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The Biodex Balance System and postural control in female rugby and netball players and dancers

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Abstract
Introduction. **Sporting performance is characterized by center of mass control that prevents a loss of balance, which may have performance and injury implications.** Aim of Study. **The aims of this study were to determine postural stability scores in female rugby and netball players and dancers, and to determine differences in non-dominant and dominant limb performance within each group.** Material and Methods. **A total of 39 rugby players, 35 netballers, and 30 dancers completed the Athlete Single Leg Stability Testing program at Level 4 of the Biodex Balance System (BBS: Shirley, New York, USA), which quantitatively measures postural control. During the trial the participants maintained a unipedal stance and Antero-Posterior Stability Index (APSI), Medio-Lateral Stability Index (MLSI), and Overall Stability Index (OSI) were measured in dominant and non-dominant limbs.** Results. **For APSI, there was a significant difference in a non-dominant limb between rugby and netball ($p = 0.04$), and rugby and dance ($p = 0.003$), and in a dominant limb between rugby and dance ($p = 0.01$). For MLSI, a significant difference existed in a dominant limb between rugby and dance ($p = 0.004$), and netball and dance ($p = 0.02$). For OSI, there was a significant difference in a non-dominant limb between rugby and dance ($p = 0.02$).** Conclusions. **The APSI and MLSI values make specific contributions to OSI, and dancers have superior postural control in comparison to rugby players and netballers. However, for MLSI these differences are reduced in the non-dominant limb which may highlight an area for a potential training intervention.**

KEYWORDS: injury, dynamic balance, antero-posterior, medio-lateral, non-dominant limb.

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Introduction

Balance or postural control is an ability of an individual to maintain their center of mass within their base of support [16], and is a requirement for activities of daily living and sports. Static balance involves the center of mass movements within a static base of support, whereas dynamic balance requires movements of both the center of mass and the base of support. Static and dynamic balance contribute to effective execution of motor skills. Sporting performance is characterized by center of mass control that prevents a loss of balance, which may have performance and injury implications. Three very different performance activities are rugby union, netball, and dance, but they are all characterized by a need for optimal dynamic balance. Rugby union is a collision sport with repeated, short duration, high-intensity workloads [10]. Netball requires periods of high intensity including sprinting, jumping, and directional changes, as well as lower intensity walking and standing [6]. In dance, short sets of explosive movements require coordination and balance to achieve effective performance [2].
The Biodex Balance System (BBS: Shirley, New York, USA) can quantitatively measure posture during static and dynamic conditions and is composed of a circular platform that can move in anterior, posterior, medial, and lateral directions and utilizes three measurements,

namely: Antero-Posterior Stability Index (APSI), Medio-Lateral Stability Index (MLSI), and Overall Stability Index (OSI). The primary aim of this study was to determine postural stability scores via the BBS in female rugby and netball players and dancers with consideration of specific movement requirements. The secondary aim was to determine differences in non-dominant and dominant limbs' performance within each group.

Materials and Methods

Participants

One hundred and four participants volunteered to participate in this study (n = 39 rugby players, n = 35 netballers, n = 30 dancers) and demographics are outlined in Table 1. Groups were standardized for weekly participation levels of 10 hours per week of training/matches and rehearsals. All participants were female, 18 years of age or older, and were excluded from the study if they had suffered an injury in the previous 30 days that prevented them from participating in trainings, matches, or dance classes [2]. To calculate a sample size, statistical software (GPower; University of Düsseldorf, Düsseldorf, Germany) was used. Given the study design (Welch's ANOVA), an effect size = 0.40, alpha error < 0.05, and desired power (1-ß error) = 0.95, the total sample size calculation resulted in a total of 102 participants. Allowing for potential attrition, the minimal sample size was set at 104 participants.

The participants completed a medical screening questionnaire prior to participating in the study, and additional exclusion criteria included heart disease, pregnancy, and potential balance disorders such as vertigo, stroke, diabetes, and neuropathy. Informed consents were obtained from all individual participants included in the study. Participation was voluntary, and the participants were provided with information sheets and completed informed consent forms prior to the participation. All procedures involving human participants were performed in accordance with the ethical standards of the Institutional Research Committee (SPA-REC-2015-185) and the Declaration of Helsinki of 1975, as revised in 1983.

Table 1. Participants demographics

Group	Age (years)	Height (cm)	Weight (kg)
Rugby (n = 39)	20.39 (1.34)	167.46 (5.30)	68.80 (5.56)
Netball (n = 36)	20.60 (1.16)	169.64 (6.72)	63.01 (5.95)
Dance (n = 30)	20.44 (1.13)	163.96 (7.99)	57.58 (7.43)

Data is presented as mean (SD).

