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Original Article

Assessment of static and dynamic balance performance in team sports athletes

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Abstract:
Static balance and dynamic balance are crucial to an athlete's motor skills and are pivotal determinants of performance in team sports (TS) players. Training to enhance balance prevents falls and reduces the incidence of sports-related injuries. However, the existing literature presents conflicting data regarding the impact of an athlete's sex on balance performance and the potential associations between static and dynamic balance characteristics. The aims of our study were: 1) to assess and compare the static and dynamic balance performance between TS players and the control group (CG) and 2) to examine and analyze sex differences in static and dynamic balance tests within both the TS players and CG. A total of 97 subjects who were 19–24 years of age participated in the study. The participants were categorized into two groups: 1) TS players (males: n = 30, females: n = 25), with a mean weekly training duration of 10.1 ± 1.5 h, including sport-specific balance exercises twice per week for 15 min, and training experience in football, basketball, or volleyball averaging 9.7 ± 3.3 years and 2) a CG (males: n = 17, females: n = 25) engaged in regular physical activity for at least 2–3 h per week. The stork stand static balance test was employed to measure static balance, revealing no significant differences between TS players and their same-sex counterparts in the CG ($p > 0.05$). However, males exhibited higher static balance values overall than females ($p < 0.01$). Dynamic balance assessment, conducted using the Y-lower body dynamic balance test, showed that TS players of both sexes displayed significantly higher normalized leg reach distances (anterior, posteromedial, and posterolateral) and composite scores compared to the CG ($p < 0.001$). Notably, the dynamic stability normalized results did not differ significantly between males and females within the TS players and CG, respectively ($p < 0.01$). No significant correlation existed between static and dynamic balance test results in any participant groups ($p > 0.05$).
Keywords: Stork stand balance test; Y-lower body balance test; team sports; task-specific balance training; basketball; volleyball; football.

Introduction

As defined by Macpherson and Horak (2013), static balance involves maintaining equilibrium in unperturbed environments, such as quiet standing or the ability to sustain a base of support with minimal movement, as explained by Hrisomallis (2011). Alternatively, dynamic balance refers to the capacity to execute tasks while preserving or recovering a stable position or sustaining or regaining balance on an unstable surface with minimal extraneous motion, as outlined by Hrisomallis (2011) and Paillard (2019).

Numerous movement patterns observed in team sports (TS) players contribute to the development of balance ability, including changes in running direction, accelerations, decelerations, activity shifts, lateral movements, and jumps (Taylor et al., 2017). However, the diverse skill requirements and environmental conditions inherent in each team sport present unique challenges to the sensorimotor systems, potentially affecting the balance abilities of players. For instance, football players frequently use lower-extremity passing, shooting, and dribbling skills under variable turf conditions (Orchard, 2002), while basketball players perform upper-extremity passing, shooting, and dribbling skills on flat, solid surfaces. The latter also involves significant joint accelerations from jump landings and cutting maneuvers (McClay et al., 1994). Notably, in the Star Excursion Balance Test, female basketball players exhibited lower dynamic balance than football players, highlighting those specific sensorimotor challenges, rather than general sports activity, play a pivotal role in achieving optimal balance (Bressel et al., 2007). It is essential to recognize that the effectiveness of balance training may be task specific. Giboin et al. (2015) demonstrated that a two-week balance training regimen improved performance solely in the specific balance task that was trained. This effect did not extend to similar non-trained tasks, even when utilizing the same training device or perturbation direction, emphasizing the importance of tailoring training to specific sensorimotor challenges rather than expecting a broad transfer of skills across similar tasks in young, healthy participants.

Karimi and Solomonidis (2011), Pau et al. (2015), and Sell (2012) failed to identify a significant correlation between static and dynamic balance performance. Sell (2012) exemplified this lack of correlation by

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revealing an absence of connection between static balance, assessed during a single-leg standing task, and dynamic balance, measured during a single-leg landing task, in healthy, physically active young males and females. In another study, Pau et al. (2015) assessed static and dynamic balance in national-level football players by gauging vertical time stabilization and postural sway calculations based on the center of pressure trajectories on a force platform. While static balance was measured during a 20-s single-leg stance, dynamic balance was evaluated during a single-leg landing task. Notably, these researchers did not find significant correlations between the static and dynamic balance characteristics under consideration. Similarly, Karimi and Solomonidis (2011) observed no significant correlations between static balance in quiet standing and standing while transverse and vertical hand-reaching tasks were performed in healthy young subjects.

