Validating a Dance-specific Screening Test for Balance

Preliminary Results from Multisite Testing

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Few dance-specific screening tools adequately capture balance. The aim of this study was to administer and modify the Star Excursion Balance Test ($_{O}$SEBT) to examine its utility as a balance screen for dancers. The $_{O}$SEBT involves standing on one leg while lightly targeting with the opposite foot to the farthest distance along eight spokes of a star-shaped grid. This task simulates dance in the spatial pattern and movement quality of the gesturing limb. The $_{O}$SEBT was validated for distance on athletes with history of ankle sprain. **METHOD:** Thirty-three dancers (age 20.1 ± 1.4 yrs) participated from two contemporary dance conservatories (UK and US), with or without a history of lower extremity injury. Dancers were verbally instructed (without physical demonstration) to execute the $_{O}$SEBT and four modifications (mSEBT): timed (speed), timed with cognitive interference (answering questions aloud), and sensory disadvantaging (foam mat). Stepping strategies were tracked and performance strategies video-recorded. **RESULTS:** Unlike the $_{O}$SEBT results, distances reached were not significant statistically ($p = 0.05$) or descriptively (i.e., shorter) for either group. Performance styles varied widely, despite sample homogeneity and instructions to control for strategy. Descriptive analysis of mSEBT showed an increased number of near-falls and decreased timing on the injured limb. **CONCLUSIONS:** Dancers appeared to employ variable strategies to keep balance during this test. Quantitative analysis is warranted to define balance strategies for further validation of the SEBT (and its modification) **<AU: as meant?>** to determine its utility as a balance screening tool. *Med Probl Perform Art* 2010; 25:103–108.

Balance in dancers is a complex phenomenon demanding evaluation of many factors, including postural response patterns, range of motion, strength, history of injury, and environmental conditions.[1] While pre-professional dancers routinely are screened for balance deficits before the start of an intensive dance program,[2] tests usually are limited in capturing the scope of balance.[3] Tools such as single-leg stance, Romberg test, or foam-and-dome[4] do not adequately challenge the range of dynamic balance, nor simulate dance-specific conditions.[5] While simple to administer, these tests lack the sensitivity to assess neuromuscular and proprioceptive deficits, especially after a history of lower extremity injury,[6] nor the readiness to return to performance.[7] The challenge among dance scientists has been to develop valid dance-specific balance tests that are sensitive, efficient, easy to administer, and cost effective.

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The purpose of this study was to examine the validity of a test for balance from exercise science, the Star Excursion Balance Test (SEBT),[8] on pre-professional dancers from two contemporary dance conservatories. The SEBT involves standing on one leg while lightly targeting with the opposite foot to the farthest point along each of eight spokes of a star-shaped grid taped to the floor. This task simulates dance in utilizing the same eight cardinal directions of classical ballet in limb gesture (targeting pointing in space) and in quality of movement—lightly dabbing with the targeting toe of the gesturing lower extremity while alternately flexing and extending the opposite (standing) knee. The original SEBT ($_{O}$SEBT) was validated only for distance on athletes with history of ankle sprain.[8] The current research builds on the original study as well as on descriptive pilot data on dancers.[9] In this latter research, balance performance of five dancers with a history of ankle-foot injury and five age-matched, activity-matched, injury-free controls was compared using the NeuroCom Balance System and the SEBT as outcomes. Despite the small sample, the SEBT generated quantitative and qualitative data that merited further investigation.

The second aim of this current study was to modify the original SEBT (mSEBT) to pose greater balance challenges to dancers by altering timing, attentional focus, and sensory conditions. The addition of sensorimotor and cognitive challenges appeared warranted in dance where mental as well as physical strategies enter highly into motor skill execution.[10] These balance challenges were designed to simulate those posed by the cognitive component of the Timed "Up and Go" test[11] and the Contributions to Sensory Organization and Balance,[12] tests well validated on nondancer populations.[11,12]

METHOD

Subjects

Thirty-three subjects were recruited from two dance conservatories, one in the United Kingdom (UK) and one in the United States (US). **<AU: give names?>** Before recruitment, the study was reviewed and approved the Institutional Review Boards of both institutions. All subjects gave informed consent to participate in accordance with the Institutional Review Board guidelines for ethical research from each institution. Eligibility criteria included: 1) absence of history of injury; 2) history of lower extremity injury, but reporting no pain or disability at time of testing; and 3) absence of history of cerebral concussion, vestibular disorders, or current complaints of dizziness due to upper respiratory infections, ear infections, or other causes.

