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Developing the Temporal and Order Characteristics of a Dance-Specific Star Excursion Balance Test (dsSEBT)

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Abstract

Previous studies have made crucial steps towards developing a dance-specific balance test to challenge dancer's balance capabilities. However, the authentic performance nature of the protocols could be questioned. The aim of this study was to examine the effects of different tempo and order variations on the previously developed Dance-Specific Star Excursion Balance Test (dsSEBT). Twenty-two female dancers voluntarily took part in the research (Stature 162.68± 6.57cm; Mass 61.35± 11.25kg). This research looks at three different temporal variations as well as an alternate reach order, to the traditional order, to examine the effect it may have on individual spoke scores. Reach distances (% of limb length), center of pressure (cm^2), and error scores were measured. Overall, the varying tempos did not create a statistically significant change in any of the variables measured ($p = 0.067 - 1.00$) which suggests that dancers have a unique ability to adapt to temporal changes due to the nature of ever-changing tempos in class and performance. Additionally, the altered reach order did not affect the

difficulty level of each individual spoke, which corresponds with previous research suggesting that the crossed side and crossed front spokes are in fact the most challenging spokes for ballet and contemporary dancers to accomplish. Results support the utilisation of all eight spokes of the dsSEBT in identifying balance deficits in this genre of dancers. The data collected in this study provides useful baseline measurements to further develop a reliable dance-specific dynamic balance test protocol to be used by ballet and contemporary dancers.

Word Count

4,049 words

Key Points

1. The data collected in this study may inform future research to further develop a reliable dance-specific dynamic balance test protocol to be used by ballet and contemporary dancers.
2. There were no statistically significant differences with regards to tempo variations of the dsSEBT; suggesting the increase and decrease in bpm had no relevant effect on all three core variables in any one tempo condition when compared to the others.
3. The crossed side and crossed front spokes are the most challenging regardless of performance order, further meriting the use of an 8-spoke design for dancers.

Introduction

Achieving postural control through dynamic stability; functionally and aesthetically is an important requirement for most dance genres.[1-5] To assess dancers' balance capabilities, dynamic balance tests should be utilized as most balance tasks used in training and performance require dynamic stability.[6-12] Dynamic balance involves some level of expected movement around the base of support requiring additional demands of range of motion, strength, and proprioception.[13,14] Movement while balancing dynamically can be classified as tasks, such as landing from a jump and attempting to achieve a motionless center of mass; or attempting to purposefully segment movements, such as reaching, while maintaining the established base of support.[13-16]

Although most dynamic balance tests have been criticized for lacking sensitivity and challenge for dancers and other athletes, the Star Excursion Balance Test (SEBT) is regarded as sufficiently sensitive for the majority of these populations.[13,17,18] The overarching goal of the SEBT is to encourage the participant to disturb their equilibrium to a maximal point before returning to their central state.[19] The test was first described as a rehabilitation tool and is currently considered to be a reliable and valid measure which is sensitive to change to assess dynamic balance for physically active individuals.[20] Past research has shown that SEBT performance can improve after training and suggestions have been made to use the SEBT as a screening tool for sport participation as well as for post-rehabilitation to ensure functional symmetry.[18,21] Since many dance genres involve various movements which are similar to the movements performed in the SEBT, this could mean that dancers are already predisposed to balance disturbance when performing the

SEBT. Therefore, dancers may already possess proficiency at performing the SEBT which may explain why it is not considered to be challenging enough.[22,23]

As a development of the SEBT, the Y Balance Test (YBT) prioritises the front, open back, and crossed back directions for future research.[14,16,21,24] However, other research has suggested that while the three directions do reduce the time needed to perform the SEBT, all eight directions provide individual and unique challenges to the body. Each individual spoke requires unique and complex trunk and leg coordination between all spatial planes of the body.[14,25] For example, Earl and Hertel[26] found muscle activation differences using EMG dependant on reach distance, justifying the use of various reach distances for clinicians who want to test patients with impairments in specific muscles. Furthermore, the YBT Kit may also not be feasible financially for all clinicians and researchers.[27] Additionally, Clarke et al.[8] discovered that the open side, crossed back, and crossed front spokes were predictors of repertoire and technique performance grades in ballet, contemporary, and jazz dance genres.

