion and hip flexion angles, along with CAI, were part of a model that predicted 49% of the variance in SEBT performance, meaning that the positioning of the knee and hip of the stance limb played an important role in why participants with CAI demonstrated shorter reaching distances and subsequently worse dynamic postural-control than the healthy participants. With 2 studies, the researchers provided data suggesting that kinematic pattern differences in the knee and hip differ in participants with CAI and might help to explain why this condition is associated with a reduction in dynamic postural-control when performing this test.

Aminaka and Gribble[9] examined similar contributions of the kinematics of the stance limb to the performance on the SEBT between participants with and without patellofemoral pain syndrome (PFPS). In the anterior direction, participants with PFPS demonstrated a reduction in normalized reaching distances, but contradictory to what was observed for participants with CAI, the kinematic patterns of the stance leg did not differ between the groups. Whereas the lack of significant findings throughout the study does lend support to the possibility that stance-limb positioning influences SEBT performance, the large differences in means between the injured side of the PFPS group and the matched side of the control group without the use of the taping intervention are interesting. The authors did not report effect sizes for these relationships, which could provide useful information. Considering the data from this study and the potential effect sizes at the knee, the control participants used more flexion (48.85° ± 3.98°) than the participants with PFPS (43.80° ± 3.88°), which was associated with a large effect size and a 95% confidence interval (CI) that did not cross zero (Cohen d = 1.28, 95% CI = 0.58, 1.94). Similarly, they found a large effect size (Cohen d = 1.13, 95% CI = 0.44, 1.77) associated with differences in hip flexion between the control participants (11.05° ± 3.18°) and participants with PFPS (7.36° ± 3.35°).

Given this collection of studies, knee and hip flexion appear to provide important contributions to SEBT and might help to explain the differences in performance between men and women, as well as the deficiencies in participants with lower extremity pathologic conditions. This is likely due to the influence of large muscle groups controlling these joints that are vital for motion and stability during dynamic tasks. In our experiences, we have observed that patients and research participants report feeling limited in the task by the amount of motion in the ankle of the stance limb, especially in the anterior direction. Investigators have reported diminished ankle dorsiflexion in individuals with CAI.[39–41] However, contrary to the findings noted in the aforementioned studies, no one has reported differences in sagittal-plane motion of the ankle joint during performance of the SEBT.[1,2,34]

Perhaps clinicians and researchers need to quantify the movement patterns of the SEBT to appreciate the subjective and objective contributions to task performance that are reported. Gribble et al[42] demonstrated that as a low-cost alternative to motion capture systems, moderate to strong reliability of the sagittal-plane positions of the ankle, knee, and hip at the point of maximum reaching distance (ICC = 0.76–0.89) is achievable with a 2-dimensional software package and a standard digital video camera. However, perhaps more sophisticated instrumentation is needed to quantify the kinematic information, especially at the ankle. In addition, examining kinematic contributions in the frontal and transverse planes and coordinating those with the sagittal-plane information that is available will be important. Examining the quality of the movement of the stance limb in addition to the global outcome of the reaching distances during this task will help clinicians and researchers understand the contributing deficits to dynamic postural-control and might aid in developing effective interventions for overcoming these deficiencies.

Other Influences. Researchers have considered other factors that might influence SEBT performance but do not fit into the categories presented. Gribble et al[43] were interested in the potential influence that circadian rhythms might have on balance in healthy individuals. They reported that dynamic postural-control measured with the SEBT was better in the morning (10:00) than in the afternoon (15:00) and evening (20:00), suggesting that investigators using the SEBT across multiple testing days should consider standardizing the time of day that assessments are made.

Ozunlu et al[44] wanted to estimate how dynamic postural-control might be altered in the presence of extra weight. To examine the effect of carrying heavy loads on balance among school-aged children, healthy adolescent participants performed the SEBT with and without wearing an additional 20% of their body mass in a backpack. Performance declined during the posteromedial reaching direction when participants were wearing the backpacks ($P = .004$), with an associated moderate effect size (Cohen d = 0.67, 95% CI = 0.02, 1.29). The performance in the other 7 directions was not influenced by the extra carrying weight, with small effect sizes (Cohen d range, 0.05–0.38) and a 95% CI that crossed zero. The authors stated that, whereas the effect of carrying a backpack on dynamic postural-control performance measured with the SEBT was small, the posteromedial reaching direction might be a useful testing tool in the future for examining risks and influences on musculoskeletal injury, such as carrying extra weight.

PART II: USING THE SEBT TO DETECT CLINICAL DEFICITS—A SYSTEMATIC REVIEW

Whereas the SEBT originally was designed to be used as a rehabilitative tool for lower extremity pathologic conditions, researchers and clinicians have adopted it as a diagnostic tool to differentiate the presence of pathologic conditions, the success of interventions, and the predictive value in detecting risk of injury. However, although the application of the SEBT as a diagnostic tool is widespread in the literature, no one knows what magnitude of differences the SEBT can detect and if these magnitudes vary across the applications of the test as a diagnostic tool. Therefore, the purpose of this systematic review was to determine the strength of the SEBT as a diagnostic tool in 4 clinical areas: (1) ability to differentiate participants with lower extremity conditions from healthy participants, (2) ability to differentiate influences on performance, (3) ability to demonstrate outcomes from planned interventions, and (4) ability to predict risk of injury. Establishing these qualities and the magnitudes of these relationships will help clinicians determine how best to implement the SEBT in the management of lower extremity injury. Including all 4 of these subareas helps to make a more comprehensive review of the overall purpose: assessing the effectiveness of the SEBT as a diagnostic tool.

METHODS

Data Sources

An online search using Web of Science was performed on January 5, 2011, to obtain peer-reviewed articles published between 1980 and 2010. The Web of Science allows the search of multiple databases (Derwent Innovations Index, BIOSIS Previews, Journal Citation Reports, and MEDLINE) simultaneously. The search terms included *Star Excursion Balance Test* and *SEBT*.

Study Selection

The criteria for article selection were (1) The study was original research. (2) The study was written in English. (3) The SEBT was used as a measurement tool. References from pertinent articles were cross-referenced to locate any further relevant articles that we did not find with the initial search.

Data Extraction

After the initial search for publications using the SEBT as a diagnostic tool was completed, we read the articles and placed them in the 4 clinical areas pertaining to the stated purposes (Figure 3). If an article addressed more than 1 clinical area, it was included in all appropriate subgroupings, which explains why the sum of articles in all 4 clinical areas exceeds the total number of articles reviewed.

RESULTS

Forty-eight published articles were discovered from the original search (Figure 3). After reviewing the citations by title and abstract, we determined the SEBT was used as a measurement tool in 44 articles. When cross-referencing references from the pertinent articles to locate other relevant articles, we found no additional articles.

Ability of the SEBT to Differentiate Pathologic Conditions

Lower extremity musculoskeletal pathologic conditions typically are associated with deficits in postural and neuromuscular control. The SEBT has been used extensively in research and clinical applications to differentiate the level of dynamic postural-control among participants and patients with various lower extremity injuries, including CAI,[1,2,7,8,10–12,45–48] anterior cruciate ligament (ACL) reconstruction,[3] and PFPS.[9] The premise of using the SEBT for this purpose is to determine if, while standing on the injured or affected limb to maintain stability, a deficit is produced in the reaching distances, indicating a deficiency in dynamic postural-control that might be associated with the pathologic condition in the stance limb. This can provide easily attainable, important information to identify a deficit that might need intervention or correction.