TABLE 1. Intake Demographics of Dancers

	Mean (± SD)								
	Age	Training (yrs)	Height (m)	Weight (kg)	LLr (cm)	LLl (cm)	DFr (deg)	DFl (deg)	Injuries*
Group A (n = 22)	20.6 (± 1.5)	2.6 (± 2.7)	1.5 (± 0.1)	54.9 (± 8.4)	85.2 (± 6.0)	85.4 (± 6.0)	64.6 (± 7.6)	63.7 (± 7.2)	14
Group B (n = 15)	19.8 (± 1.5)	9.6 (± 4.6)	1.59 (± 0.1)	52.6 (± 9.3)	83.3 (± 11.8)	85.9 (± 12.0)	64.4 (± 9.3)	65.6 (± 5.6)	3

LL = leg lengths for right and left leg (in centimeters); DF = dorsiflexion for right and left leg (in degrees).
* Injuries in Group A included 6 to the right lower extremity (RLE), 5 left (LLE), and 3 both (BLEs); in Group B, 2 RLE, 1 LLE, 0 BLEs, and 3 previous back surgery.

Twenty-two subjects came from the UK conservatory (Group A), including 20 women and 2 men, mean age 20.6 (± 2.6) yrs, with 2.6 (± 2.7) years of training in ballet and modern (contemporary) dance. Fifteen subjects came from the US conservatory (Group B), including 13 women and 2 men, mean age 19.8 (± 1.5) yrs, with 9.6 (± 4.6) yrs of similar mixed ballet and modern dance training (Table 1). Fourteen reported a history of lower extremity injury in Group A, with 3 reporting an injury history in Group B. Two subjects in Group B also reported back surgeries for herniated disks. All subjects reportedly were pain free at the time of testing and attending full-time dance classes and rehearsals without interruption due to physical therapy or other rehabilitative programs.

Procedure

The $_{O}$SEBT is a functional test of balance that requires the subject to stand on one leg in the center of the grid, while reaching with the toes of the opposite foot lightly (dabbing) to target the farthest distance from the point of standing stability. Attempts were made to replicate the original SEBT testing environment as closely as possible. The testing took place in a dance science lab (UK) and a dance studio (US), both with a Marley® floor. The star-shaped grid was constructed from 2-in (5-cm)-wide adhesive tape and enclosed in a 182.9 × 182.9-cm square on the Marley floor. The eight lines of the grip were taped to the floor, using a goniometer to extend the lines from the center at 45° increments. The direction of excursion for each of the eight lines was labeled relative to the stance leg: anterolateral (AL), anterior (A), anteromedial (AM), medial (M), posteromedial (PM), posterior (P), posterolateral (PL), and lateral (L) (Fig. 1).

Approximately 2 weeks before testing, six dancers with master's degrees in dance science (UK) and four physical therapy graduate students (US) underwent training in accordance with ethical research requirements for the two countries. Two hours of additional training were provided on the mechanics of administering the $_{O}$SEBT (called the "basic test") and the mSEBT (with three modifications, see below). The most difficult portion of the education lay in training testers to abstain from physically demonstrating any portion of the test, by mimicking it with their bodies or gesturing with their hands. To control for testing error, each tester memorized or read from a verbal script. Concordance in documentation and interpretation of results was reached.

The test was conducted according to a schedule of convenience for the dancers over the course of a 2-week period. Testers were randomized. The basic test ($_{O}$SEBT) was administered first, followed by randomized testing of the three modifications (mSEBT). At the start of each test, subjects were instructed to stand first on their preferred leg with their hands on their hips and the opposite foot poised at the ankle (parallel *sur le cou-de-pied*), called the "ready position" (RP) (Fig. 2). On the word "go," the subject would reach at a self-selected pace to each of the spokes, touching his or her toe (lightly "dabbing") to the farthest point reached and returning to the ready position before reaching for the next spoke. Subjects were invited to "use any strategy to accomplish the tests," with one main constraint for the axial trunk: they must keep their navel facing forward for all trials and to refrain from axial rotation (turning). Flexing and extending the knee was permitted on the standing leg as well as any other counterbalancing strategy of the upper and lower trunk and head, as long as hands remained on hips and the trunk facing forward. Subjects needed to complete each of the lines of the star in sequential order, both a clockwise and counterclockwise direction, before standing fully on the targeting foot again. No practice trials or other warm-up was permitted. Subjects were asked if they understood the nature of each test before starting.