Procedures

All testing was conducted under supervision of the same researcher and prior to the testing the participants' height (cm) was measured using a stadiometer (Leicester Height Measure, Child Growth Foundation, Leicester, UK) and body weight (kg) was recorded using digital scales (Salter 9028, Kent, UK). The participants' age was recorded and participation in other sports and dances was self-reported prior to the testing, with the participants completing a form to ensure they did not cross participate. No individuals were found to cross participate and demographics of the participants are reported in Table 1. The testing was conducted prior to training or dance rehearsal and the participants did not exercise for at least 12 hours prior to the testing to prevent any potential fatigue effects on balance.

Biodex Balance System Testing

The BBS (Shirley, New York, USA) is a valid and reliable measure of postural stability [1], and APSI, MLSI, and OSI measurements are calculated from a degree of platform oscillation, with lower values representing good stability. The BBS consists of a circular platform that moves in anterior, posterior, medial, and lateral directions with up to 20° of platform tilt in a 360° range of motion, which can occur simultaneously in antero-posterior and medio-lateral planes [5]. The BBS has settings from level 1 to level 12, with level 12 being the most stable and level 1 being the least stable. The varying levels of tilt create a dynamic situation that results in instability. A high stability index represents an angular excursion of the center of gravity and is indicative of a high degree of movement during a test and therefore poor balance [14]. Prior to a movement, the platform is locked in a stable position which allows participants to mount the platform.

The participants completed the Athlete Single Leg Stability Testing program at Level 4 barefoot, with their hands on their hips and eyes open. Level 4 is sufficiently challenging as a measure of postural stability [5]. During the trial, the participants attempted to maintain a cursor on a screen in a central position by adjusting their posture accordingly to keep the platform in a neutral position. The platform is interfaced with computer software that provides an objective balance assessment [14]. The participants maintained a unipedal stance during the trial. Following a familiarization trial, the participants completed three trials of 20 seconds on one leg with a 30-second rest period. Leg order was randomized using Random Allocation Software (Version 10). Data collection was performed by a Chartered Physiotherapist trained in the BBS. A mean of the three trials was calculated.

Statistical analysis
A Welch's ANOVA determined differences in the participants' demographics for age, height, and weight of the three groups, and a post-hoc analysis was completed using a Games–Howell test. A Shapiro–Wilk test was used to determine normality of APSI, MLSI, and OSI data, and a Levene's test assessed homogeneity of variance. The Welch's ANOVA determined a difference between OSI for non-dominant and dominant limbs for the three groups, and the post-hoc analysis was completed using the Games–Howell test. These tests were used because assumptions of normal distribution and homogeneity of variance were not met. ANOVA is robust in dealing with violations of normality, and samples of 25 participants per condition should be used [15], which is in accordance with this study design. The Welch's ANOVA is robust in dealing with violations of homogeneity of variance [17]. A partial eta-squared test (η^2) was used to calculate an effect size of groups, with effect sizes classified as 0.01 (small), 0.06 (medium), and 0.13 (large) [6]. A Wilcoxon signed-rank test investigated whether there was a statistically significant difference between a non-dominant and dominant limb in the three stability indexes of APSI, MLSI, and OSI for the three groups. All analyses were completed using SPSS version 24 (IBM, USA) and significance was set at $p < 0.05$, and 95% confidence intervals (CI) reported. Data is presented as mean (± Standard Deviation [SD]).

Results

Participants' demographics
Analysis of age, height, and weight of the three groups revealed no significant difference for age between the three groups: rugby and netball (p = 0.74, CI -0.90 to 0.48), rugby and dance (p = 0.98, CI -0.77 to 0.65), and netball and dance (p = 0.86, CI -0.52 to 0.83). For height, there was a significant difference between netball and dance (p = 0.009, CI 1.26 to 10.11), but no significant difference existed between rugby and netball (p = 2.74, CI -5.55 to 1.19), and rugby and dance (p = 0.11, CI -0.58 to 7.58). For weight, a significant difference existed between rugby and netball (p = 0.00, CI 2.61 to 8.99), rugby and dance (p = 0.00, CI 7.31 to 15.3), and netball and dance (p = 0.006, CI 1.38 to 9.47).