Previous research has set out to develop a dynamic balance test which targets dancers specifically, all of which utilized the SEBT as a base to build upon. These developments altered the timing, attentional focus, stability, and reach order.[25,28-30] Rapid postural responses are required to maintain balance in changing, dynamic environments.[31] Remaining balanced while completing fast-paced tasks has been suggested to provide challenges to the neuromuscular system that may not occur during slow-paced tasks.[32] Previous research has recommended to examine the effects of a range of tempos to find the best training for equilibrium responses.[10,29] In Batson's[28] research, speed played a role in altering reach distance as dancers tightened their degrees of freedom to accomplish the task, which is a common phenomenon often referred to as the speed-accuracy trade-off.[33] Unfortunately, no numerical results were reported for future researchers to compare to. Additionally, the researcher identifies a lack of intra-tester and inter-tester reliability, so conclusive results should be taken with caution.[28]

Smitt[30] modified the SEBT further to include a secondary arm task (S-SEBT) alongside a time signature of 50 bpm (R-SEBT). The 50 bpm tempo was determined by opinions of ballet and contemporary teachers in her testing institution considering what would be commonly used in dance. The teachers also offered an alternatively common tempo of 70bpm; Smit chose the 50bpm alternative to accurately accommodate her secondary arm task. While a specified tempo was used, it was not specified whether the instructions were given to perform the task using one or two beats per movement which may drastically change the outcome of the results if this study was to be replicated. When reporting results, the researcher deemed normalizing the reach distance data unnecessary as the same participants were used throughout. This is seen as another limitation as future researchers will have difficulty comparing results. Smitt concluded that the speed variation introduced resulted in an increase in errors that was not seen in the original SEBT compared. However, Smitt followed in Batson's[28] footsteps, allowing no practice trails, and only administering one trial on the preferred standing leg; due to these limitations, this study's results should be approached with caution.

Beckman and Brouner[29] developed the SEBT further by altering foot positioning, adding instability by stimulating being on rise, establishing dance-specific upper body positioning (dsSEBT), and developing a three-tier error-rating system. The authors identified that the foot positioning did not show a statistically significant change between parallel and turnout for their dancers. They also found that creating instability in balance surfaces caused an overall increase in difficulty to the SEBT. The upper body restrictions did not inhibit the dancer to reach maximally, and the error-rating system discovered that 62.61% of all errors occurred in the crossed side and crossed front directions. Additionally, Beckman and Brouner discovered a great range in time to complete each SEBT trial, which led to the recommendation that future research would benefit from testing varying tempos. Additionally, it is recommended that future researchers increase overall reliability in measurement by adding reach indicators like those used by Plisky[21] in the YBT Kit. Lastly, it has been recommended that future researchers alter reach order to start with the crossed side spoke to gain useful data as to why there were more errors made in the crossed side and crossed front directions.

All researchers above recommend measuring number of errors in the movement as well as reach distance to get a better sense of the dancers' level of proprioceptive sense, as accuracy is highly desirable in dance training. Previous research also recommends utilizing force plate center of pressure (COP) data to improve the methodology of test execution and pave the way toward a more valid test for screening balance deficits in dancers.[28,29] While the above studies made crucial steps towards dance-specific alterations and difficulty of the SEBT, all researchers have concluded that current modifications to the SEBT have not conclusively produced a valid dance-specific test.[25,28-30]

The aim of this study is to further develop the usability of the dsSEBT by testing new reach order and varying tempos.

Methods

Participants

Twenty-two female ballet and contemporary dancers from two UK-based undergraduate dance programmes volunteered and consented to participate. Ethical approval was gained prior to data collection by the Trinity Laban Research Ethics Committee.

Inclusion criteria was set as being over 18 years old, and had at least three years of dance training. Exclusion criteria included if they had any disorders that may affect their vestibular system, any lower extremity injury in the six months prior to data collection, complaints of dizziness due to respiratory or ear infections, or a history of cerebral concussions. At any stage, the participants had the right to withdraw. Regression analysis was appropriate for this sample size of 22 participants as power analysis calculations concluded that 21 participants would be needed for this research assuming a power level of 80% with an alpha level of 5%. See Table 1 for participant characteristics.

Table 1 Participant Characteristics

Age (yrs) (mean± SD)	Stature (cm) (mean± SD)	Mass (kg) (mean± SD)	Body Mass Index (BMI) (mean± SD)	Leg Length (cm) (mean± SD)	Dance Experience (yrs) (mean± SD)
21.18± 3.90	162.68± 6.57	61.35± 11.25	23.54± 3.59	85.55± 5.17	13.09± 5.81

Prior to data collection, medical PAR-Q and relevant consent forms were completed. Limb length was measured using a standard measuring tape with the participant lying supine from the anterior superior iliac spine to the middle of the medial malleolus.[14,16,22,34]

Procedures

The same initial procedures regarding setup of the SEBT grid, instruction, warm-up, and SEBT spoke vocabulary were followed as outlined in Beckman and Brouner's[29] research. Following Plisky et al.'s[21] research, reach indicators pushed by the participant with their toes off the ground were used to identify a more accurate reach distance. The reach indicators were weighted to ensure final reach measures did not exceed the maximal reach distance.