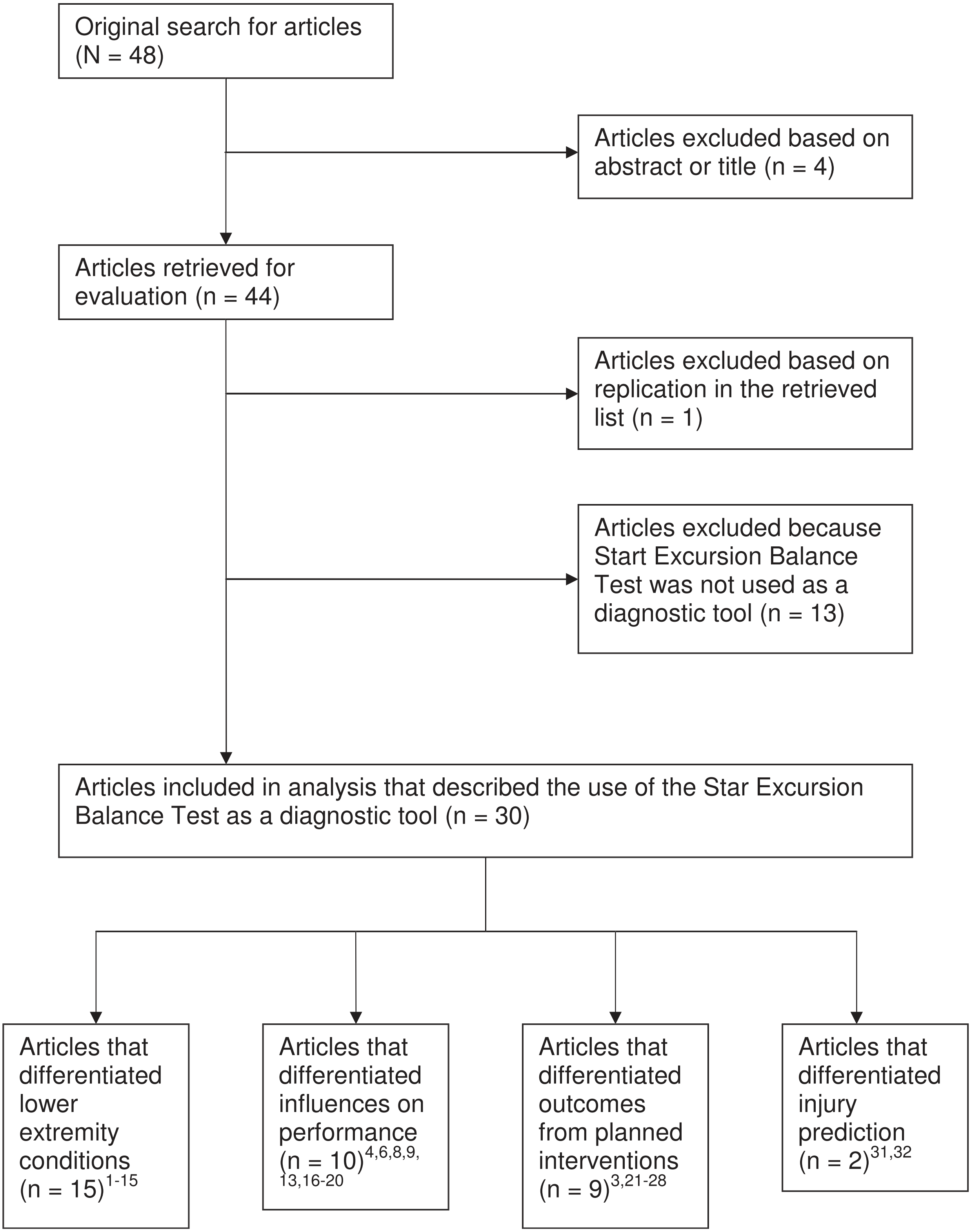

Figure 3. Flow chart of the evidence search.

Ankle Instability. The first and most common joint that has been addressed with SEBT testing is the ankle. Various balance and other sensorimotor deficits have been associated with ankle instability.[10,12,46,48] Consistently in the literature, people with acute ankle instability and CAI perform worse on the SEBT than people with uninjured limbs (Table 1). Olmsted et al[45] were the first to make these comparisons, demonstrating that participants with CAI performed worse on the total score in all 8 directions when using their affected limbs as the stance limbs compared with their unaffected limbs, as well as compared with the performance of matched limbs of the control group participants ($P = .05$). Akbari et al[47] compared the injured and uninjured sides of participants with unilateral ankle

Table 1. Ability of the Star Excursion Balance Test to Differentiate Pathologic Conditions: Ankle Instability[a]

Authors	Main Comparison	N	Normalized to Leg Length?	Result	*P* Value	Effect Size (95% CI)
Akbari et al,[47] 2006	Unknown direction for injured and uninjured limbs	30	No	Injured limb = 84.97 ± 10.26 cm Uninjured limb = 86.8 ± 9.34 cm	.03	0.19 (−0.32, 0.69)
Gribble et al,[2] 2004	Anterior direction for CAI-IS and CAI-US	15	Yes	CAI-IS = 78.4% ± 6.2% CAI-US = 81.8% ± 6.6%	.03	0.53 (−0.21, 1.24)
	Medial direction for CAI-IS and CAI-US	15	Yes	CAI-IS = 87.5% ± 5.8% CAI-US = 90.0% ± 7.0%	.02	0.39 (−0.34, 1.10)
	Posterior direction for CAI-IS and CAI-US	15	Yes	CAI-IS = 89.0% ± 9.3% CAI-US = 90.9% ± 9.3%	.01	0.20 (−0.52, 0.92)
Hale et al,[7] 2007[a]	Posteromedial direction for IS and US	29	Yes	IS = 80.0% ± 12.5% US = 83.5% ± 11.5%	.047	0.29 (−0.23, 0.80)
	Posterolateral direction for IS and US	29	Yes	IS = 73.5% ± 10.5% US = 77.5% ± 10.5%	.007	0.38 (−0.14, 0.90)
	Lateral direction for IS and US	29	Yes	IS = 65.5% ± 10.0% US = 70.0% ± 10.5%	.03	0.44 (−0.09, 0.95)
Hertel et al,[29] 2006	Anteromedial direction for CAI-IS and CAI-US and for CAI-IS and CMS	CAI = 48 Control = 39	Yes	CAI-IS = 80.0% ± 10.0% CAI-US = 82.0% ± 9.0% CMS = 84.0% ± 10.0%	.005	Within groups = 0.21 (−0.22, 0.63) Between groups = 0.40 (−0.03, 0.82)
	Medial direction for CAI-IS and CAI-US and for CAI-IS and CMS	CAI = 48 Control = 39	Yes	CAI-IS = 85.0% ± 10.0% CAI-US = 88.0% ± 9.0% CMS = 89.0% ± 9.0%	<.001	Within groups = 0.32 (−0.09, 0.72) Between groups = 0.42 (−0.01, 0.84)
	Posteromedial direction for CAI-IS and CAI-US and for CAI-IS and CMS	CAI = 48 Control = 39	Yes	CAI-IS = 85.0% ± 13.0% CAI-US = 89.0% ± 13.0% CMS = 90.0% ± 13.0%	.03	Within groups = 0.31 (−0.10, 0.71) Between groups = 0.38 (−0.05, 0.81)
Nakagawa and Hoffman,[37] 2004	Total for CAI and control (distance height)	CAI = 19 Control = 19	Yes	CAI = 1.71 ± 0.18[b] Control = 1.80 ± 0.15[b]	.01	0.55 (−0.12, 1.18)
Olmsted and Hertel,[4] 2004	Total for CAI-IS and CAI-US and for CAI-IS and CMS	CAI = 20 Control = 20	No	CAI-IS = 78.6 ± 10.66 cm CAI-US = 81.2 ± 10.91 cm CMS = 82.8 ± 11.54 cm	.05	Within groups = 0.24 (−0.39, 0.86) Between groups = 0.38 (−0.26, 1.00)
Sefton et al,[12] 2009	Anteromedial direction for CAI-IS and CMS	CAI = 22 Control = 21	Yes	CAI-IS = 88.67% ± 6.73% CMS = 88.90% ± 6.10%	.91	0.04 (−0.56, 0.63)
	Medial direction for CAI-IS and CAI-US	22	Yes	CAI-IS = 89.11% ± 6.78% CAI-US = 91.10% ± 7.08%	.35	0.29 (−0.32, 0.88)
	Posteromedial direction for CAI-IS and CAI-US	22	Yes	CAI-IS = 90.49% ± 7.35% CAI-US = 95.12% ± 8.24%	.14	0.59 (−0.02, 1.20)
Martinez-Ramirez et al,[11] 2010	Anterior direction for CAI and control	CAI = 13 Control = 12	Yes	CAI = 70.6% ± 6.55% Control = 66.4% ± 4.45%	>.05 (not specified)	0.74 (−0.09,1.53)
	Posteromedial direction for CAI and control	CAI = 13 Control = 12	Yes	CAI = 89.05% ± 7.45% Control = 88.05% ± 7.05%	>.05 (not specified)	0.13 (−0.66, 0.91)
	Posterolateral direction for CAI and control	CAI = 13 Control = 12	Yes	CAI = 82.8% ± 9.3% Control = 79.85% ± 8.95%	>.05 (not specified)	0.32 (−0.48,1.10)

