consisted of five bends of the supporting leg with the arms adducted horizontally in order to touch the floor with the fingertips[34]. As the support leg extended to return to the start position, the arms abducted horizontally again to 90˚. The number of times the fingertips touched the floor was recorded up to, and including, five (0-5) instances. The termination test criterion was displacement of the supporting foot, knee valgus, hip internal rotation, or pelvic drop[34].

The Romberg test is a widely used neurology test[33] with various modifications[34,41]. The modified Romberg was selected for this study to provide a potentially greater balance challenge for dancers, replicating an earlier study on dancers[34]. The test comprised a single-leg balance in a parallel bare foot stance. It was conducted with the non-supporting leg slightly bent and not touching the supporting leg. Arms were crossed across the chest and a blindfold was worn[34,41]. Romberg tests are commonly measured up to 30 seconds' duration[34], subsequently this protocol was followed with the additional data recording of sustained balances up to a minute, so 0-60 seconds, allowing for the participants' healthy profile and skill ability. Termination test criterion was the non-weight bearing foot touching the floor and pronation of the supporting foot.

The BioSway™ (Biodex Medical Systems Inc, New York, USA) used for the purposes of this study has shown acceptable intratester reliability of ICC= 0.82-0.43 for stability index and ICC= 0.81-0.55 for foot placement, with the overall stability index scores showing the most reliable stability scores (0.82 for intratester and 0.70 for intertester)[42]. The Biosway Postural Sway test used in this study assessed neuromuscular control by measuring a participant's ability to maintain unilateral postural stability on a static surface using the Stability Index to quantify a participant's ability to maintain their centre of balance in unilateral stance, thus measuring postural sway. The BioSway balance tests were conducted with eyes open in single-leg bare foot stance and participants were asked to look ahead during the tests. Participants were asked to step onto the platform and to place their arms in a neutral position. Foot position coordinates marked out on the platform were maintained for the supporting foot throughout all the trials. Participants performed three 20 second trials on each leg. Data quantified postural stability:overall stability, anterior/posterior and medial/lateral, and the overall stability data was recorded for further analysis. Data were excluded if the non-supporting foot was put down, or if the supporting foot moved from the marked coordinates.

Data Analyses

All variables were tested for normality using the Kolmogorov-Smirnov and Shapiro-Wilk test. Following the results of testing, Spearman's Rank Order Correlation (rho) was selected for correlational analysis of the data. The strength of the value of the correlation coefficient (rho) was determined by Cohen's[43] guidelines and interpreted based on the following scale: 0.10 to 0.29 (small), 0.30-0.49 (medium), 0.50 to 1.0 (large). Statistical significance was set at $p<0.05$ using the SPSS 26 (IBM Corporation, Chicago, Ill).

Results

Test descriptive measures are presented in Table 1. Spearman's correlations for all test variables are presented in Table 2. The strongest correlations were shown for the following SEBT reach directions: SEBT 45˚ and SEBT 90˚ ($r = 0.809$, $p < 0.01$), SEBT 135˚ and SEBT 180˚ ($r = 0.808$, $p < 0.01$), SEBT 225˚ and SEBT 270˚ ($r = 0.787$, $p < 0.01$), SEBT 0˚ and SEBT 45˚ ($r = 0.776$, $p < 0.01$). Some further fairly strong to moderate correlations between SEBT reach direction variables can also be seen in Table 2. Otherwise, the Romberg showed a weak correlation with SEBT 0˚ ($r = 0.240$, $p < 0.01$), the Pirouette test showed weak correlations with SEBT 0˚ ($r = 0.193$, $p < 0.05$), SEBT 45˚ ($r = 0.202$, $p < 0.05$), SEBT 180˚ ($r = -0.203$, $p < 0.05$), SEBT 225˚ ($r = -0.256$, $p < 0.01$) and SEBT 270˚ ($r = -0.236$, $p < 0.01$). The Biosway™ showed moderate correlations with SEBT 0˚ ($r = 0.307$, $p < 0.01$) and

SEBT 45˚ (r = 0.307, $p < 0.01$) and weak correlations with SEBT 90˚ (r = 0.208, $p < 0.05$), SEBT 225˚ (r = -0.247, $p < 0.05$) and SEBT 270˚ (r = -0.250, $p < 0.05$). The Airplane test showed a weak correlation with the Romberg (r = 0.295, $p < 0.01$).