There are also indications that dynamic balance training can improve static balance. For instance, Kenville et al. (2021) noted that dynamic balance training (involving bipedal stance on a challenge disc using its software (shifting body weight in different directions) twice per week for four weeks) resulted in static balance enhancement in one-leg stance among male football players and gymnasts who were 9–12 years old. The discrepancies in these findings may be attributed to the qualifications and training experiences of the participants. Kenville et al. (2021) highlighted static balance improvement resulting from dynamic balance training in children. In contrast, Holm et al. (2004) and Kovacs et al. (2004) supported a ceiling effect theory of static balance trainability in experienced athletes. Both studies concluded that a static assessment might not yield sufficient improvements in balance ability among healthy, athletic subjects. For example, Holm et al. (2004) identified the dynamic balance improvements in adult elite female handball players after an 8-week regimen of balance training sessions three times per week for 15 min, incorporating floor, wobble board, and balance mat exercises with a progressive increase in difficulty level, while static balance, leg muscle strength, and proprioception remained unchanged.

The current consensus does not clarify whether the performance of TS athletes in a static balance test, such as the stork stand, is correlated with their dynamic balance, as determined by the Y-lower body dynamic balance test.

McGuine et al. (2000) identified poor balance, altered motor control, or a lack of neuromuscular control as predisposing factors that heighten the risk of injuries in athletes. Consequently, a targeted injury prevention program focusing on balance improvement is recommended for such athletes. One of the screening tools for assessing injury risk based on dynamic balance and its side asymmetry in athletes is the Y-lower body dynamic balance test (Y-LBDBT) (Plisky et al., 2009; Fullam et al., 2014).

Research data regarding static and dynamic balance norms across sexes have been controversial. Female-specific advantages, such as a lower body gravity center due to a wider pelvis and narrower shoulders (Nolan et al., 2005; Hamilton et al., 2023), contribute to superior static balance in tests measuring postural sway characteristics. Sell et al. (2018) confirmed this advantage by determining that female soldiers exhibited significantly better static postural stability, measured as the standard deviation of ground reaction force components in a 10-s single-leg stance, than males. Additionally, Andreeva et al. (2020) found lower sway velocity of the body center of pressure in adolescent and adult females compared to males. Mocanu et al. (2022) observed better performance by females than males in Flamingo and Bass balance tests. However, sex-based differences in static balance outcomes vary when the task involves standing on one leg for as long as possible. For instance, Springer et al. (2007) reported no difference in the duration of the one-leg stance test between sexes across all age groups, including 18–39-year-old males and females. However, Bonis and Tillery (2021) noted significantly better static balance in males for both the dominant and non-dominant legs in the Stork stand test time. This discrepancy is attributed to lower ankle stiffness in females, both in the sagittal and frontal planes during quiet standing. The reasons behind this include sex differences in passive resistance to joint motion and anatomical factors, such as a larger range of motion, lower Young's modulus, and higher ligamentous laxity in females than in males (Wilkerson & Mason, 2000; Kubo et al., 2003). Importantly, ankle joint stiffness in quiet standing depends on the stiffness of the foot, Achilles tendon, and aponeurosis rather than the activated calf muscle fibers (Loram & Lakie, 2002).

Ankle stiffness is a considerable contributor to neuromuscular control of dynamic stability (Loram & Lakie, 2002; Lee & Hogan, 2015; Adjei et al., 2020). According to Loram and Lakie (2002), the calf muscles play a crucial role in maintaining dynamic balance by acting as a spring-like element, predictively controlling the proximal offset of this spring-like element in a ballistic-like manner. The lower stiffness observed in females during muscle co-contraction can be attributed to sex differences in active muscle mechanics. Males, having more leg muscle mass (Janssen et al., 2000), experience hormonal influences, resulting in gene expression differences. This leads to larger skeletal muscle mass, a greater number of fast-twitch fibers in muscles, and a higher rate of force production in males than in females (Haizlip et al., 2015).

In studies assessing dynamic stability through various tests, sex differences in reach distances have been a subject of investigation. Gribble and Hertel (2003) noted that males reached farther than females in all directions in the star excursion balance test, but when distances were normalized to leg length, sex differences vanished. Conversely, Alnahdi et al. (2015) observed greater Y-LBDBT normalized reach distances in healthy male college students aged 18–29 compared to female students in anterior (A), posteromedial (PM), and posterolateral (PL) directions for both dominant and non-dominant legs and showed better test composite scores.

Gorman et al. (2012) also found that males perform better in normalized reach distances scores, whereas Gribble et al. (2009) found that female athletes excelled in normalized reach distances results. Chimera et al. (2015) determined that male and female athletes had similar overall Y-LBDBT scores, with greater differences in A-reach asymmetry for male athletes, due to specialization in sports such as football that exhibit side-asymmetry during leg usage (kicking the ball by the dominant leg). Similarly, Muehlbauer et al. (2019) observed Y-LBDBT A-reach distances' side asymmetry above 4 cm in young football players. Lai et al. (2017) revealed that none of the asymmetric cut-off scores of the Y-LBDBT were associated with earlier or increased injury rates in collegiate athletes and recommended against using Y-LBDBT scores alone to predict injury risk. Despite the extensive examination of balance performance in numerous studies, the influence of regular training in TS on sex differences in static and dynamic balance performance among players remains largely unexplored.