Abbreviations: CAI, chronic ankle instability; CAI-IS, chronic ankle instability of the injured side; CAI-US, chronic ankle instability of the uninjured side; CMS, control matched side; IS, injured side; US, uninjured side.

[a] Level of evidence for all entries is 3b, except for that of Hale et al,[7] 2007, which is 2b. Phillips B, Ball C, Sackett D, et al. *The Oxford Centre for Evidence-Based Medicine: Levels of Evidence (March 2009)* [updated by Howick J in March 2009]. Oxford Centre for Evidence-Based Medicine. http://www.cebm.net/index.aspx?o=1025. Accessed November 29, 2011.

[b] Nakagawa and Hoffman[37] did not provide units of measure.

Table 2. Ability of the Star Excursion Balance Test to Differentiate Pathologic Lesions: Anterior Cruciate Ligament Injury[a]

Authors	Main Comparisons	N	Normalized to Leg Length?	Results	*P* Value	Effect Size (95% CI)
Herrington et al,[3] 2009	Anterior direction for ACL-D IS and CMS	ACL = 25 Control = 25	Yes	ACL-D IS = 41.4% ± 2.9% CMS = 46.8% ± 5.1%	.003	1.30 (0.67, 1.89)
	Lateral direction for ACL-D IS and CMS	ACL = 25 Control = 25	Yes	ACL-D IS = 29.8% ± 4.1% CMS = 57.4% ± 2.3%	.005	8.30 (6.48, 9.87)
	Posteromedial direction for ACL-D IS and CMS	ACL = 25 Control = 25	Yes	ACL-D IS = 90.4% ± 4.4% CMS = 97.6% ± 1.0%	.002	2.26 (1.52, 2.93)
	Medial direction for ACL-D IS and CMS	ACL = 25 Control = 25	Yes	ACL-D IS = 61.4% ± 4.8% Control = 82.6% ± 1.0%	.001	6.11 (4.72, 7.32)
	Lateral direction for ACL-D US and CMS	ACL = 25 Control = 25	Yes	ACL-D US = 34.6% ± 8.9% Control = 57.4% ± 2.3%	.001	3.51 (2.58, 4.33)
	Medial direction for ACL-D US and CMS	ACL = 25 Control = 25	Yes	ACL-D US = 67.4% ± 3.2% Control = 82.6% ± 1.0%	.001	6.41 (4.96, 7.67)

Abbreviations: ACL, anterior cruciate ligament; ACL-D, anterior cruciate ligament reconstruction and deficiency; CMS, control matched side; IS, injured side; US, uninjured side.

[a] Level of evidence for all entries is 3b. Phillips B, Ball C, Sackett D, et al. *The Oxford Centre for Evidence-Based Medicine: Levels of Evidence (March 2009)* [updated by Howick J in March 2009]. Oxford Centre for Evidence-Based Medicine. http://www.cebm.net/index.aspx?o=1025. Accessed November 29, 2011.

instability and reported that the performance of the injured side was worse than that of the uninjured side ($P = .03$). It is unclear which direction or directions were used in this study and how much time had passed since participants had sustained the ankle injuries. In both studies, the reported reaching distances were not normalized, and we have discussed the importance of this procedure.

Using normalized reaching distances, Gribble et al[2] reported decreased performance of the CAI group on their injured sides in the anterior ($P = .03$), medial ($P = .02$), and posterior ($P = .01$) directions. Similarly, Hertel et al[29] reported group-by-side interactions that demonstrated decreased normalized reaching distances on the injured sides of participants with CAI for the anteromedial ($P = .005$), medial ($P < .001$), and posteromedial ($P = .03$) directions. Additionally, Hale et al[7] confirmed the deficit in task performance in participants with CAI at baseline before implementation of a rehabilitation protocol, with injured limbs producing worse dynamic postural-control than the uninjured limbs for the posteromedial ($P = .047$), posterolateral ($P = .007$), and lateral ($P = .03$) directions. Finally, Nakagawa and Hoffman[37] reported better total score performance in healthy control participants than participants with CAI ($P = .01$). Whereas their data were normalized, they used a variation of the procedure by multiplying rather than dividing the reaching distances by height.

Although the authors of these studies consistently showed that ankle instability is associated with a diminished level of dynamic postural-control measured with the SEBT, authors of 2 studies have presented conflicting results. Sefton et al[12] reported no differences in participants with and without CAI using the anteromedial, medial, and posteromedial directions. However, how the participants with CAI were selected raises concerns. The authors used the Foot and Ankle Disability Index (FADI) and the FADI-Sport to differentiate the level of functional deficits in the identified participants with a history of ankle sprains. Although the FADI instruments commonly are used for this purpose, the range of scores for the FADI (37%) and FADI-Sport (56.2%) and the reported standard deviations for the combined score (75.35%) of the CAI group were quite large, which could have jeopardized the homogeneity of the sample of injured participants. In addition, the normalized scores that Sefton et al[12] reported for the CAI group were much larger than those reported in the body of work we have reviewed. Similarly, Martinez-Ramirez et al[11] did not report differences between groups with and without CAI among the anterior, posteromedial, and posterolateral reaching directions, but they found close to a strong effect size for the anterior direction (Cohen d = 0.74). The authors stated that their inclusion criteria for CAI might not have been specific enough, raising concerns similar to those noted in the study by Sefton et al.[12] This issue has been discussed further in a recent investigation by Delahunt et al.[49]

Anterior Cruciate Ligament Reconstruction. Anterior cruciate ligament injuries also are very common among lower extremity pathologic conditions, and authors of many studies that are too numerous to discuss here have

Table 3. Ability of the Star Excursion Balance Test to Differentiate Pathologic Lesions: Patellofemoral Pain[a]

Authors	Main Comparisons	N	Normalized to Leg Length?	Results	*P* Value	Effect Size (95% CI)
Aminaka and Gribble,[9] 2008	Anterior direction for PFP IL and CML	PFP IL = 20 Control = 20	Yes	PFP IL = 62.8% ± 1.2% Control = 65.6% ± 1.2%	.03	2.33 (1.49, 3.08)

Abbreviations: CML, control matched limb; IL, injured limb; PFP, patellofemoral pain.

[a] Level of evidence for all entries is 2b. Phillips B, Ball C, Sackett D, et al. *The Oxford Centre for Evidence-Based Medicine: Levels of Evidence (March 2009)* [updated by Howick J in March 2009]. Oxford Centre for Evidence-Based Medicine. http://www.cebm.net/index.aspx?o=1025. Accessed November 29, 2011.