Table 1. Mean and Standard Deviation of the measures of the field balance tests

Variables	Mean ± SD
SEBT 0° (n=158)	65.53 ± 11.02
SEBT 45° (n=158)	69.31 ± 11.32
SEBT 90° (n=158)	77.10 ± 13.20
SEBT 135° (n=158)	84.86 ± 12.68
SEBT 180° (n=158)	88.39 ± 14.93
SEBT 225° (n=158)	84.07 ± 17.41
SEBT 270° (n=158)	73.14 ± 21.04
SEBT 315° (n=158)	69.12 ± 28.12
Romberg (n=158)	34.55 ± 16.90
Pirouette (n=148)	48.50 ± 31.34
Biosway (n=100)	0.78 ± 0.40
Airplane (n=114)	4.61 ± 0.93

Note: right and left legs tested so n=total number of leg tests. Units of measurement: SEBT reach directions were measured in centimetres (cm), Romberg in seconds, Pirouettes in cm, Biosway™ in Stability Index (sway) and Airplane in touches to floor (1-5)

Table 2 about here (attached at end of paper)

(Table 2. Spearman's correlations between measures of field balance tests)

Discussion

The purpose of this study was to assess associations between static and dynamic balance tests used to measure postural stability in dancers. Although our results indicated strong relationships between some SEBT reach directions, other relationships between the balance test variables were weak, except for a moderate correlation between the Biosway and SEBT 0˚ and the Biosway and SEBT 45˚. The only correlation not including a SEBT reach direction was between the Airplane and Romberg although this was a weak relationship. In this study the eight SEBT reach directions were assessed rather than a composite SEBT score or the Y test to see if any of the eight directions had an association with each other or with the other balance tests. Those SEBT directions demonstrating the strongest relationships with other directions were close in proximity on the SEBT grid although it is not possible to ascertain potential causes of these associations. In reference to dancers' abilities in the SEBT reach directions, the few studies utilising the SEBT in studies on dance populations have reported mixed results. For example, a randomised controlled trial testing eight SEBT directions following a whole body vibration (WBV) intervention, noted an improvement in the anterior, anteriomedial, medial and anterior lateral directions [44], whilst in another study, dancers achieved higher scores than non-dancers in the medial and posteriomedial planes of movement[24]. Currently, there is inconclusive evidence in the literature on dancers' balance ability in the SEBT reach directions.

Whilst these five tests have been used previously in research studies on dancers' balance, it was acknowledged that each test has different protocols and conditions, resulting in some variations in assessment of postural stability, and this does not necessarily diminish the value of each task. A key example is the Romberg performed with eyes closed. Mixed findings have been reported on dancers' balance ability in vision conditions[14] and it has been argued that whilst dance training increases the influence of proprioceptive skills over vision information, dancers' balance strategies rely on different senses in the multimodal processing depending on the specific balance task[45]. Although clinical assessments have identified classifications of balance and postural control strategies for those with balance problems[46,47], to date, no such balance tool is available for assessing dancers. The five tests in this study demonstrate some resonance with the clinically based Balance Evaluation Systems Test (BESTest)[46], most notably, the pirouette in their Anticipatory Postural Adjustments category and the Romberg in their Sensory Orientation category but it should be remembered that the BESTest was designed for a very different population.

In previous literature, the SEBT, Airplane, Biosway, Romberg, and Pirouette tests have been identified as reliable or accepted balance tasks for the dance population in previous literature[9,14,34,35,36,40]. It is possible that, in past research, assumptions have been made about the functionality of the tests for dancers even though there have been clear differences in test conditions, and no replication of studies, for example, pirouette studies which have included a range of differing turn tasks[9,35,36]. Therefore, the predominately weak associations between these field tests revealed in this study may suggest that some balance measures are inadequate for an accurate assessment of dancers' postural stability, but this may not diminish the validity for some of the tests for different populations. The participants in this study were undergraduate dancers and injury free and it should be noted that there may be differences in what the tests evaluate for postural stability for alternative populations. For example, different results might be elicited in a symptomatic dance population or for professional dancers.