All participants completed the original SEBT (oSEBT)[20] followed by four variations of the dsSEBT; all of which were performed in parallel. The variations included three different tempo changes as well as a change to the order in which directions were completed. The three tempo speeds chosen were based off the research completed by Beckman and Brouner[29], wherein it was found that the average time to complete each trial utilized a tempo of 72 bpm if each movement was given two beats. To choose the faster and slower tempo variations, one standard deviation (SD) was taken on each side of the 72 bpm mean: therefore, making the three tempo 50 bpm, 72 bpm, and 100 bpm. The new order variation starts with the crossed side spoke and ends on the open side spoke changing from crossing the front half of the body to the back half of the body. The order was changed in such way to isolate whether the surplus of errors recorded in previous research for the crossed side and crossed front spokes[29] were due to these being the only spokes wherein the midline was crossed, these spokes being the last ones reached, or simply because of their orientation in space relative to the standing leg. See figure 1 for a visual example of the order change from the regular order to the new variation. See Table 2 for the protocol details.

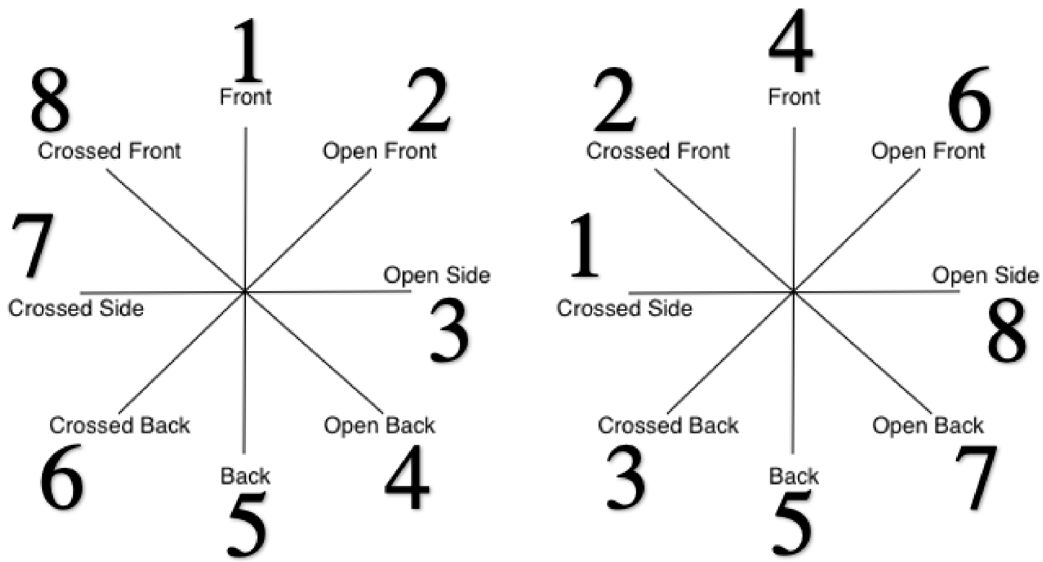

Figure 1. Left Stance: Original Order (Left) and New Order Variation (Right)

Table 2 Protocol Details

Variation Name	Recommended Criteria
oSEBT	- Shoes off - Testing order of spokes will begin with the front spoke moving clockwise for the left standing foot and counterclockwise for the right standing foot - Minimal stance foot movement is allowed, no heel raises - Trunk movement allowed under control - Hands placed on hips for all trials [14,21]
dsSEBT Average Tempo (72bpm)	- Shoes off - Keep navel facing forward - Refrain from axial rotation (turning) - Testing order of spokes will begin with the front spoke moving clockwise for the left standing foot and counterclockwise for the right standing foot - Minimal stance foot movement is allowed, no heel raises - Flexing and extending of the supporting leg's knee is permitted - Participants must return to the starting position before reaching to the next spoke - Participants must complete test on all spokes before standing fully on gesture limb again - Arms in second position (running roughly parallel to the ground and rounded slightly) - Head is to remain still, gaze fixed on a target [1,22,28,29]
dsSEBT Slow Tempo (50bpm)	- Same as Average Tempo with new slower tempo
dsSEBT Fast Tempo (100bpm)	- Same as Average Tempo with new faster tempo
dsSEBT Order Change	- Same as Average Tempo with two modifications: - Testing order of spokes will be crossed side, crossed front, crossed back, front, back, open front, open back, open side - No tempo; self-selected pace

Data Collection

Reach distance, COP, and error scores were measured. Reach distance was recorded manually by the primary researcher the moment as the participant completed the reach by reading the values on the inside of the reach indicator. Reach values were originally recorded in centimeters then converted and reported as a percentage of limb length using the same formula as previous research.[13,14,21,22,29] COP positioning was measured in medial/lateral and anterior/posterior directions at the full extension of the reach at each spoke using a Tekscan pressure mat (MatScan, TekScan MA, USA), with COP measured in cm^2. Error scores were determined by the same rating system as used by Beckman and Brouner.[29] For the purposes of this research, trials could continue regardless of errors, apart from full falls.[35]