Table 4. **Ability of the Star Excursion Balance Test to Differentiate Effects of External Influences and Interventions: Taping, Bracing, and Orthoses**

Authors	Main Comparisons	N	Normalized to Leg Length?	Results	*P* Value	Effect Size (95% CI)	Level of Evidence[a]
Aminaka and Gribble,[9] 2008	Anterior direction for patellofemoral pain syndrome group in no-tape and tape conditions	20	Yes	No tape = 62.88% ± 1.2% Tape = 63.5% ± 1.3%	.03	0.50 (−0.14, 1.11)	2b
	Anterior direction for healthy group in no-tape and tape conditions	20	Yes	No tape = 65.6% ± 1.2% Tape = 64.8% ± 1.3%	.03	0.64 (−0.01, 1.26)	2b
Hardy et al,[13] 2008	Semirigid, lace-up, and no-brace conditions among healthy participants	36	Yes	No differences	All comparisons > .05	All comparisons < 0.25	3b
Olmsted and Hertel,[4] 2004	Within-session anterolateral, posterolateral, and lateral directions for participants with cavus feet in orthoses and no-orthoses conditions	7	Yes	Anterolateral-O = 81% ± 3% Anterolateral-NO = 79% ± 4% Posterolateral-O = 95% ± 5% Posterolateral-NO = 93% ± 5% Lateral-O = 81% ± 5% Lateral-NO = 79% ± 4%	Condition-by-direction-by-group interaction = .03	Anterolateral = 0.4 (−0.68, 1.43) Posterolateral = 0.4 (−0.68, 1.43) Lateral = 0.57 (−0.54, 1.59)	2b
	Between-sessions (2 weeks; D1 and D2) anterior, anteromedial medial, posteromedial, posterior, posterolateral, and anterolateral directions for participants with cavus feet	7	Yes	Anterior D1 = 91% ± 3% Anterior D2 = 94% ± 4% Anteromedial D1 = 93% ± 3% Anteromedial D2 = 96% ± 3% Medial D1 = 95% ± 4% Medial D2 = 102% ± 4% Posteromedial D1 = 98% ± 4% Posteromedial D2 = 106% ± 4% Posterior D1 = 97% ± 5% Posterior D2 = 104% ± 5% Posterolateral D1 = 90% ± 5% Posterolateral D2 = 98% ± 5% Lateral D1 = 76% ± 5% Lateral D2 = 84% ± 5% Anterolateral D1 = 77% ± 4% Anterolateral D2 = 83% ± 3%	Day-by-direction-by-group interaction = .03	Anterior = 0.85 (−0.30, 1.88) Anteromedial = 1.00 (−0.17, 2.03) Medial = 1.75 (0.42, 2.84) Posteromedial = 2.00 (0.61, 3.11) Posterior = 1.40 (0.15, 2.46) Posterolateral = 1.60 (0.30, 2.67) Lateral = 1.60 (0.30, 2.67) Anterolateral = 1.70 (0.38, 2.78)	2b
Sawkins et al,[14] 2007	Anterior, posterior, and posteromedial directions for real tape, placebo tape, and no-tape conditions in participants with ankle instability	30	No	No differences	Condition-by-direction interaction = .08	All comparisons <0.17	3b
Sesma et al,[51] 2008	Anterior direction for orthoses and no-orthoses conditions	20	Yes	Orthoses = 94.6% ± 3.47% No orthoses = 93.3% ± 3.3%	.004	0.39 (−0.24, 1.01)	3b
	Anteromedial direction for orthoses and no-orthoses conditions	20	Yes	Orthoses = 98.5% ± 4.5% No orthoses = 96.9% ± 3.6%	.007	0.40 (−0.24, 1.01)	3b
	Medial direction for orthoses and no-orthoses conditions	20	Yes	Orthoses = 97.1% ± 7.7% No orthoses = 94.5% ± 7.4%	.001	0.34 (−0.29, 0.96)	3b
	Posteromedial direction for orthoses and no-orthoses conditions	20	Yes	Orthoses = 95.8% ± 9.4% No orthoses = 93.6% ± 9.7%	.001	0.23 (−0.40, 0.85)	3b
	Posterior direction for orthoses and no-orthoses conditions	20	Yes	Orthoses = 90.9% ± 9.9% No orthoses = 88.5% ± 10.8%	.001	0.23 (−0.39, 0.85)	3b

Table 4. Continued

Authors	Main Comparisons	N	Normalized to Leg Length?	Results	*P* Value	Effect Size (95% CI)	Level of Evidence[a]
	Posterolateral direction for orthoses and no-orthoses conditions	20	Yes	Orthoses = 86.0% ± 9.2% No orthoses = 83.0% ± 9.5%	.001	0.32 (−0.31, 0.94)	3b
	Lateral direction for orthoses and no-orthoses conditions	20	Yes	Orthoses = 78.6% ± 8.5% No orthoses = 75.4% ± 9.4%	.001	0.36 (−0.27, 0.98)	3b
	Anterolateral direction for orthoses and no-orthoses conditions	20	Yes	Orthoses = 80.4% ± 5.4% No orthoses = 79.3% ± 5.0%	.04	0.22 (−0.40, 0.84)	3b

Abbreviations: Anterolateral-NO, anterolateral direction no orthoses condition; Anterolateral-O, anterolateral direction orthoses condition; CI, confidence interval; D1, day 1; D2, day 2; Lateral-NO, lateral direction no orthoses condition; Lateral-O, lateral direction orthoses condition; Posterolateral-NO, posterolateral direction no orthoses condition; Posterolateral-O, posterolateral direction orthoses condition.

[a] Phillips B, Ball C, Sackett D, et al. *The Oxford Centre for Evidence-Based Medicine: Levels of Evidence (March 2009)* [updated by Howick J in March 2009]. Oxford Centre for Evidence-Based Medicine. http://www.cebm.net/index.aspx?o=1025. Accessed November 29, 2011.

focused on the neuromuscular control, postural-control, and functional performance deficits that exist among populations with ACL reconstruction and deficiency (ACL-D). However, in only 1 study, the investigators[3] appear to have used the SEBT as a screening tool to examine dynamic postural-control deficits in participants with ACL-D (range, 5 months to 2 years after injury). The performance of the ACL-D group in all 8 directions of the SEBT while standing on the injured limb was compared with performances of the uninjured limb and the matched limb of a group of healthy control participants. In the anterior ($P = .003$), lateral ($P = .005$), posteromedial ($P = .002$), and medial ($P = .001$) directions, the ACL-D limb exhibited worse dynamic postural-control than the limb of the control group, with performance differences between limbs ranging between 5% and 28% (Table 2). Interestingly, performance of the uninjured limb of the ACL-D group also was worse than that of the control-group limb in the medial ($P = .001$) and lateral ($P = .001$) directions, with differences between the limbs of 22.8% and 15.2%, respectively.[3] Therefore, although the research is limited, the prospect of using the SEBT to screen for deficits after ACL injury is promising.

Patellofemoral Pain Syndrome. Another common knee condition is PFPS. Similar to ACL injury, PFPS has been studied extensively and will not be discussed in this review, which is devoted to understanding its causes and neuromuscular control deficits. Studies of the SEBT to further quantify potential deficits in dynamic postural-control in patients with PFPS have been very limited. Aminaka and Gribble[9] compared SEBT performance in the anterior direction between participants with and without unilateral PFPS. The anterior direction was selected because of its ability to elicit a high level of quadriceps muscle activation,[33] which commonly is observed clinically as a deficiency in people with PFPS. An additional purpose of this study was to examine the effect of McConnell taping on SEBT performance,[9] and we discuss this result elsewhere in our review. On the baseline SEBT measures, participants with PFPS produced shorter reaching distances than did the control participants ($P = .03$; Table 3). Although this finding demonstrates a deficiency in dynamic postural-control in participants with PFPS, the authors recommended that electromyography of hip and knee muscles should be included in future investigations to understand more fully the source of these differences.[9]

Most authors strongly agree that participants with ankle instability, ACL-D, and PFPS have a lower level of performance on the SEBT than participants who do not have these conditions. However, the effect sizes (Cohen d) and 95% CIs do not lend as much support for this outcome in the ankle instability literature. When we examine the outcomes from Table 1, the average effect size reported in the ankle instability literature is 0.35, which would be considered low, and the largest calculated effect size (0.74) reported is only in the moderate category. Although only 1 study was reviewed for ACL-D and 1 was reviewed for PFPS, these effect sizes were very strong (range, 1.30–8.30; Tables 2 and 3).