APSI
The Shapiro–Wilk test revealed that APSI was not normally distributed for the three groups for a non-dominant (rugby, p = 0.00; netball, p = 0.00; and dance, p = 0.04) and dominant limb (rugby, p = 0.00; netball, p = 0.01; and dance, p = 0.01). There was no homogeneity of variance for a non-dominant (p = 0.00) and dominant limb (p = 0.005). A significant difference existed between the groups for a non-dominant limb F(2, 102) = [7.33], p = 0.001), with the post-hoc analysis identifying a significant difference between rugby and netball (p = 0.04, CI 0.02 to 0.98), rugby and dance (p = 0.003, CI 0.22 to 1.17), and the partial η^2 was 0.12, indicating a medium effect size (Table 3).
A significant difference between the groups existed for a dominant limb F(2, 102) = [5.48], p = 0.006), with the post-hoc analysis identifying a significant difference between rugby and dance (p = 0.01, CI 0.14 to 0.96), and the partial η^2 was 0.10, indicating a medium effect size (Table 4).

MLSI
The Shapiro–Wilk test revealed that MPSI was not normally distributed for the three groups for a non-dominant (rugby, p = 0.00; netball, p = 0.00; and dance, p = 0.00) and dominant limb (rugby, p = 0.00; netball, p = 0.001; and dance, p = 0.01). There was no homogeneity of variance for non-dominant limb (p = 0.007) and dominant limb (p = 0.00). No significant difference existed between the groups for a non-dominant limb F(2, 102) = [2.84], p = 0.06), and the partial η^2 was 0.05, indicating a small effect size (Table 3).
A significant difference existed between the groups for a dominant limb F(2, 102) = [6.71], p = 0.002), with the post-hoc analysis identifying a significant difference between rugby and dance (p = 0.004, CI 0.18 to 1.03), and netball and dance (p = 0.02, CI 0.24 to 0.39). The partial η^2 was 0.12, indicating a medium effect size (Table 4).

OSI
The Shapiro–Wilk test revealed that OSI was not normally distributed for the three groups for a non-dominant (p = 0.00) and dominant limb (p = 0.00). There was no homogeneity of variance for a non-dominant (p = 0.00) and dominant limb (p = 0.00).
A significant difference existed between the groups for a non-dominant limb F(2, 102) = [7.06], p = 0.001), with the post-hoc analysis identifying a significant difference between rugby and dance (p = 0.02, CI 0.31 to 1.62), and the partial η^2 was 0.13, indicating a large effect size (Table 3).

A significant difference existed for a dominant limb $F(2, 102) = [9.39]$, $p = 0.01$), with the post-hoc analysis identifying a significant difference between rugby and netball ($p = 0.03$, CI 0.05 to 1.21), rugby and dance ($p = 0.00$, CI 0.41 to 1.49), and netball and dance ($p = 0.04$, CI 0.02 to 0.62). The partial η^2 was 0.16, indicating a large effect size (Table 4).

Non-dominant and dominant limb within groups

The Wilcoxon signed-rank test found no significant difference between a non-dominant and dominant limb for all groups as follows.

For rugby players the values were: APSI ($Z = -0.99$, $p = 0.33$), MLSI ($Z = -0.63$, $p = 0.53$), and OSI ($Z = -0.87$, $p = 0.38$). For netballers the values were: APSI ($Z = -0.04$, $p = 0.97$), MLSI ($Z = -1.72$, $p = 0.09$), and OSI ($Z = -1.13$, $p = 0.26$). For dancers the values were: APSI ($Z = -0.65$, $p = 0.52$), MLSI ($Z = -1.81$, $p = 0.07$), and OSI ($Z = -1.30$, $p = 0.19$). Table 2 reports a stability measure (mean ± SD) for the three groups.

Table 2. Stability measures

Stability measure	Rugby (n = 39)	Netball (n = 36)	Dance (n = 30)
NDAPSI	1.62 (± 1.12)	1.12 (± 0.52)	0.93 (± 0.45)
DAPSI	1.42 (± 0.95)	1.11 (± 0.50)	0.87 (± 0.43)
NDMLSI	1.21 (± 1.19)	0.96 (± 0.66)	0.72 (± 0.39)
DMLSI	1.18 (± 1.06)	0.79 (± 0.40)	0.58 (± 0.20)
NDOSI	2.19 (± 1.58)	1.56 (± 0.75)	1.22 (± 0.52)
DOSI	2.06 (± 1.38)	1.42 (± 0.57)	1.11 (± 0.44)

Note: NDAPSI – nondominant antero-posterior stability index, DAPSI – dominant antero-posterior stability index, NDMLSI – nondominant medio-lateral stability index, DMLSI – dominant medio-lateral stability index, NDOSI – nondominant overall stability index, DOSI – dominant overall stability index
Data is presented as mean (SD).

