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Associations Between Static and Dynamic Field Balance Tests in Assessing Postural Stability of Female Undergraduate Dancers

Frances Clarke, PhD[1,2], Yiannis Koutedakis, PhD[3,4], Margaret Wilson, PhD[5], Matthew Wyon, PhD[2,4]

[1]Trinity Laban Conservatoire of Music & Dance, London, UK

[2]National Institute of Dance Medicine and Science, UK

[3]Department of Sport and Exercise Sciences, University of Thessaly, Trikala, Greece

[4]Sport and Physical Activity Research Centre and School of Performing Arts, University of Wolverhampton, Walsall, UK

[5]Department of Theatre and Dance, University of Wyoming, Laramie, Wyoming, USA

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Correspondence address:

Frances Clarke
Faculty of Dance,
Trinity Laban Conservatoire of Music & Dance,
Creekside,
London, SE8 3DZ
UK

Phone: +44 020 8305 9422
Email: f.clarke@trinitylaban.ac.uk

Abstract

Balance testing on dancers has revealed a wide variety of assessment tools. However, as most field balance tests have been developed for either sport or elderly populations, the evidence of associations between tests and their functional relevance to dance is inconclusive. We assessed possible associations between five such field balance tests**.** The total of 83 female undergraduate dance students (20±1.5 years; 163 ±6.6 cm; 61 ±10.8 kg) volunteered for the tests. They executed the Star Excursion Balance Test (SEBT), the modified Romberg test, the Airplane test, the BioSway Balance System (Biodex, USA) and a dance-specific pirouette test. Spearman's correlation coefficients examined relationships between the measures of the balance tests. Results showed quite strong to strong relationships between some SEBT reach directions ($p<0.01$), and very weak to moderate relationships between some balance tests including some SEBT directions, Romberg, Airplane, Biosway, and pirouette ($p<0.01$ and $p<0.05$). Our findings suggest that current tests used to assess dancers' postural stability need further investigation to ensure functionality and relevance.

Introduction

Field static and dynamic balance tests are useful tools in assessing dancers' postural stability, as they can be set up and utilised in dance studios and laboratories; they are also quick and efficient to use. The importance of testing balance is widely recognised as important for dancers[1,2] and an integral part of the assessment of dancers in codified theatrical dance techniques[2,3] and assessing optimal performance[4,5]. Field balance tests are frequently used to evaluate postural stability in dance screening programmes at the beginning of a performance or study season[3], and/or following injuries and subsequent rehabilitation work[6,7]. Furthermore, field tests have been utilised in balance studies on dancer-specific skills[8,9], comparisons between dancers and athletes[10,] and dancers and non-dancers[11], and investigations on specific sensory organisation of the visual, proprioceptive and vestibular senses[3,12]. However, to date, a wide range of field assessment tools and test protocols have been employed for assessing dancers' balance but with no evident replication power[13,14] or analysis of associations between tests.

Balance has been defined as an individual's ability to control equilibrium[15,16] and is a complex phenomenon in the case of dancers[3,17]. The balance process maintains the position of the body's centre of gravity over the base of support, relying on continuous, rapid feedback from visual, vestibular, and somatosensory structures and followed by coordinated neuromuscular actions[18,19]. Balance is required during both locomotion and stance, thus, two major types of balance have been defined for measurement purposes. Static balance is the ability to maintain postural stability with the centre of mass over the base of support with minimal movement or at rest[20], whereas dynamic balance is the ability to maintain postural stability with the centre of mass over the base of support with the body in motion[20]. Theatrical dance genres demand expert skill in both static and dynamic balance.

Dancers, like gymnasts, use both quick and slow movements in their repertoire, and often use a small base of support[13,15,21]. Moreover, many balances in dance relate more to dynamic equilibrium in response to sudden movements such as acceleration, deceleration, and rotation[16,22,23]. Surprisingly, assessments of ballet dancers' balance ability are based predominately on static balance tests[13], although assessment measures not utilising force plates, such as field tests, do use more dynamic balance tests[24]. The majority of static balance tests perform one-legged stance positions[25,26,27] which may not relate to the complex, dynamic dance movements[28] in dance repertoire.

As aforementioned, a range of field assessment tools have been utilised to assess dancers' postural stability but the majority of these were developed for sports people and the general population. The Star Excursion Balance Test (SEBT) was originally developed as a rehabilitative tool[29] but has been adapted with a number of modifications including the Y

Balance Test[30,31], and a modified SEBT (m/r SEBT)[32] . One study which utilised a battery of tests including the SEBT, the Balance Error Scoring System (BESS) and the Modified Bass Test of Dynamic Balance (BASS) found mixed results between dancers and non-dancers' balance ability[24]. Other field tests have used a bespoke one-legged stance[8,25], a modified Romberg test[33,34], the Biosway Balance test[12], the Airplane test[34], or more complex, dance-specific tasks such as a modified ronds de jambe[6] and pirouettes[28,35,36].