In addition, examining the 95% CIs around the effect sizes is important because they help indicate if the effect size is repeatable 95% of the time within an acceptable range. An interval that does not cross zero implies that

Table 5. Ability of the Star Excursion Balance Test to Differentiate Outcomes From Exercise Intervention: Participants With Chronic Ankle Instability[a]

Authors	Main Comparisons	N	Normalized to Leg Length?	Results	*P* Value	Effect Size (95% CI)
McKeon et al,[52] 2008	Posteromedial direction for BTG prerehabilitation and postrehabilitation	16	Yes	Prerehabilitation = 82% ± 14% Postrehabilitation = 91% ± 13%	Group-by-time interaction =.01	0.67 (−0.06, 1.36)
	Posteromedial direction for BTG and CG postrehabilitation	BTG = 16 CG = 15	Yes	BTG = 91% ± 13% CG = 80% ± 6%		1.07 (0.30, 1.80)
	Posterolateral direction for BTG prerehabilitation and postrehabilitation	16	Yes	Prerehabilitation = 77% ± 15% Postrehabilitation = 87% ± 13%	Group-by-time interaction = .03	0.71 (−0.02, 1.41)
	Posterolateral direction for BTG and CG postrehabilitation	BTG = 16 CG = 15	Yes	BTG = 87% ± 13% CG =78% ± 9%		0.80 (0.05, 1.51)

Abbreviations: BTG, balance-training group; CG, control group.

[a] Level of evidence for all entries is 1b. Phillips B, Ball C, Sackett D, et al. *The Oxford Centre for Evidence-Based Medicine: Levels of Evidence (March 2009)* [updated by Howick J in March 2009]. Oxford Centre for Evidence-Based Medicine. http://www.cebm.net/index.aspx?o=1025. Accessed November 29, 2011.

95% of the time, replication of the study would not yield an effect size of zero or would yield the potential for no effect. If the interval does cross zero, one should consider whether a true difference actually was detected and how reliable the effect size would be if the study was repeated. Therefore, studies with significant results or large effect sizes and small CIs that do not cross zero have the greatest clinical importance.

In the ankle literature, all of the calculated CIs crossed zero. In the single ACL-D and PFPS studies that were reviewed, the CIs did not cross zero. Although this could be a surprising outcome, it might be explained by considering how these 3 conditions are defined. Definitions of ACL-D and PFPS might be more consistent than definitions of ankle instability. Herrington et al[3] defined ACL-D through physical examination and either arthroscopy or magnetic resonance imaging (MRI). Aminaka and Gribble[9] categorized PFPS based on specific criteria of the duration of pain and which activities caused pain. In the ankle literature, the definition of ankle instability differs considerably, with researchers reporting varying numbers of previous sprain incidences, times since last substantial sprain, residual mechanical and functional instabilities, and levels of pain. Even with some of these criteria, contemporary theory is that subsets of copers who do not exhibit functional limitations despite similar histories and symptoms related to their ankle injuries might exist.[49,50] Therefore, a history of ankle injury possibly can create a deficit in dynamic postural-control that the SEBT is sensitive enough to detect, as evidenced by the differences observed in these studies. However, because of the potential variability in the level of ankle instability within a group of injured participants under the criteria used in the studies we have reviewed, this possibly contributed to higher group standard deviations that resulted in smaller effect sizes and 95% CIs that crossed zero. Researchers are encouraged to define ankle instability as succinctly as possible to determine the sensitivity of the SEBT for screening dynamic postural-control deficits related to this condition. In the future, determining the minimal clinically important difference when using the SEBT to screen for these conditions also might be valuable to further elucidate the effectiveness of this test as an outcome tool.

Ability of the SEBT to Differentiate Effects of External Influences and Interventions

In addition to identifying the deficits in dynamic postural-control that lower extremity conditions can create, the SEBT also can be used to display the influence of external interventions and influences on dynamic postural-control. The external influences that have been investigated include taping, bracing, orthoses, and induced fatigue, all of which can affect physical performance or risk of injury. These comparisons have implications for how the SEBT might be used to address effective intervention and prevention strategies for lower extremity injuries in clinical and laboratory settings.

Taping, Bracing, and Orthoses. Externally applied devices, such as taping, bracing, and orthoses, are used to enhance joint stability and mechanics. The intended improvements in joint congruency and efficient arthrokinematics often are considered avenues to heighten postural-control. Specific to performance on the SEBT, the literature appears to be mixed on the optimization of dynamic postural-control with such interventions.

Olmsted and Hertel[4] examined the use of custom-made orthoses in uninjured participants with pes cavus, pes planus, or pes rectus feet. Participants performed all 8 directions of the SEBT during 2 testing sessions that were 2 weeks apart. During each session, the participants were evaluated with and without the orthoses to examine the immediate effects of the orthoses. In the 2-week period between testing sessions, they were instructed to wear the orthoses, which provided an outcome on the continued use for this intervention. For the first purpose, a condition-by-group-by-direction interaction ($P = .03$) supported that, among the participants with pes cavus, immediate application of the orthoses improved reaching distances in 3 of the 8 directions (Table 4). However, these relationships were associated with low to moderate effect sizes, with CIs crossing zero. When comparing groups across the 2-week period of wearing the orthoses, again only the pes cavus group experienced an improvement, this time demonstrating increased reaching distances in all 8 directions (P = .03). These relationships yielded strong effect sizes, with 6 of the 8 having CIs that did not cross zero (Table 4). Therefore, in a healthy population, introducing orthoses for a few weeks of wear appears to have had a positive effect on dynamic postural-control.

Studying patients with CAI, Sesma et al[51] examined the influence of using custom orthoses for 4 weeks on dynamic balance performance. Regardless of limb or the difference over time, the orthoses allowed the patients to produce farther normalized reaching distances in all 8 directions (Table 4). Whereas this outcome is similar to what was observed in healthy participants,[4] all associated effect sizes were small (range, 0.22–0.40), with 95% CIs crossing zero.[51]

Aminaka and Gribble[9] applied a McConnell taping technique for lateral patellar glide to participants with and without PFPS to determine the effect on anterior reach performance. In the PFPS group, the application of the tape resulted in performance improvements (P = .03) with a moderate effect size (Cohen d = 0.50; Table 4). Interestingly, when the tape was applied to the knees of the healthy participants, performance decreased (P = .03), with a moderate effect size (Cohen d = 0.64). The authors hypothesized that the tape achieved its goal of helping the group with PFPS more efficiently perform a task with demands on the knee. Whereas this benefitted the participants with PFPS, the authors believed the intervention, with its intended lateral repositioning of the patella, caused pain and altered knee arthrokinematics in healthy knees, leading to a decline in performance on the SEBT. The CIs for these moderate effect sizes did cross zero.

Contradictory evidence has demonstrated that externally applied devices do not affect SEBT performance. Hardy et al[13] questioned if the application of commonly used ankle braces improved or impaired dynamic postural-control. They reported no disruption in normalized reaching distances with a semirigid or a lace-up style brace among healthy participants (Table 4). Similarly, Sawkins et al[14] observed no differences among purposeful ankle taping, placebo taping, and no taping in healthy participants performing the SEBT. However, in this article, male and female participants were studied, and the reaching distances were not normalized, as typically is suggested. Similarly, Delahunt et al[8] found no positive influence of taping on SEBT reaching performance in participants with CAI. However, the participants reported improved confidence, stability, and reassurance when performing the task with the applied tape. Nonetheless, these papers provide evidence that prophylactic support applied to the ankle complex neither hinders nor enhances the dynamic postural-control measurement during this task. Therefore, perhaps clinicians do not need to worry about the presence of ankle support when assessing or screening healthy participants with the SEBT. However, continued work is needed to determine what effect taping and bracing the ankle might have on SEBT performance among populations with ankle conditions.