Table 3. Nondominant limb's APSI, MLSI, and OSI

Group	MD	CI	p value	Partial η^2
Rugby vs Netball NDAPSI	0.50	0.02 to 0.98	0.04*	0.12
Rugby vs Dance NDAPSI	0.69	0.22 to 1.17	0.003*	
Netball vs Dance NDAPSI	0.19	-0.09 to 0.48	0.25	
Rugby vs Netball NDMLSI	0.25	-0.27 to 0.78	0.49	0.05
Rugby vs Dance NDMLSI	0.49	-0.01 to 0.98	0.05	
Netball vs Dance NDMLSI	0.24	-0.08 to 0.55	0.17	
Rugby vs Netball NDOSI	0.63	-0.04 to 1.31	0.07	0.13
Rugby vs Dance NDOSI	0.97	0.31 to 1.62	0.002*	
Netball vs Dance NDOSI	0.33	-0.05 to 0.71	0.096	

Note: NDAPSI – nondominant antero-posterior stability index, NDMLSI – nondominant medio-lateral stability index, NDOSI – nondominant overall stability index, MD – mean difference, CI – confidence interval, Partial η^2 – partial eta-squared
* statistically significant at $p < 0.05$

Table 4. Dominant limb's APSI, MLSI, and OSI

Group	MD	CI	P value	Partial η^2
Rugby vs Netball DAPSI	0.31	-0.11 to 0.73	0.18	0.10
Rugby vs Dance DAPSI	0.55	0.14 to 0.96	0.01*	
Netball vs Dance DAPSI	0.24	-0.38 to 0.51	0.10	
Rugby vs Netball DMLSI	0.39	-0.05 to 0.84	0.09	0.12
Rugby vs Dance DMLSI	0.60	0.18 to 1.03	0.004*	
Netball vs Dance DMLSI	0.21	0.24 to 0.39	0.02*	
Rugby vs Netball DOSI	0.63	0.05 to 1.21	0.03*	0.16
Rugby vs Dance DOSI	0.95	0.41 to 1.49	0.00*	
Netball vs Dance DOSI	0.32	0.02 to 0.62	0.04*	

Note: DAPSI – dominant antero-posterior stability index, DMLSI – dominant medio-lateral stability index, DOSI – dominant overall stability index, MD – mean difference, CI – confidence interval, Partial η^2 – partial eta-squared
* statistically significant at $p < 0.05$

Discussion

The primary aim of the study was to determine postural stability scores vis the BBS in rugby players, netballers, and dancers. The analysis of the results provided some interesting findings in relation to the stability indexes and limb dominance. The mean scores for APSI, MLSI, and OSI (Table 2) were the lowest in dancers, with netball and rugby players having the poorest postural stability with higher scores, indicating poorer balance, probably reflecting greater postural stability demands of dance and netball.

APSI

The results indicated that there are significant differences in APSI between rugby and netball, and rugby and dance for a non-dominant limb, and between rugby and dance for a dominant limb. For the non-dominant limb, this may indicate that dancers and netballers obtain a higher level of proficiency, possibly due to the demands of their activities, which require repeated unipedal balance, and that the antero-posterior direction is one that is repeatedly challenged. For the dominant limb, it is possible that dancers achieve a greater degree of proficiency due to specific dance movements such as retiré and arabesque, especially in ballet, which challenge dynamic and static balance. The medium effect sizes for both limbs suggest that this direction contributes more to the observed variance than MLSI. Although this finding of the medium effect size could lead to a suggestion that there is a need to focus on APSI development, a more considered approach would be to focus on all directions of postural stability in group or team training, supplemented by individual sessions to improve any individual weaknesses or position specific attributes. For example, in rugby union, a scrum-half or winger is more likely to perform directional changes in medio-lateral planes and may benefit from training specific to this movement. In contrast, looseheads, tighthead props, and second row forwards, who are involved in a scrum, may benefit from antero-posterior training as this is a main movement direction of the scrum. For dance, any intervention in addition to general balance training would have to consider a dance genre and its specific demands, such as a number and type of jumps and whether partner lifts are required. In netball, balance demands may be less position specific than in rugby, as all netballers are subject to the footwork rule, which ensures that players must maintain contact with their landing foot and a ground without taking additional steps, and therefore balance specific training might not require the same volume of position specific training.