In the original SEBT, athletic subjects were give six practice trials in each of the eight directions for each leg, as well as 5 minutes of stationary bike riding at a self-selected pace, followed by stretching of the lower leg muscles.[8] Further, subjects were allowed up to three reaches in each direction and to put full weight-bearing on the targeting leg after restoring upright balance. In this study, only one trial was recorded for most tests. The rationale was to simulate real dance training conditions, where dancers rarely have the time for adequate warm-up before auditions, rehearsals, or even between classes. Further, not allowing practice trials was designed to simulate screening conditions by minimizing motor-learning effects. Dancer-subjects waited their turn outside a closed door, filling out an injury history questionnaire until called and were given

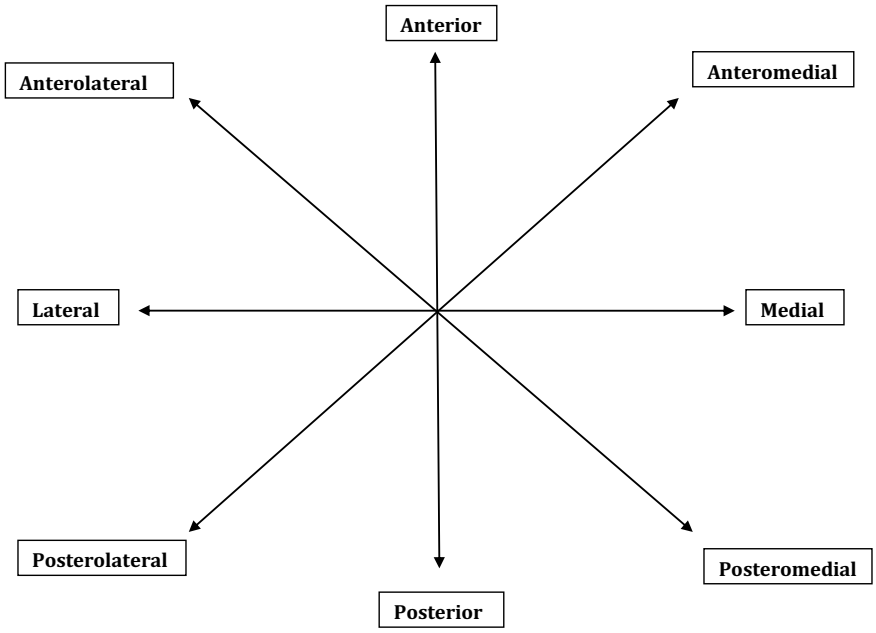

FIGURE 1. Star Excursion Balance Test grid, referencing the left standing leg (adapted from Olmstead[8]).

only one trial to complete the test. Once the test started, subjects were stopped only if they experienced pain, repeatedly put excessive weight down on the grid, did not return the targeting foot to the ready position, or actually fell.

After completing the basic test, three other modifications immediately followed to increase balance challenges:

1. A timed test (speed in seconds) in which the dancer-subject completed the clockwise and counterclockwise star pattern "as fast and safe as possible,"
2. A timed test with cognitive interference, in which the dancer-subject completed the same sequence "as fast and safe as possible" while answering questions aloud, as quickly as possible, and
3. Standing on a foam Airex® pad and completing the clockwise and counterclockwise directions at a self-selected pace. <AU: foam? Pls clarify>

Data exceeding three trials to attain correct performance were discarded. In all conditions, "near-falls" and actual falls were tracked. Near-falls were characterized as stepping strategies in which the subject had to touch down with the targeting foot to restore balance. The entire test took approximately 20 minutes to administer, giving dancers time to return to lunch and their classes.

Statistical Analysis

A 2 x 3 × 8 repeated-measures analysis of variance (ANOVA) was used to analyze the between-subjects factor (group with 2 levels, injured and noninjured), while the within-subjects factors were side with 3 levels (right, left, and both sides), and direction with 8 levels (AL, A, AM, M, PM, P, Pl, L). Post hoc tests were not performed due to nonsignificant results. The alpha level was set at $p < 0.05$ for all analyses.[13] Pearson Product Moment correlation coefficient was calculated for right and left leg lengths for the eight directions. Simple means for distance (centimeters) were calculated for all eight directions (clockwise and counterclockwise directions) for both injured and noninjured subjects to assess differences between the two groups and sides of injury (in centimeters). Descriptive analyses were made of injury and near-fall rates for the three modifications—timed, timed cognitive, and foam. Video analysis of performance strategies was conducted by the research team and two objective observers unrelated to the study.