This body of literature does not allow for a consistent conclusion that introducing external support or stability to an aspect of the lower extremity allows participants to improve reach performance in this measure of dynamic postural-control. Interestingly, Sabin et al[35] demonstrated that, when performing the SEBT on an unstable surface, reaching distances declined, partially supporting the notion that a stable base of support is necessary for optimizing SEBT performance. An externally applied prophylactic support is designed to create a more stable ankle, but it does not appear that this consistently improves dynamic stability measured with the SEBT. Therefore, the SEBT might be a potentially useful tool for clinicians to determine if an intervention designed to mechanically improve joint stability or congruency is effective, but more information is needed, especially among groups with lower extremity pathologic conditions.

Fatigue. It is widely accepted that fatigue (physiologic, neurologic, and psychological) affects markers of physical performance. Fatigue changes the efficiency of contraction capability in the extrafusal muscle fibers and challenges the efficiency of the afferent information from muscle spindles, which ultimately alters neuromuscular control. With this basic idea, assuming that fatigue could affect SEBT performance is logical. However, investigation has been limited.

In 3 studies, the same group of researchers has considered fatigue as a factor that might affect dynamic postural-control measured with the SEBT. In 2 studies,[1,2] the researchers examined the combined effects of fatigue and CAI on performance, whereas in a third study,[34] the authors were concerned with influences of fatigue as well as sex. In all 3 studies, the study design (4-way interactions[2,34] or regression analyses[1]) and the volume of resultant data produced made it difficult to report effect sizes consistent with the rest of our review, so we provide a summary of these studies.

In all studies, the participants were subjected to 4 different fatigue protocols (isometrically applied fatigue to the ankle, knee, and hip and continuous lunging) to determine how varied applications of fatigue to the lower extremity might affect dynamic postural-control. In the first study, Gribble et al[2] used this protocol to examine the effect of fatigue (immediately prefatigue and postfatigue, as well as among the different protocols), along with the influence of CAI and the injured and uninjured sides, on SEBT performance in the anterior, medial, and posterior directions. A 4-way interaction for the normalized reaching distance in the posterior reaching direction ($P < .001$) was reported whereby all 4 fatigue conditions had a diminishing effect on dynamic postural-control in both groups for the uninvolved and involved sides. Furthermore, after all fatigue conditions, the involved side of the CAI group experienced a larger decrease in normalized reaching distance than the uninvolved sides of both the CAI group and the healthy group.

As discussed in our review, kinematic patterns might have some explanatory properties for SEBT performance. In the study by Gribble et al,[2] fatigue also created kinematic pattern changes in the knee and hip during performance of the SEBT. The authors wanted to examine further this influence of fatigue and CAI on SEBT and kinematic patterns, choosing to apply a regression analysis model to their previous findings.[1] In this case, the change in SEBT

Table 6. Ability of the Star Excursion Balance Test to Differentiate Outcomes From Exercise Intervention: Healthy Participants

Authors	Main Comparisons	N	Normalized to Leg Length?	Results	*P* Value	Effect Size (95% CI)	Level of Evidence[a]
Bouillon et al,[15] 2009	Anterolateral direction for PostE and PC	PostE = 10 PC = 7	Yes	PostE = 80.71% ± 5.9% PC = 73.0% ± 9.6%	.07	1.01 (−0.06, 1.98)	1b
	Anterior direction for PostE and PC	PostE = 10 PC = 7	Yes	PostE = 94.1% ± 9.0% PC = 82.2% ± 6.7%	.006	1.46 (0.31, 2.46)	1b
	Anteromedial direction for PostE and PC	PostE = 10 PC = 7	Yes	PostE = 92.3% ± 6.98% PC = 83.9% ± 7.12%	.03	1.19 (0.09, 2.17)	1b
	Medial direction for PostE and PC	PostE = 10 PC = 7	Yes	PostE = 92.1% ± 9.26% PC = 80.0% ± 6.1%	.005	1.49 (0.33, 2.49)	1b
	Posteromedial for PostE and PC	PostE = 10 PC = 7	Yes	PostE = 89.1% ± 8.14% PC = 76.6% ± 6.2%	.005	1.68 (0.49, 2.70)	1b
	Posterior direction for PostE and PC	PostE = 10 PC = 7	Yes	PostE = 86.7% ± 4.7% PC = 77.2% ± 5.0%	.001	1.97 (0.72, 3.02)	1b
	Posterolateral direction for PostE and PC	PostE = 10 PC = 7	Yes	PostE = 78.3% ± 7.5% PC = 70.7% ± 7.4%	.07	1.02 (−0.05, 1.99)	1b
	Lateral direction for PostE and PC	PostE = 10 PC = 7	Yes	PostE = 72.7% ± 3.4% PC = 64.0% ± 9.1%	.06	1.37 (0.24, 2.37)	1b
Kahle and Gribble,[5] 2009	Anteromedial direction for PreE and PostE	PreE = 15 PostE = 15	Yes	PreE = 84.9% ± 7.6% PostE = 89.0% ± 6.6%	.001	0.58 (−0.17, 1.29)	2b
	Medial direction for PreE group and PostE and for PostE and PC	PreE = 15 PostE = 15 PC = 15	Yes	PreE = 85.1% ± 8.9% PostE = 91.1% ± 7.7% PC = 84.3% ± 7.0%	Group-by-time interaction = <.001	Within exercise group = 0.72 (−0.04, 1.44) Between groups = 0.92 (0.15, 1.65)	2b
Eisen et al,[34] 2010	Posteromedial direction for DynaDisc,[b] rocker board, and control groups PreT and PostT	DynaDisc[b] = 12 Rocker board = 12 Control = 12	Yes	DynaDisc PreT = 98.0% ± 8.3% DynaDisc PostT = 101.0% ± 8.8% Rocker board PreT = 97.0% ± 8.5% Rocker board PostT = 102.0% ± 6.8% Control PreT = 98.0% ± 8.6% Control PostT = 100.0% ± 9.0%	Time main effect = .007	DynaDisc[b] group = 0.35 (−0.47, 1.14) Rocker board group = 0.65 (−0.19, 1.45)	2b
Leavey et al,[19] 2010	Anterior direction for combination group PreT and PostT	12	Yes	PreT = 90.11% ± 8.64% PostT = 95.59% ± 9.20%	Group-by-time Interaction = .001	0.61 (−0.22, 1.41)	2b
	Anteromedial direction for combination group PreT and PostT	12	Yes	PreT = 94.29% ± 10.42% PostT = 97.54% ± 11.48%		0.30 (−0.52, 1.09)	2b
	Anterolateral direction for combination group PreT and PostT	12	Yes	PreT = 81.78% ± 9.58% PostT = 86.15% ± 11.92%		0.40 (−0.42, 1.20)	2b
	Medial direction for combination group PreT and PostT	12	Yes	PreT = 99.41% ± 12.19% PostT = 104.32% ± 11.04%		0.42 (−0.40, 1.22)	2b
	Lateral direction for combination group PreT and PostT	12	Yes	PreT = 83.33% ± 10.16% PostT = 86.18% ± 12.28%		0.25 (−0.56, 1.05)	2b
	Posterior direction for combination group PreT and PostT	12	Yes	PreT = 109.36% ± 17.04% PostT = 115.62% ± 18.24%		0.35 (−0.46, 1.15)	2b
	Posteromedial direction for combination group PreT and PostT	12	Yes	PreT = 105.43% ± 15.02% PostT = 111.18% ± 16.02%		0.37 (−0.45, 1.16)	2b
	Posterolateral direction for combination group PreT and PostT	12	Yes	PreT = 100.22% ± 17.00% PostT = 106.36% ± 18.58%		0.34 (−0.47, 1.14)	2b
Fitzgerald et al,[18] 2010	Anterior direction for balance and exercising groups combined PreT and PostT	20	Yes	PreT = 81.8% ± 5.0% PostT = 84.45% ± 5.25%	Time main effect = .02	0.58 (−0.07, 1.20)	1b