Statistical Analysis

The alpha levels were initially set to 0.05 for all tests and data was analyzed using SPSS (version 26). Histograms, quantile plots, and Shapiro-Wilk tests were utilized to determine equal variance and normality assumptions for all data. Means and SDs were reported for the non-normally distributed data and the normally distributed data. A Bonferroni correction was applied where relevant to determine new respective alpha levels. Regardless of distribution, 95% Confidence intervals have been reported.

Three Repeated Measures Analysis of Variances (RM ANOVAS) were performed to test statistically significant differences in the variables recorded across the five test variations.

All spoke scores were averaged to get an overall mean for each condition. Data was found to be normally distributed for the reach distance data; however, the data was not normally distributed for the COP and error score data sets. Due to this, a RM ANOVA was performed for the reach distance data and a Friedman test was performed for COP and error score data sets. Mauchley's Test of Sphericity was not statistically significant for the reach distance data, which confirmed that the sphericity assumption has been met. For the COP and error score data sets, post hoc analysis used the Wilcoxon signed ranked test.

Additionally, three RM ANOVAs were performed to test significance in the same three variables across the 8 spokes. All condition scores were averaged to get an overall mean for each spoke. Data was found to be normally distributed for the reach distance data only. Therefore, an RM ANOVA was performed for the reach distance data and a Friedman test was performed for COP and error score data sets, using a Wilcoxon signed rank test with a Bonferroni correction for post hoc analyses. For reach distance, Mauchley's Test of Sphericity was statistically significant, meaning the sphericity assumption was not met, and therefore the Greenhouse-Geisser correction was applied. For the COP and error score data sets, the Wilcoxon signed rank test was again used.

Individual spokes were investigated deeper by comparing each condition with each spoke. This was to see the effects that changing the order may have had on reach distance, COP, and error score data sets. A total of 24 RM ANOVAs were completed as to test significance in each core variable in every condition across the 8 spokes to get a picture of each spoke individually to measure any effects changing the order may have had. Data was normally distributed for the reach distances; therefore, a RM ANOVA was found appropriate to use in testing difference between conditions in each spoke. The data for COP and error scores was found to be not normally distributed, therefore a Friedman test was used with the Wilcoxon signed rank test in post hoc analysis.

Results

A statistically significant difference was found between conditions, $F(4,84) = 14.14$, $p < 0.001$, ηp2 = 0.40. Post hoc analyses uncovered that reach distances for the original condition were significantly greater than the other four conditions. A statistically significant difference was found between conditions with regards to movement in overall COP area by a Friedman test, $X^2(4) = 12.66$, $p < 0.05$, $W = 0.19$. The only statistically significant difference detected was that the original condition had a significantly greater COP area squared than the order change condition specifically. A Friedman test detected a statistically significant difference in error scores between conditions, $X^2(4) = 21.64$, $p < 0.001$, $W = 0.27$. The post hoc revealed that the original condition resulted in significantly fewer errors than the rest of the conditions (See Table 3).

Table 3 Dynamic balance performance per condition as shown by the core variables, averaged across all reach directions

Condition	Average Reach Distance (% of limb length) mean ± SD (95% CI)	Average Center of Pressure (cm^2) mean ± SD (95% CI)	Average Error Scores (rating system) mean ± SD (95% CI)
oSEBT	84.65± 5.64 (82.15,87.15)	4.90± 1.75 (3.99,5.80)	1.19± 1.10 (0.67,1.68)
dsSEBT Avg. Tempo	81.22± 4.76[a,b] (79.11,83.33)	3.93± 0.89 (3.47,4.39)	3.33± 1.99[a] (2.39,4.24)
dsSEBT Slow Tempo	82.60± 4.82[a] (80.47,84.74)	3.86± 0.97 (3.36,4.36)	3.52± 2.03[a] (2.57,4.46)
dsSEBT Fast Tempo	81.24± 5.11[a] (78.97,83.50)	4.12± 1.08 (3.57,4.68)	2.73± 1.89[a] (1.84,3.61)
dsSEBT Order Change	82.30± 4.87[a] (80.14, 84.46)	3.95± 1.02[a] (3.43,4.47)	2.87± 1.76[a] (2.05,3.69)

[a] statistically significant difference from oSEBT ($p < 0.05$ for RD and $p < 0.005$ for COP & ES)
[b] statistically significant difference from dsSEBT Slow Tempo ($p < 0.05$)