RESULTS

Of the original 33 subjects, 29 completed all aspects of testing (18 from Group A and 15 from Group B). For Group A, trials for 2 subjects were discarded when a fire alarm interrupted testing, rendering 31 subjects for the basic test. Two other subjects voluntarily stopped during the modifications due to complaints of pain. All 15 of Group B completed the tests without incident.

Similar to the results on the original SEBT,[8] results of this study showed a positive correlation for leg length and distance with most directions ($r \geq 0.70$, $p = 0.01$). ANOVA results did not concur with those of the original basic SEBT ($F_{1,31} = 0.379$, $p = 0.05$). In the original test, significant differences were reported for distance reached from both limbs and both groups ($F_{1,38} = 3.99$, $p = 0.05$).[8] Subjects in the original study reached farther when standing on the uninjured limb (average of 3 cm). In this study, no significant side-by-group interaction was calculated. Significance was attained for two similar spokes for the right and left limb only: posterolateral right (0.05) and lateral (0.04) on the right limb, and posteromedial (0.02) and lateral on the left limb (0.04).

FIGURE 2. The ready position.

Descriptive analysis of the mSEBT test showed remarkable homogeneity of performance. Means analysis revealed that dancers reached comparable distances for most spokes of the grid, regardless of standing limb. The main discrepancy in mean distance reached (average 15 cm) was observed for the two back diagonal spokes only: posterolateral (PL_L) spoke for counterclockwise execution on the left limb, and the posteromedial (PM_R) spoke for clockwise execution on the right. Uninjured dancers reached 61.5 cm while those with left-sided injury reached 41.0 cm on the PL_L spoke. For the PM_R spoke, uninjured dancers reached 56.6 cm, as opposed to those with right-sided injury who reached 37.6 cm. Dancers reporting an injury history on both limbs reached 71.3 and 72.5 cm, respectively.

Homogeneity of performance was also attained for speed for the timed and time cognitive tests, as well as the near-fall rates for all three modifications (Fig. 3). Slightly faster execution especially was observed on the injured vs the noninjured leg, although this was not statistically significant.

DISCUSSION

The purpose of this study was to collect preliminary data toward validating the SEBT as a screen for balance for preprofessional dancers with and without a history of lower extremity injury. A second aim of the study was to increase the rigor of the original design for a dance population in three ways: timing the test (for speed), timing the test with cognitive interference (distracting questions), and proprioceptive disadvantaging through changing the floor-foot interface (foam).

Principal findings revealed a lack of concurrence with findings in the original instrument. Dancers appeared to reach comparable distances with either limb, regardless of the side of lower extremity injury with few exceptions. Despite a positive correlation between leg length and distance, subjects did not reach significantly less far when standing on their injured limb compared to the sound limb, with the exception of two spokes of the back diagonals of the grid (posterolateral and posteromedial).

What emerges as a potential reason for these findings is in the dancers' use of variable strategies. Attempts were made to control for strategy by asking subjects to keep their hands on their hips and avoid axial rotation. When challenged to perform well, however, dancers appear to have chosen a variety of counterbalancing strategies. On the basic test, when asked to reach with the targeting foot "as far as possible," style of execution varied greatly. The extent to which dancers exploit degrees of freedom has been observed by other researchers.[4,14] When comparing motor performance to nondancers, dancers more readily might choose strategies distinct and more variable in terms of body relationships and kinematics.[4] For this sample, the dancers appeared to exploit a more variable set of learned strategies for balance, which influenced torso and leg relationships, a phenomenon also observed among the sample of dancers in other equilibrium studies.[14-16] Posttest qualitative analysis of video recordings revealed a wide range of variability in execution, despite relative homogeneity of the sample in terms of age, years of training, type of training, and anthropomorphic characteristics (Table 1).

These differences in variability were both inter- (between dancers) and intra-subject (within the dancer him- or herself). For the trunk, for example, two primary strategies were observed: movement of the torso *en bloc* vs segmenting the trunk between upper and lower body. Gross differences between dancers in execution partially might be accounted for by differences in training (more classical vs release-based training). Examples included greater counterbalancing between upper and lower trunk, deeper knee and hip flexion, and more variability of head and eye gaze among the "release" dancers. Dancers also showed several options for leg gesture, basically varying between a more pendulous vs a more joint segmentation approach. In the pendulous leg approach, dancers swung each leg loosely from the hip like a pendulum in each direction; whereas in the segmented approach, dancers would raise the thigh to 90°, alternately flexing and extending the knee as they reached and retreated with the targeting foot.