Table 6. Continued

Authors	Main Comparisons	N	Normalized to Leg Length?	Results	*P* Value	Effect Size (95% CI)	Level of Evidence[a]
	Posteromedial direction for balance and exercising groups combined PreT and PostT	20	Yes	PreT = 89.2% ± 8.6% PostT = 96.65% ± 7.0%	Time main effect = .01	0.95 (0.28, 1.58)	1b
	Posterolateral direction for balance and exercising groups combined PreT and PostT	20	Yes	PreT = 79.95% ± 10.5% PostT = 89.35% ± 8.1%	Time main effect = .001	1.00 (0.33, 1.64)	1b
Filipa et al,[17] 2010	Composite for neuromuscular training group right side PreT and PostT	13	Yes	PreT = 96.4% ± 11.7% PostT = 104.6% ± 6.1%	.03	0.80 (0.10, 1.47)	2b
	Composite for neuromuscular training group left side PreT and PostT	13	Yes	PreT = 96.9% ± 10.1% PostT = 103.4% ± 8.0%	.04	0.64 (−0.05, 1.30)	2b

Abbreviations: PC, postcontrol group; PreE, pre-exercise group; PreT, pretraining; PostE, postexercise group; PostT, posttraining.

[a] Phillips B, Ball C, Sackett D, et al. *The Oxford Centre for Evidence-Based Medicine: Levels of Evidence (March 2009)* [updated by Howick J in March 2009]. Oxford Centre for Evidence-Based Medicine. http://www.cebm.net/index.aspx?o=1025. Accessed November 29, 2011.

[b] DynaDisc, Exertools, Inc, Petaluma, CA.

reaching distances after fatigue was influenced positively by CAI and variances in knee flexion and hip flexion angle. An additional important point of this analysis was that of the 4 fatigue protocols, continuous lunging was the most dynamic, and it produced the strongest predictive models for decline in SEBT performance. Therefore, the authors concluded that SEBT performance might provide a useful tool for assessing decline in dynamic postural-control from fatigue during dynamic activities.

In the most recent of the 3 studies, the authors used a similar design from the study by Gribble et al[2] but included sex and limb dominance as independent variables in addition to the immediate (within-sessions prefatigue-postfatigue) and across-protocol fatigue effects to produce a 4-way interaction model.[34] For the anterior direction, men and women had a decline in reaching distances from all forms of fatigue. However, when knee fatigue was introduced, the men had a 4% larger decline than women ($P = .01$) For the medial reaching direction, men and women experienced a reduction in dynamic postural-control for all forms of fatigue ($P < .001$), with men again having almost a 4% greater decline in performance after fatigue than women ($P = .03$). Finally, for the posterior direction, ankle, knee, and lunge fatigue protocols produced reductions in reaching distance ($P = .001$) and, consistently, women were more resistant to a decline in performance from fatigue ($P = .02$).

In summary, the authors of these papers concluded that fatigue does affect negatively the dynamic postural-control of healthy participants and participants with CAI. Therefore, clinicians should be aware that these declines and reactions to fatigue will be different between people with and without CAI and also appear to be different between healthy men and women.

Ability of the SEBT to Demonstrate Outcomes From Exercise Intervention

A typical goal of clinicians is to return athletes and patients to a desired level of functional activity. Innumerable intervention protocols and functional assessment tools exist, but unfortunately, too few are validated either independently or in combination. As we have demonstrated in this review, the SEBT provides a highly reliable tool that can differentiate deficits from threats to neuromuscular and postural-control, such as lower extremity injury and fatigue. Because of its usefulness at differentiating baseline differences from knee and ankle injuries, some authors have examined if the SEBT could be used as an outcome tool to identify improvements in known injury-related deficiencies and to improve performance in otherwise healthy participants after designed exercise interventions.

Improvements in Participants With CAI. Several investigators have examined the success of rehabilitation protocols for participants with CAI using the SEBT as an outcome measure. Hale et al[7] reported that a 4-week protocol of strength, ROM, and neuromuscular control exercises allowed improvement in participants with CAI who underwent the protocol compared with a healthy control group and a CAI group that did not perform the protocol. These differences were observed in the posteromedial ($P = .03$), posterolateral ($P = .01$), and lateral ($P = .009$) directions and a composite score of all 8 directions (P

Table 7. Performance Recommendations

Recommendation	Rationale
Shoes off	Individuals attend testing in a variety of footwear so it is difficult to standardize
4 Practice trials[27]	Learning effect
Video instruction	Likely to increase efficiency of testing protocol and standardizes instruction. This might be most important when multiple assessors are performing mass screenings.
Control testing order[a]	Improves consistency in administration of test
Keep starting position of the stance foot in a uniform and reproducible position to which the reach foot can be referenced. Different methods are used for aligning the stance foot. A recent method is to have the stance foot aligned at the most distal aspect of the toes for forward directions (anterior, anteromedial, and anterolateral) and the most posterior aspect of the heel for the backward directions (posterior, posteromedial, and posterolateral).	In the original test, the foot is centered in the grid. In recent usage, the toes or heel are aligned at the end of one of the grid lines. This might help to minimize differences in foot length, potentially influencing reach distances. The most important thing is that the same foot position is used for all assessments when comparing sides, before and after intervention, or when testing multiple patients.
Minimal stance foot movement is allowed[a]	Reduce error from determining if heel/forefoot is lifted slightly from the surface
Trunk movement allowed under control[a]	Difficult to standardize amount of movement allowed
Reach distances (centimeters with 1 decimal place) normalized to limb length of the stance limb[24]	Normalization standardizes measurement to each individual.
Hands placed on hips during trial[b]	Helps to standardize movements outside the trunk and lower limbs

[a] References 1–5, 7–9, 11–15, 17–19, 23–27, 29, 31, 33–37, 42, 45–47, and 51–53.
[b] References 1–3, 5, 7–9, 12–14, 23, 24, 27, 31, 33–37, 42, 46, 51, and 53.

= .03). The mean change scores rather than means and standard deviations from the pretesting and posttesting periods were reported, preventing us from calculating effect sizes from this study.

Similarly, McKeon et al[52] implemented a 4-week protocol using balance-training exercises for participants with CAI and used the SEBT as an outcome measure, this time focusing on the anterior, posteromedial, and posterolateral directions. They reported a favorable outcome on the SEBT performance after the rehabilitation protocol for the posteromedial ($P = .01$) and posterolateral ($P = .03$) directions, with moderate to strong effect sizes (range, 0.67–1.07; Table 5).

Improvements in Healthy People. Dynamic postural-control is also important in healthy individuals and might be an outcome measure of interest after an exercise intervention to improve performance and reduce the risk of injury. Kahle and Gribble[5] were interested in the influence of core stability on improvement of dynamic stability. Using a 6-week intervention training program, healthy, physically active young adults demonstrated improvements in SEBT performance compared with a control group. Specifically, in the anteromedial direction, the exercise group improved their scores by more than 4% ($P = .001$; Table 6). In the medial direction, after rehabilitation, the exercise group had improved 6% from baseline and was more than 6% better than the control group at the posttesting ($P < .001$). These differences produced moderate to strong effect sizes, with the moderate effect sizes having CIs that did cross zero (Table 6).

Bouillon et al[15] used the SEBT and other clinical balance indices to compare 2 cycle-ergometer protocols among middle-aged women. The exercise group improved their dynamic stability compared with the control group in 6 of 8 reaching directions with the exception of the anterolateral ($P = .07$) and posterolateral ($P = .07$) directions, which had a relationship that was not different. Upon request, the authors of the original study provided the means and standard deviations of their results so we could calculate effect sizes. In all 8 directions, we discovered large effect sizes that were greater than 1.0, and only 2 had CIs crossing zero (Table 6).