A statistically significant difference was found in reach distances between spokes, $F(2.37,49.68) = 64.98$, $p < 0.001$, ηp2 = 0.76. Using a post hoc analysis, it was discovered that reach distances for the crossed front spoke were significantly lower than the reach distances for the rest of the spokes. Compared to all other spokes, significantly greater reach distances were achieved in the back spoke. However, it was also shown that when compared specifically to the front, open front, open side, crossed side, and crossed front spokes, the crossed back and open back spokes reached significantly greater distances. The Friedman Test for the COP data set detected a statistically significant difference between spokes, $X^2(7) = 82.09$, $p < 0.001$, 0.65. COP movement was found to be greater in the open front spoke than the open side, open back, back, crossed back, and crossed side spokes. Overall, the open back, back, and crossed back spokes had significantly lower changes in COP than the front, open front, open side, and crossed front spokes. A Friedman test showed that there was a statistically significant difference between spokes for error scores, $X^2(7) = 80.24$, $p < .001$, 0.64. Post hoc analysis shows that the crossed side and crossed front spokes had the most errors when compared to the front, open front, open side, open back, back, and crossed back spokes. However, post hoc analysis also revealed that the crossed side spoke also had a significantly higher error score than the crossed front spoke (See Table 4).

Table 4 Dynamic balance performance per spoke as shown by the core variables, averaged across all conditions

Spoke	Average Reach Distance (% of limb length) mean ± SD (95% CI)	Average Center of Pressure (cm^2) mean ± SD (95% CI)	Average Error Scores (rating system) mean ± SD (95% CI)
Front	78.73± 5.16[c,d,e,g] (76.44,81.01)	5.90± 2.10[c,d,e,f] (4.85,6.94)	0.21± 0.20[f,g] (0.11,0.31)
Open Front	80.70± 4.74[a,c,d,e,g] (78.60,82.80)	6.87± 2.78[c,d,e,f] (5.49,8.26)	0.20± 0.20[f,g] (0.10,0.29)
Open Side	81.51± 5.26[a,c,d,e,g] (79.17,83.84)	4.57± 1.50[b,c,d,e] (3.83,5.32)	0.20± 0.23[f,g] (0.08,0.31)
Open Back	85.37± 5.53[a,d,g] (82.91,87.82)	2.92± 0.67[b] (2.59,3.26)	0.13± 0.13[f,g] (0.06,0.20)
Back	90.41± 6.63[a,g] (87.47,93.35)	2.81± 1.18[b] (2.22,3.38)	0.07± 0.07[f,g] (0.03,0.10)
Crossed Back	87.52± 6.44[a,d,g] (84.66,90.37)	2.71± 0.84[b] (2.29,3.12)	0.11± 0.10[f,g] (0.06,0.15)
Crossed Side	79.49± 5.32[c,d,e,g] (77.13,81.85)	3.50± 1.45[b] (2.78,4.22)	0.98± 0.51 (0.75,1.25)
Crossed Front	75.49± 4.69[a,c,d,e] (73.42,77.57)	4.97± 1.25[c,d,e,f] (4.35,5.58)	0.57± 0.27[f] (0.44,0.71)

[a] statistically significant difference from front spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[b] statistically significant difference from open front spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[c] statistically significant difference from open back spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[d] statistically significant difference from back spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[e] statistically significant difference from crossed back spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[f] statistically significant difference from crossed side spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[g] statistically significant difference from crossed front spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)

When specifically comparing the changed order condition to the other dsSEBT conditions, those which altered tempo, there were found to be only a couple statistically significant differences in reach distance data. On the open side spoke, greater reach distance was achieved in the order change condition than the average and fast tempo conditions ($p < 0.05$). It was also found that reach distance decreased in the crossed side spoke for the order change condition when compared to the slow tempo condition ($p < 0.05$). The only statistically significant difference seen in COP data was in the front spoke. When comparing the changed order condition and the fast tempo condition, the fast tempo condition had a greater COP movement ($p < 0.001$). There were no statistically significant differences found within spokes between conditions for the error score data.

Discussion

Tempos were added to standardise the protocol further and additionally see the effects on the outcome of the SEBT as dance is often practiced and performed in a precise and coordinated manner with rhythmic guidelines.[36,37] The tempos utilised were in line with Smitt[30] as well as those used in the Dance Aerobic Fitness Test (DAFT), where tempos range from 68-108bpm dependant on the stage.[38] As stated previously, since Smitt[30] did not state whether her tempo of 50 bpm allowed for one or two beats per movement, it is unclear whether her tempo is in line with that of the slow or the fast tempo variations used in this study.