Researchers have speculated that coordination between hips and shoulders, as well as upper and lower trunk, varies among dancers in complex movements[15] and may be secondary to training.[14] On the basis of the results of this study, we speculate that dancers employ a number of variable strategies for executing the same movement, not only in gross (kinematic movement) but also at the level of submovements (micromovements).<**AU: edited as meant?**> In some cases, the balance strategy might appear visually similar, yet closer visual analysis revealed smaller submovements emerging from exploring multiple degrees of freedom, the hallmark of dance training.[14]

Intra-dancer variability also was observed, with the same dancer changing to different strategies during various por-

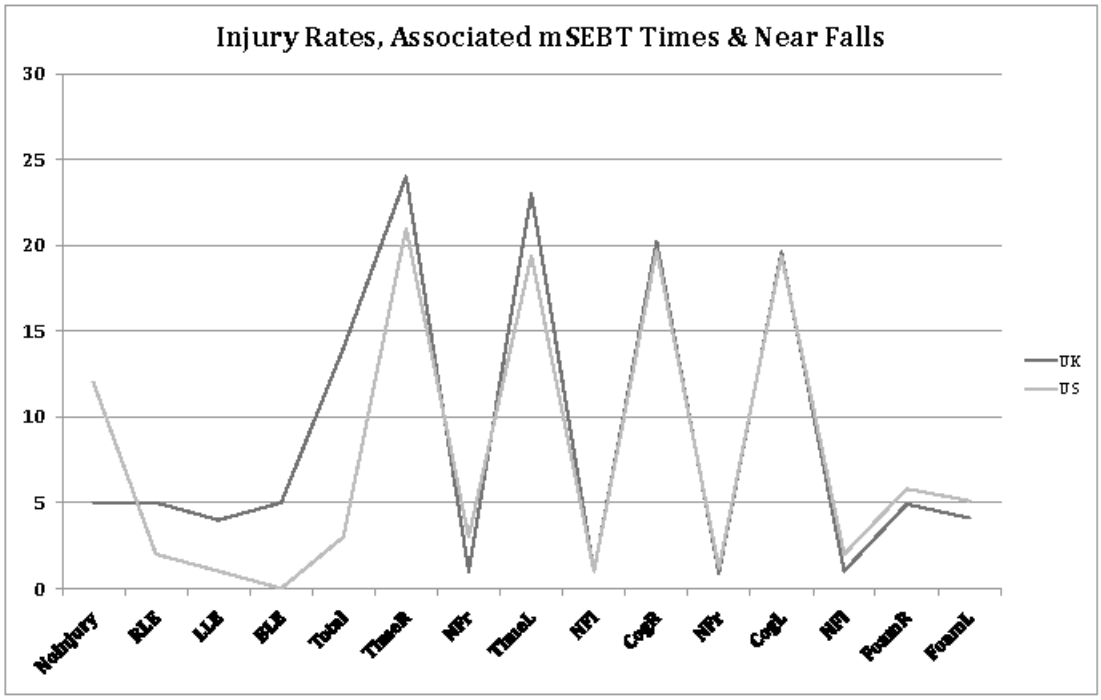

FIGURE 3. Injury rates, associated mSEBT times, and near-falls in Group A (UK, *n* = 22) vs Group B (US, *n* = 15). <AU: pls explain abbr used on y-axis, unless clear in text>

tions of the mSEBT. Timed testing ("fast and safe as possible") showed the least variability. As speed replaced distance as the most important variable, performance strategies came closer to a mean style of execution, as both groups tightened up degrees of freedom to accomplish the task, a common phenomenon of speed-accuracy tradeoff.[18]

In the timed-cognitive tests, dancers were asked to answer questions out loud while completing the star pattern as "fast and safe as possible." The point of this test was to simulate a dance classroom in which dancers often are receiving multiple instructions while executing movement (multi-tasking). Testers called out a randomized set of declarative memory questions ("When did you last get your haircut?") as well as calculations ("What's 79 minus 13?"). Dancers were supposed to respond aloud to the questions as quickly as possible. Although not statistically significant, time spent on the injured leg was observed to be slightly shorter than that on the noninjured leg. Whether this potentially reflects unresolved balance deficits on the injured side (e.g., decreased strength, proprioceptive impairment, etc.) warrants further investigation.