Other researchers have found consistent improvements in SEBT performance after exercise-intervention programs that focused on balance[16,19,53] or neuromuscular[17,18] training exercises. Eisen et al[16] reported that 4 weeks of balance training using either a rocker board or DynaDisc (Exertools, Inc, Petaluma, CA) resulted in an average improvement in SEBT performance of 3.8%. Using a combination of balance training and gluteal strengthening, Leavey et al[19] noted improvements in SEBT performance after 6 weeks that ranged from 2.85% to 6.22% across the 8 reaching directions. Although these researchers showed improvements in dynamic postural-control with balance training, the effect sizes were low to moderate, ranging from 0.25 to 0.61, with all 95% CIs crossing zero (Table 6). Valovich McLeod et al[53] also found improved SEBT performance after a 6-week balance-training program, but they did not provide any means or point estimates to support the reported differences, preventing us from calculating effect sizes and appreciating the magnitude of the differences from the intervention.

Similar to balance-training interventions, neuromuscular control exercise programs seem to encourage improved dynamic postural-control measured with the SEBT. Fitzgerald et al[18] reported improvements of 2.95% to 9.4% in the anterior, posteromedial, and posterolateral directions after 12 exercise sessions of wobble board "exergaming" or postural-stability training. Similarly, Filipa et al[17] found that 8 weeks of neuromuscular control training in young female athletes improved performance in the same 3 directions by 1.75% to 9.5%. Support for the use of neuromuscular control training is provided by mostly moderate to strong effect sizes that ranged from 0.58 to 1.00 (Table 6). In the study by Filipa et al,[17] only performance in the anterior direction was associated with a low effect size.

This literature demonstrates that the SEBT can be used to identify improvements in dynamic stability after exercise intervention among healthy individuals and those with

CAI. This is important for clinicians and researchers seeking a cost-effective, easy-to-use outcome tool to measure progression in prevention and rehabilitation programs. Most of the effect sizes were moderate to strong between pretesting and posttesting sessions, with most CIs not crossing zero. This indicates a strong magnitude of improvement in dynamic stability as assessed by the SEBT, and it supports the use of the SEBT in these measures and the effectiveness of these intervention programs.

Ability of the SEBT to Predict Lower Extremity Injury

An important clinical application of the SEBT is using the level of demonstrated dynamic stability on the test to predict the risk of injury to lower extremity joints. Other forms of balance assessment have been useful in predicting injury risk. McGuine et al[54] found that high school basketball players who had higher static postural-sway measurements during the preseason were 7 times more likely to sustain ankle injuries, supporting the need for balance screening of athletes. Using dynamic postural-control measures might be of equal or even greater use in predicting these injuries.

Plisky et al[36] had male and female high school basketball players from 7 schools perform the SEBT before the beginning of the competitive season. Rates of lower extremity injury were documented and compared with preseason performances to determine the predictive quality of the SEBT measure. They reported that basketball players with anterior right-to-left reach differences of more than 4 cm were 2.5 times more likely to sustain lower extremity injuries. They also found that girls with a composite reach score of less than 94% of their limb length were 6.5 times more likely to sustain a lower extremity injury.

DISCUSSION

This portion of the review has provided support for the SEBT to be used effectively to screen for deficits in dynamic postural-control among groups with lower extremity conditions; reflect changes in dynamic postural-control from external devices, fatigue, and intervention programs; and predict lower extremity injury. Although continued investigation is warranted, we believe the moderate to strong effect sizes across this body of literature suggest that the SEBT should be incorporated as a diagnostic tool within clinical practice and research. However, some inconsistencies in findings, as well as CIs crossing zero, suggest that more attention is needed in these areas to create stronger conclusions to guide clinical implementation of the SEBT.

Clinical Applications and Implications

Patients and athletes sustain initial and repetitive injuries, so clinicians must identify initial risk of injury and determine if patients have been restored to a level of function that minimizes the risk of injury when they return to activity. The SEBT can be administered quickly and easily to help the clinician determine if the patient possesses or has returned to normal, symmetrical levels of dynamic balance. Because the test requires the person to maintain balance at his or her limits of stability, the SEBT can be used to discriminate neuromuscular control abilities at the more demanding levels that are required for athletes, occupational workers, and active individuals. As discussed, the SEBT can differentiate participants with lower extremity injuries[1–3,9,29,44,45]; therefore, it might be used as a marker of normalization of neuromuscular control after those injuries.

Because the SEBT can be administered quickly and reliably, it also can be used in the preparticipation physical examination to identify those at greater risk of injury. Limited information has indicated that the SEBT might be useful in predicting future athletic injury.[36] Furthermore, because the SEBT requires strength, flexibility, neuromuscular control, core stability, ROM, balance, and proprioception, it makes an excellent test for preparticipation physicals and clinical examinations because 1 faulty component in any of these systems will cause a positive test. The SEBT can be used to identify those athletes who have not fully rehabilitated or normalized their dynamic balance after an injury. As discussed, clinicians have limited information for screening at-risk athletes using cutoff scores and side-to-side differences[36] to maximize sensitivity and specificity, which might provide good predictive standards. However, whereas these studies were well controlled and provide good information, we believe that more investigation is needed before these recommendations are adopted globally.

Progression of the Test

Authors have attempted to improve the reliability and clinical utility of the test. For example, Hertel et al[29] and Robinson and Gribble[27] demonstrated that redundancy exists across the 8 reaching directions, leading to conclusions that the test can be performed with greater efficiency using only 1 direction or a few directions without sacrificing the quality of information that might be gathered from the screening. One of the primary variations of the testing method and potential sources of error in the SEBT is whether the reach foot touches the floor. Touching down with the reach foot introduces error by making it difficult to quantify the amount of support gained from that touchdown. If touchdown is not allowed, standardizing the distance from the ground that the person reaches, as well as instantaneously marking the farthest reach point, is difficult. Both protocols make it challenging for the examiner to observe the dynamic alignment of the participant and pay careful attention to the stance foot. Another disparity in SEBT protocols is where the stance foot is aligned at the starting position. The starting point has been reported to be at the bisection of the lateral malleolus, which is at the most distal aspect of the toes in the center of the foot, and to vary according to reach direction.[14,22,31,33,36] We have provided a list of recommendations and instructions for performing the SEBT in Table 7. These are based on what we have observed in our own experiences and appear to be consistent and supported within the literature.

In an attempt to improve the reliability and clinical utility, the Y Balance Test protocol was developed to address some of the limitations of the traditional SEBT testing methods, such as standard reach height from the ground, starting point reference, and the ability of the reach indicator to remain over the tape measure after performance of the trial. Plisky et al[31] reported that, if the examiners focused on monitoring stance-foot movement, simultaneously marking reaching distance was nearly impossible. In addition, determining how much movement of the stance foot was allowed in a successful trial was difficult for examiners (ie, it was difficult to determine if and when the heel or forefoot actually lifted from the surface). Thus, the testing procedure was changed to allow the participant to lift the heel off the ground. Furthermore, the starting position was changed to the distal end of the longest toe to improve repeatability and clinical experience.

Because the performance on the SEBT varies depending on sport, sex, and age, researchers need to collect normative data using varied populations (eg, collegiate, high school, basketball, hockey, military, elderly, firefighters). With normative data and prospective studies, we can determine better if the SEBT predicts injury in different populations and can establish appropriate risk-threshold reaching distances for each population.

CONCLUSIONS

The SEBT has become a widely used dynamic test for clinical and research testing purposes. More than a decade of research findings has established a comprehensive portfolio of validity for the SEBT, and it should be considered a highly representative noninstrumented dynamic balance test for physically active individuals. The SEBT has been shown to be a reliable measure and has validity as a dynamic test to predict risk of lower extremity injury, to identify dynamic balance deficits in patients with a variety of lower extremity conditions, and to be responsive to training programs in both healthy participants and participants with lower extremity injuries. Clinicians and researchers should be confident in employing the SEBT as a lower extremity functional test.

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