There were no statistically significant differences with regards to tempo variations of the dsSEBT; suggesting the increase and decrease in bpm had no relevant effect on all three core variables in any one tempo condition when compared to the others. These results may be a reflection on the dancers' abilities to adapt to the temporal changes as they are able to in dance class and performance where performers learn to recognize temporal changes and in turn are taught to synchronize their movements to the changed tempo without losing the aesthetic qualities required.[37] These results do not support Batson's[28] work where executing the mSEBT as fast as possible caused a statistically significant reduction in reach performance. However, the highest bpm used may not be comparable to a maximal velocity performance therefore not having the same impact of balance reaction. Examination of maximal velocity, task completion as fast as possible, against the current 100bpm would offer further development of stressing balance. Yet, the results from this study are in line with Smitt[30] where no decrease in reach distance was achieved when change in tempo was introduced.

Additionally, there were no statistically significant differences in core variables between the original reach direction order and the altered reach direction order. This suggests that the increase in errors for the crossed side and crossed front spokes are not due to them being the last spokes to be completed. Nor were the raised error scores due to the transition of the reaching foot across the midline of the body as this was included as a transition between every spoke due to the nature of the altered reach order. These results indicate that the crossed side and crossed front spokes are the most challenging regardless of performance order, further meriting the use of an 8-spoke design for the dsSEBT. These findings are in line with previous research, which further recommend the use of an 8-spoke SEBT design over the 3-spoke YBT design.[8,14,25-27,39] Importantly, the eight spokes also reflect the directions ballet and contemporary dancers commonly utilize in performance, therefore aid in the screening aspect of the dsSEBT being an authentic movement pattern of assessment. Seeing as there were no statistically significant differences found when the reach order changed, it is suggested that the original reach order is used for future research as it has been used in previous studies.[14,21]

As with previous research,[29] the crossed side and crossed front spokes were shown to account for an average of 62.61-71.10% of all errors made. Additionally, the crossed side and crossed front spokes specifically were among the lowest reaching spokes with average values ranging from 75.49-79.49% of limb length. Studies using healthy young adults reported similar values with their participants reaching 71.00-80.53% of their limb length in the crossed side and crossed front directions.[16,24] These reach directions are expected to be shorter overall due to the gesture limb reaching directly behind or in front of the standing limb. However, when comparing these values to the average composite reach value of 81.22-84.65% in this study, it is evident that there is more than just a minor decrease in reach values. Unfortunately, most dancer-specific studies either use the YBT or have used the 8-spoke SEBT but have only reported composite reach values and not individual spoke values. Overall, this data indicates that the crossed side and crossed front spokes are among the most challenging spokes to achieve, which makes them valuable to measure. While these reach directions may be used in dance, perhaps they are not as common which is why they prove to be such a challenge. Testing these directions give the dancer a movement they may have done before but is not as second nature to them as the other reach directions may be.

Interestingly, the front spoke has also proven to be challenging. This reach direction often had the second or third lowest reach distance achieved overall with values ranging from 70.27-78.82% of limb length depending on the phase. While far behind the crossed side and crossed front spokes with regards to error score values, the front spoke did however account for 5.69-7.80% of all errors made in the trials. This spoke is arguably one of the more common reach directions that may be used by dancers and healthy adults; however, it can also be argued that these values are a reflection on the fact that it was the first spoke performed.[30] However, during the order change condition, there was no statistically significant difference in core values for the front spoke. Additionally, in previous studies,[29] the front spoke had the greatest area of COP movement with 14.87cm^2 and the second greatest value in this study with 5.38cm^2 of movement. The COP data from this study regarding the front direction is in line with previous research where the front reach resulted in a greater COP area.[42] While again, this may be a sign of inferior balance in this direction, Keith et al.[42] speculates that the front direction requires greater movement of COP to achieve maximal reach. Although this reach direction is common in dance, the values support the notion that each spoke is valuable to be measured regardless of if it may seem to be second nature for dancers.

The open back, back, and crossed back spokes were the three spokes to have the greatest reach distance achieved with values ranging from 85.37-90.41% of limb length.

These three spokes were also the ones with the least change in COP area with values ranging from 2.42-2.94 cm^2. Additionally, these three had the least number of errors made, accounting for a combined total of only 11.01-21.14 % of all errors made in this study supporting the low error rate observed in Beckman and Brouner.[29] This data indicates that these three spokes are among the least challenging spokes for ballet and contemporary dancers to achieve, which may be due to their common use in dance practices. The back reach direction is common for ballet and contemporary dance movements such as arabesques and développés. The open back reach direction may feel quite familiar considering this is the direction dancers may reach towards if they do not yet have the strength or coordination to reach directly behind them yet. Finally, the crossed back reach direction is quite similar to a fourth position of the feet in ballet and specifically reminiscent of a fourth position lunge a dancer may end in after completing a pirouette[22]. However, this research studied only healthy participants, previous research on injured dancers have shown discrepancies in the open back and crossed back spokes with regards to injured vs non-injured limbs that were not present in uninjured dancers.[28]