Results of these data are to be viewed with caution. First, for many of the Group A dancers, English was not their primary language. For others, questions involving calculations proved too difficult to answer quickly, and many dancers delayed answering the questions, completing the test before responding. Future studies merit a honing of methodology for employing cognitive interference to challenge balance.

Performance of the SEBT on foam was the most challenging of the four tests. The balance challenge here involved a shift from a primarily proprioceptive strategy for keeping stability to a visual one in which vision compensated for altered proprioception. Once foot proprioception was "disadvantaged" by altering the normal surface characteristics of the floor, dancers often were forced to look down to maintain a stable foot-to-foam contact. Near-falls and falls increased the most for this test, and four dancers in Group A and three dancers in Group B could not finish the test within the three trials allowed (with two from Group A voluntarily stopping altogether due to pain in the injured limb).

In tracking near-falls and falls, few dancers actually fell in any of the tests. Near-falls averaged one for the basic test, regardless of standing leg, direction, or spoke. Of all the tests (basic and three modifications), the most near-falls occurred on the injured limb side when proprioception was disadvantaged (Fig. 3), suggesting that despite rehabilitation and/or return to full dancing, balance deficits due to injury could still be extant. Of the eight spokes of the start grid, dancers tended to miss the posteromedial spoke more than any other one in the grid. The posterolateral and posteromedial diagonals rendered the most significant clinical data in terms of distance reached and were also the two most missed diagonals in performance. Although not significant, these results concur with a factorial analysis of the SEBT that showed significant redundancy in many of the spokes.[19] The "Y" test is a truncated version of the SEBT, targeting only the back three spokes (posteromedial, posterolateral, and posterior) and has been postulated as adequately capturing balance within the constraints of the SEBT.[18,19]

Study Limitations

A study such as this always begs the issue of sample size, although conducting the study on a relatively homogeneous sample of dancers from two conservatories from two different countries was sufficient to produce results clarifying direction for further research. Other limitations involve aspects of reliability, validity, and sensitivity. First, during intake data collection, the accuracy of injury history was questionable, with dancers not remembering the number of injuries, dates, types, or side of injury. Second, the lack of inter- and intra-rater reliability testing posed possible limitations in interpretation of data. Despite several hours of training by the principal investigator on test administration, use of a script for test instructions, and concurrence of documentation, test interpretation may have varied among the testers both within and between institutions.

The wide variability in performance strategy was not anticipated, which suggests better selection and stratification of subjects by years and type of training. Future studies need to normalize for leg length differences to better explain variability of performance. Further, quantitative analysis, as force plate and 3D motion analysis, must be conducted to assess and define balance strategies. Future studies using quantitative motion analysis can capture a more representative picture more accurately of the long-term effects of injury on balance, as well as the variations in kinematics when strategy is essentially controlled.

Finally, the question of validity remains: Does the SEBT detect balance deficits in dancers, with or without a history of lower extremity injury? Do the modifications sharpen the results of the basic test in terms of uncovering balance deficits by tracking rates of near-falls and falls? The strength of this study lay mainly in uncovering the diversity of strategies utilized to accomplish the tests. While the SEBT is a dynamic test of balance, requiring internal perturbation of the axial body by the targeting leg and complex coordination dynamics, it is still a relatively "static" test of balance. As a "screen" for balance, it is relatively quick and simple to administer and cost effective. It appears to be more dance-specific, in terms of stabilizing the torso against an elevated, gesturing limb. Yet, further research is needed.

CONCLUSIONS

The SEBT and the mSEBT appear to show promise as screening tools for identifying balance deficits in dancer-subjects with a history of lower extremity injury. Given its clinical utility, it holds potential as an effective tool for assessing dynamic balance of the dancer standing in one location in space, such as replicated in center floor work. Further research is warranted, however, that would entail kinematic and kinetic measures to provide insight into the variable movement strategies chosen and their relationship to both intrinsic and extrinsic factors impacting on the dancer and on training. Force plate and motion analysis studies, as well as lab analysis or other form of visual analysis of performance strategies would pave the way for understanding these relationships. Defining these and other variables would help improve the methodology of test execution and point the way toward a more valid test for screening balance deficits in dancers.

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