Despite the range of studies, and to the best of our knowledge, no previous research has investigated the associations between field balance tests. This limited knowledge in the field may impede the choice of appropriate tests to assess balance ability in dance training, screening and research studies. Therefore, the aim of this study was to assess possible relationships between balance tests assessing static and dynamic balance and to ascertain their relevance to measuring dancers' balance. To assess the association between recognised field balance tests, the researchers selected five field tests used in assessing postural stability of adult dancers who were either in full time dance training or working as professional dancers in theatrical dance genres[14]. Both static and dynamic balance are essential to dance performance, therefore results were compared between static and dynamic balance tests. Three dynamic balance tests were selected: Star Excursion Balance Test, the pirouette test and the Airplane test, and two static balance tests were selected: modified Romberg and the Biosway test. The tests varied in the nature of their test protocols, which may imply assessment of different aspects of postural stability. However, as the tests selected for this study are commonly used in screening, training programmes, and research tests on dancers, the analysis of possible associations between them was deemed to be important in order to examine their potential functional relevance for dancers. It was hypothesised that there would be no significant relationships between the five field balance tests.

Methods

Participants

Following approval by a University Ethics Committee, and *a priori* power analysis assuming an 80% power with an alpha level of 5%, a total of 83 female dance undergraduates (age: 20±1.5 years; height: 163 ±6.6 cm; mass: 61 ±10.8 kg; dance experience: 10.18±2.39yrs) volunteered for testing. All participants were studying on the same undergraduate dance programme and received equal hours of training in contemporary, ballet and jazz. Inclusion criteria specified that they attended dance classes for a minimum of 8 hours per week, were injury free, and that they were 18 years or older. Prior to testing, participants completed a consent form and a pre-activity health questionnaire and those with a known injury or illness were excluded.

Procedures

Prior to balance testing, anthropometric data were obtained from all volunteers, including leg length. The latter was measured with the participant lying supine, from the anterior superior iliac spine to the medial malleolus using an anthropometric tape measure[29,38]. Following the initial assessments, all participants completed a 15-minute standardised warm up session. The same researcher conducted the tests and ensured accurate positioning, alignment and performance of all participants during testing. Participants took part in tests in a randomised order; the order of supporting leg was also randomised in each test.

Measures

The Star Excursion Balance Test (SEBT) has shown a strong interrater reliability of ICC=0.35-0.93 and intrarater reliability of ICC=0.78-0.96[39]. The SEBT is marked out on a grid consisting of 8 lines marked on the floor, extending from a common point at 45˚ angle increments. The reaching directions were referenced according to the supporting leg as anterior (0˚), anteromedial (45˚), medial (90˚), posteromedial (135˚), posterior (180˚), posterolateral (225˚), lateral (270˚), and anterolateral (315˚). The test was performed on a single leg stance with the middle of the standing foot over the centre of the grid. The non-weight bearing leg extends along each designated line to maximal reach whilst maintaining the support foot on the floor and an upright posture upright facing the front[29] (Figure 1). The SEBT procedure was demonstrated by the researcher and participants performed practice trials to ensure accuracy in alignment and foot placement before the reaching distances were measured. The average of three trials was taken for each leg. The participants were instructed to bend their supporting leg as much as possible and reach in the eight directions, touching the furthest point with the most distal part of the foot. At the point of touchdown of the reaching leg, a mark was made by the researcher. Participants were not allowed to slide the foot or to put weight on the reach foot. Termination of tests criteria were displacement of the supporting foot and if weight was put on the reach foot[38]. Leg reach distances were measured (cm) for each reach direction from the centre of the grid to the touchdown mark. The reach distances in each direction were normalised to % leg length[24,29].

Figure1. Participant on the SEBT

Performance of the Star Excursion Balance Test using the left leg as the limb stance in the medial direction

Pirouettes are a recognised dance-specific balance test with en dehors turns being most widely used[28,35,56] . Although, to date, no pirouette tests have been empirically validated[14], pirouettes are recognised as having functional relevance when measuring dancer's postural stability[28]. Single en dehors pirouettes[28,35,36] were selected for this study replicating the predominant use of en dehors pirouettes in published studies[14]. In the pirouette test, participants were instructed to perform six single en dehors turns consecutively, starting from and returning to, a small open turned out position of the feet with one foot crossed in front of the other (4th position). Tests were conducted on both legs. The pirouettes were conducted on the ball of the foot (*demi pointe*), and during rotation, both legs were rotated outwards, with the non-weight bearing leg bent with a 90˚angle at the knee joint, and toes in contact and placed in front of the knee of the supporting leg *(retiré).* The arms were held in front of the body (1st position) during the rotation. The timing of the sequential turns replicated a commonly used tempo (approximately 96BPM) used in Intermediate level ballet classes, and with which the participants were familiar. Participants wore soft, thin-soled ballet shoes for the pirouette tests. Before testing began, a mark was taped to the floor to signal the start position of the supporting foot. At the start of the test, participants placed the ball (head of the metatarsals) of their front foot on the marker on the floor. At the end of the sixth turn, the final position of the ball of the front foot was marked and the displacement distance from the start mark to the finish mark was measured in centimetres (cm). Termination of tests criteria were the inaccurate placement of feet in the turn preparation position and the non-weight bearing foot touching the floor during a turn.

The Airplane test has been determined as a reliable indicator of a dancer's functional balance skill level[34,40]. The single-leg balance task was conducted in bare feet. The tests started with the non-weight bearing leg extended to the posterior direction creating a horizontal line with the torso which is flexed at 90˚. The arms were abducted to 90˚ in the start position[34]. The test 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)