MLSI

There were significant differences in MLSI between rugby and dance, and netball and dance for a dominant limb. The MLSI value had the lowest number of significant differences between the groups and the finding that no differences existed for a non-dominant limb may suggest that proficiency in this direction is more difficult to enhance in dancers compared to APSI relative to the other groups. This may highlight an area for a potential training intervention, which could involve training of invertor and evertor muscles of an ankle to develop medio-lateral control.

OSI

For OSI, significant differences existed between rugby and dance for a non-dominant limb and between rugby and netball, rugby and dance, and netball and dance for a dominant limb. These findings reflect that reporting the relative contributions of APSI and MLSI is useful and may allow identification of a specific movement direction that requires enhancement, e.g., MLSI may benefit from training to improve OSI. Reporting OSI alone may make it difficult to plan an effective postural control training program and may result in smaller clinical important postural stability issues being ignored. Although OSI provides an overview of postural stability performance, it is useful to report APSI and MLSI to provide greater understanding of performance factors [4]. While this study did not specifically measure APSI and MLSI during specific rugby, netball or dance movements, it is possible to suggest that consideration of specific movement planes and how they might relate to APSI and MLSI and a particular movement could be of performance benefit. For example, in dance, a pirouette requires rotation around a vertical axis and moves predominantly in a transverse plane, and therefore training MLSI might be useful. However, it is important to remember that many sports movements are multiplanar, so further studies could potentially consider analyzing specific movements and whether training in an APSI and/or MLSI direction enhances performance.

The constructs of postural stability are complicated [9] and require constant evaluation of proprioceptive input, therefore using all available measures of postural control should allow a more effective intervention. The significant findings for all dominant limb comparisons highlight that a dominant limb is particularly well trained in dance, and postural control training might be beneficial for a non-dominant limb.

APSI is higher than MLSI due to a center of pressure [9] defined as a central pressure point applied to a foot during ground contact or a point of application of ground reaction force [11] being located at an anterior to antero-posterior motion axis and at a lateral to medio-lateral motion axis, suggesting greater gravitational torque around the antero-posterior motion axis and greater movement compared to the medio-lateral motion axis. The medio-lateral axis is reported to have greater muscle control via invertor and evertor muscle groups with greater force fluctuations parallel to the antero-posterior axis [12].

Non-dominant and dominant limb performance

The secondary aim was to determine differences in a non-dominant and dominant limb performance within each group. Analysis of the APSI, MLSI, and OSI scores for a non-dominant and dominant limb indicated that there was no significant difference for each group, however, Table 2 highlights that all groups had better postural control in their dominant limb. The finding of better postural control in dancers is an expected consequence of a high level of balance required by this activity, while better dominant limb performance is also expected and may better reflect movement coordination. Adaptive balance strategies used by dancers may result from cognitive and physical performance training [8]. The dancers' mean scores for APSI, MLSI, and OSI for a non-dominant and dominant limb are higher than those reported in female student dancers in Taiwan [5], but are within a similar range. The significant differences reported between the three groups for the height of netballers and dancers and the weight of rugby players and netballers, rugby players and dancers, and netballers and dancers are an expected consequence of required physical attributes of the varying activities.

Development of neuromuscular training programs to improve performance and reduce injury risk requires understanding of components that contribute to specific activities. Postural training strategies to improve performance in a non-dominant limb could utilize the BBS with increasing levels of difficulty, reduce visual feedback by performing balance work with eyes closed, and implement other rehabilitation equipment with uneven surfaces, such as wobble boards and Bosu balls, with a variety of tasks such as lunges, squats, and unipedal stance. Other sports that require dynamic balance, such as basketball and football, may also benefit from such an approach. The current study provides enhanced understanding of the BBS indexes in three very different activities. It is suggested that general neuromuscular training programs may include ≥ 80% of movements that are not commonly performed within a specific discipline [13]. Potentially greater understanding of the contribution of individual components, such as APSI and MLSI, to postural control could assist in designing more activity specific programs. Future studies may wish to measure an ankle range of motion in plantarflexion, dorsiflexion, inversion, and eversion to determine how this relates to BBS performance, and this could potentially be combined with enhanced understanding of muscle activity via EMG measurements.

There were some limitations within the study, namely the study only involved female participants and therefore further studies with male participants are required. The study included university dancers who performed contemporary dance and ballet, and this should be considered in any practical application of the findings.

Conclusions

The study demonstrates that APSI and MLSI make specific contributions to OSI and that dancers have superior postural control in comparison to rugby players and netballers, however, for MLSI these differences are reduced in a non-dominant limb, which may highlight an area for a potential training intervention.

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Conflict of Interest

The author declares no conflict of interest.

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