The findings in this research further supports the relevance of testing spokes on dancers which differ from those traditionally used in the YBT and its other 3-spoke modifications. Therefore a 3-spoke balance test would not be sufficient to test ballet and contemporary dancers as the YBT and its iterations often do not include the crossed side and crossed front spokes. While the YBT commonly includes the front spoke, which is seen as being a challenge, they also often include the open back and crossed back spokes which are seen in this research as being less challenging for dancers.[21,24]

Additionally, although all other dance-specific modifications have used the traditional touch down method, keeping the toes off the ground and pushing a reach indicator more closely mimics dance movements, such as a fondu or développé, commonly seen in university-level ballet and contemporary training.[12,36] The specificity principle is important not just in training, but also in testing and screening. Testing should relate to the fundamentals of the specified activities, mimicking movements, intensities, duration, and pace to appropriately assess the competence of a specific skill.[43]

Practical and Clinical Applications and Implications:

Although there were no statistically significant differences detected between tempo variations, future research is to test dancers by incrementally increasing the tempo with each trial to find the dancers' maximal speed of movement while maintaining control. It is suspected that the speed-accuracy trade off may come into play more.[19,33]

It is suggested that dancers be given a series of balance tests where more unstable and challenging conditions can progress to employ plasticity in the neuromuscular system and lead to neuromotor excellence.[10,30,32] Due to this, future research would benefit from using this research as well as previous research[29] to further develop the dsSEBT, creating a protocol which includes dsSEBT tasks that increase in difficulty to challenge balance performance proficiency.

Conclusion

This was the first study to test the effects of different tempos and reach orders with the SEBT on ballet and contemporary dancers. The tempo and changed order conditions tested in this study have furthered the development of a dance-specific dynamic balance test which uses objective measurements for use in clinics, research, and educational performance testing. Future research is justified to develop a dance-specific SEBT protocol with sufficient validity and increasing difficulty that can be used as a performance capacity test for balance and to further be developed to examine effects of injured versus non-injured dancers.

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Legends

Table 1 Participant Characteristics

Age (yrs) (mean± SD)	Stature (cm) (mean± SD)	Mass (kg) (mean± SD)	BMI (mean± SD)	Leg Length (cm) (mean± SD)	Dance Experience (yrs) (mean± SD)
21.18± 3.90	162.68± 6.57	61.35± 11.25	23.54± 3.59	85.55± 5.17	13.09± 5.81

Table 2 Protocol Details

Variation Name	Recommended Criteria
oSEBT	- Shoes off - Testing order of spokes will begin with the front spoke moving clockwise for the left standing foot and counterclockwise for the right standing foot - Minimal stance foot movement is allowed, no heel raises - Trunk movement allowed under control - Hands placed on hips for all trials [14,21]
dsSEBT Average Tempo (72bpm)	- Shoes off - Keep navel facing forward - Refrain from axial rotation (turning) - Testing order of spokes will begin with the front spoke moving clockwise for the left standing foot and counterclockwise for the right standing foot - Minimal stance foot movement is allowed, no heel raises - Flexing and extending of the knee is permitted - Participants must complete test on all spokes before standing fully on gesture limb again - Arms in second position (running roughly parallel to the ground and rounded slightly) - Head is to remain still, gaze fixed on a target [1,22,28,29]

dsSEBT Slow Tempo (50bpm)	-	Same as Average Tempo with new slower tempo
dsSEBT Fast Tempo (100bpm)	-	Same as Average Tempo with new faster tempo
dsSEBT Order Change	- - -	Same as Average Tempo with two modifications: Testing order of spokes will be crossed side, crossed front, crossed back, front, back, open front, open back, open side No tempo; self-selected pace

Table 3 Dynamic balance performance per condition as shown by the core variables, averaged across all reach directions

Condition	Average Reach Distance (% of limb length) mean ± SD (95% CI)	Average Center of Pressure (cm^2) mean ± SD (95% CI)	Average Error Scores (rating system) mean ± SD (95% CI)
oSEBT	84.65± 5.64 (82.15,87.15)	4.90± 1.75 (3.99,5.80)	1.19± 1.10 (0.67,1.68)
dsSEBT Avg. Tempo	81.22± 4.76[a,b] (79.11,83.33)	3.93± 0.89 (3.47,4.39)	3.33± 1.99[a] (2.39,4.24)
dsSEBT Slow Tempo	82.60± 4.82[a] (80.47,84.74)	3.86± 0.97 (3.36,4.36)	3.52± 2.03[a] (2.57,4.46)
dsSEBT Fast Tempo	81.24± 5.11[a] (78.97,83.50)	4.12± 1.08 (3.57,4.68)	2.73± 1.89[a] (1.84,3.61)
dsSEBT Order Change	82.30± 4.87[a] (80.14, 84.46)	3.95± 1.02[a] (3.43,4.47)	2.87± 1.76[a] (2.05,3.69)