When considering the relevance of balance tests employed in research on dancers, several factors need be considered. To date, screening, research studies, and rehabilitation work with dancers have employed a battery of field balance tests[14] but these tests may have little or no predictive power. The lack of replicated studies in balance research on dancers[13,14] has implications for the conclusions drawn from balance studies. Assumptions on the functionality and relevance of balance tests for dancers are likely to have been made over the years, but reported results may need to be considered within the context of assessed study limitations in the literature[14,48,49].

Another factor to be considered when assessing balance tests is the task difficulty. Balance tests do not necessarily produce challenging enough demands for dancers[50,51,52,53]. Dancers' balance has been found to be more automatized than non-dancers[50] with greater behavioural flexibility[2] and less cognitive involvement[50]. They use a wide range of balance strategies to maintain, achieve or restore equilibrium and have fast anticipatory reactions. It has been suggested that dancers may reach a ceiling effect in postural automaticity particularly in eyes open tasks[50] . Further balance study limitations can include levels of expertise[50], for example, if the task is too simple and not challenging enough for the level of expertise of the dancers being assessed[54], or alternatively, too demanding[55]. Notwithstanding our results indicating weak correlations between specified static and dynamic balance tests, further investigation in this area of research is recommended.

Strengths and limitations

To our knowledge, this is the first study to examine potential associations between specific balance tests employed to measure dancers' postural stability. The relatively large number of volunteers could also be treated as a study strength[49]. However, the present results may have been subject to certain methodological limitations. There is no agreed definition for the wider construct of postural control or stability for dancers[47]. The postural control and movement complexity required for the SEBT and Airplane could be regarded as only moderately challenging for dancers. In addition, reach distances in the SEBT may have been subjected to participants' own exertion and interpretation of the given instructions. The Biosway may not have posed a sufficient challenge for the participants as it was a static position and resembled a basic element of dance technique. A limitation was that the participants were undergraduate dance students and testing on professional dancers might have yielded different results. Also, there were varying levels of expertise demonstrated in the pirouette test and it is possible that some participants were holding the body in a rigid position due to a learned effect or misperception of the required technique[55].

Conclusion

The purpose of this study was to investigate the potential associations between static and dynamic balance tests already employed in assessing dancers' postural stability, and to ascertain their relevance for assessing dancers' postural stability. Our findings indicated associations between some SEBT reach directions and certain SEBT directions with the Romberg, Pirouette, and Biosway, and the Airplane and Romberg., Except for the associations between some SEBT directions , the strength of the associations between tests was weak. Overall, these weak associations between tests may suggest that some balance measures have some limitations in assessing accurately dancers' postural stability and may not challenge dancers who have demonstrated greater behavioural flexibility in balance tasks. This study has pointed to the need for further investigation of balance assessment tools utilised to assess dancers' postural stability to help reduce study limitations in this area of research. Furthermore, identification of definitions of the wider construct of postural stability (and postural control) for dancers may enhance the choice and application of measurement tools for dancers in the future.

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Table 2. Spearman's correlation analysis between field balance tests

	SEBT 0°	SEBT 45°	SEBT 90°	SEBT 135°	SEBT 180°	SEBT 225°	SEBT 270°	SEBT 315°	Romberg	Pirouette	Biosway	Airplane
SEBT 0°	-	.776**	.600**	.447**	.370**	.205**	.080	.500**	.240**	.193*	.307**	.159
SEBT 45°	-	-	.809**	.569**	.408**	.167*	-.008	.318**	.148	.202*	.300**	.145
SEBT 90°	-	-	-	.728**	.509**	.269**	.030	.256**	.084	.065	.208*	.097
SEBT 135°	-	-	-	-	.808**	.591**	.366**	.506**	.050	-.115	.049	.023
SEBT 180°	-	-	-	-	-	.778**	.549**	.682**	.134	-.203*	-.079	.113
SEBT 225°	-	-	-	-	-	-	.787**	.695**	.065	-.256**	-.247*	.019
SEBT 270°	-	-	-	-	-	-	-	.620**	-.032	-.236**	-.250*	.056
SEBT 315°	-	-	-	-	-	-	-	-	.135	-.074	.030	.164
Romberg	-	-	-	-	-	-	-	-	-	.028	-.092	.295**
Pirouette	-	-	-	-	-	-	-	-	-	-	.100	.033
Biosway	-	-	-	-	-	-	-	-	-	-	-	-.047

Airplane	-	-	-	-	-	-	-	-	-	-	-	-

SEBT = Star Excursion Balance Test

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)