[a] statistically significant difference from oSEBT ($p < 0.05$ for RD and $p < 0.005$ for COP & ES)
[b] statistically significant difference from dsSEBT Slow Tempo ($p < 0.05$)

Table 4 Dynamic balance performance per spoke as shown by the core variables, averaged across all conditions

Spoke	Average Reach Distance	Average Center of Pressure (cm^2)	Average Error Scores

	(% of limb length) mean ± SD (95% CI)	mean ± SD (95% CI)	(rating system) mean ± SD (95% CI)
Front	78.73± 5.16[c,d,e,g] (76.44,81.01)	5.90± 2.10[c,d,e,f] (4.85,6.94)	0.21± 0.20[f,g] (0.11,0.31)
Open Front	80.70± 4.74[a,c,d,e,g] (78.60,82.80)	6.87± 2.78[c,d,e,f] (5.49,8.26)	0.20± 0.20[f,g] (0.10,0.29)
Open Side	81.51± 5.26[a,c,d,e,g] (79.17,83.84)	4.57± 1.50[b,c,d,e] (3.83,5.32)	0.20± 0.23[f,g] (0.08,0.31)
Open Back	85.37± 5.53[a,d,g] (82.91,87.82)	2.92± 0.67[b] (2.59,3.26)	0.13± 0.13[f,g] (0.06,0.20)
Back	90.41± 6.63[a,g] (87.47,93.35)	2.81± 1.18[b] (2.22,3.38)	0.07± 0.07[f,g] (0.03,0.10)
Crossed Back	87.52± 6.44[a,d,g] (84.66,90.37)	2.71± 0.84[b] (2.29,3.12)	0.11± 0.10[f,g] (0.06,0.15)
Crossed Side	79.49± 5.32[c,d,e,g] (77.13,81.85)	3.50± 1.45[b] (2.78,4.22)	0.98± 0.51 (0.75,1.25)
Crossed Front	75.49± 4.69[a,c,d,e] (73.42,77.57)	4.97± 1.25[c,d,e,f] (4.35,5.58)	0.57± 0.27[f] (0.44,0.71)

[a] statistically significant difference from front spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[b] statistically significant difference from open front spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[c] statistically significant difference from open back spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[d] statistically significant difference from back spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[e] statistically significant difference from crossed back spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[f] statistically significant difference from crossed side spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)
[g] statistically significant difference from crossed front spoke ($p < .05$ for RD and $p < .00178$ for COP & ES)

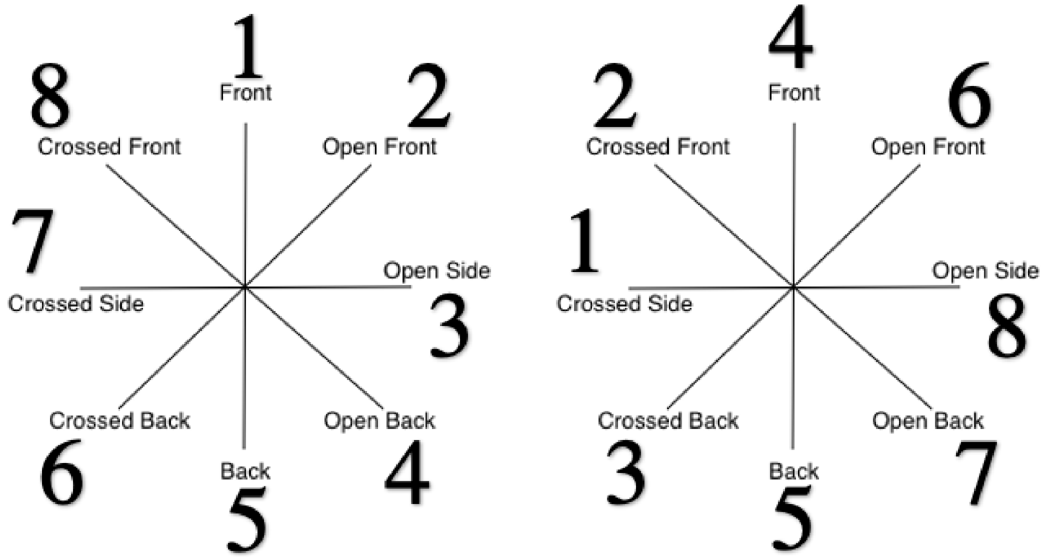

Figure 1. Left Stance: Original Order (Left) and New Order Variation (Right)