Hypotheses: 1) TS players are expected to exhibit superior static and dynamic balance performance compared to controls within their respective male and female groups; 2) among both TS players and controls, males are anticipated to demonstrate better static and dynamic balance performance than females.

The aims of our study were: 1) to assess and compare the static and dynamic balance performance between TS players and the control group (CG) and 2) to examine and analyze sex differences in static and dynamic balance tests within both the TS players and CG.

Materials & methods

This study employed a cross-sectional research design, with data collection conducted at the Latvian Academy of Sport Education from March to May 2021.

Participants

A total of 97 participants were categorized into four groups: 1) male team sports (MTS) athletes, 2) female team sports (FTS) athletes, 3) the male control group (MCG), and 4) the female control group (FCG). See Table 1.

The TS athletes were distinguished as first-league players specializing in basketball, volleyball, and football. Over the last six months, they engaged in a combination of outdoor and online training sessions at least four times per week. Due to the COVID-19 lockdown, they individually performed maximal strength, strength endurance, plyometric, and dynamic balance exercises at home. The average time spent in these training sessions was 10.1 ± 1.5 h per week. As part of their training regimen, sport-specific balance exercises were incorporated twice a week for a duration of 15 min each session, contributing to a total of 30 min per week. This training protocol was followed for 8 weeks prior to testing, and it encompassed match participation. The participants had an average training experience in TS of 9.7 ± 3.3 years, with male players having 10.6 ± 3.4 years and female players having 9.2 ± 3.4 years of experience.

The CGs consisted of healthy and physically active individuals, with separate groups for males and females. Participants were assessed using the modified Saltin–Grimby Physical Activity Level Scale (Rodjer et al., 2012). The inclusion criterion for the CG was Level 3, indicating regular physical activity and training (moderate physical activity), such as heavy gardening, running, swimming, calisthenics, tennis, badminton, and similar activities, for at least 2–3 h per week. However, regular balance training exercises were not part of their routine.

To be eligible for the study, TS players had to meet specific criteria, including playing in the first league team, participating in training sessions and games at least four to five times per week, and incorporating sport-specific balance training for a minimum of 30 min per week over 8 weeks before testing. The weekly training volume of 10.1 ± 1.5 h, involving four to five training sessions with one session per day, aligned with the minimal training volume observed in international performance-level TS players (Saavedra et al., 2018).

Exclusion criteria for all participants included experiencing painful legs during the investigation, a lower extremity or back injury, recent surgery within the last 12 months, vestibular disorders, ongoing treatment for inner ear, sinus, or upper respiratory infections, visual impairments (blindness in one eye, etc.), or a concussion within the three months prior to the study. The assessment of these exclusions was conducted through participant questioning. Additionally, exclusion from the CG was applied to those leading a sedentary lifestyle or engaging in some physical activity for at least 4 h per week, corresponding to Levels 1, 2, and 4 based on the modified Saltin–Grimby Physical Activity Level Scale (Rodjer et al., 2012).

Participants were informed of the potential risks associated with the tests, and all participants signed an informed consent form to participate in the study voluntarily. The study received approval from the Ethics Committee of the Latvian Academy of Sport Education and was conducted in accordance with the principles outlined in the Declaration of Helsinki.

Anthropometry

The heights of the athletes were measured (cm) using an MZ10020 ultrasound height measuring unit (ADE, Hamburg). Body mass, for males in briefs and females in briefs and brassieres, was measured in kilograms (kg) utilizing a BC-418 body composition analyzer (Tanita Corporation, Japan).

Procedure

Before commencing the static and dynamic balance measurements, participants performed general warm-up exercises, local warm-up, and active stretching for the leg and trunk for 15 minutes.

The dominant leg, defined as the leg used for kicking a ball (representing the best bilateral mobility task), was identified. Leg dominance did not play a role in our evaluation, given that we focused on the stability task of standing on one leg. Leg dominance can vary in stability tasks among healthy adults involved in sports that engage the legs (such as running, cycling, and football) (van Melick et al., 2017). In fact, research indicated that the dominant leg in the best mobility task (kicking a ball) aligned with a unilateral stability task of standing on one leg in 66.7% of males and 85.0% of females and in 47.6% of males and 70.0% of females for jumping on one leg (van Melick et al., 2017). Additionally, studies on young football players revealed no statistically significant leg differences in the Y–lower body dynamic balance test, regardless of age (13–19 years old) or playing experience (Muehlbauer et al., 2019). Schorderet et al. (2021) emphasized in their review that balance performance is not influenced by leg dominance, reinforcing the idea that both legs' performances can serve as a reference, with strong evidence for the one-leg stance. Consequently, we opted to compare the balance characteristics of the right and left legs of the participants.

Static balance was measured using the stork stand static balance test (SSBT) (McCurdy & Langford, 2006). The participants performed the test on both their right and left feet, maintaining a specific position with their eyes open, hands on their hips, and the uninvolved foot against the medial side of the knee of the stance leg. The goal was to stand on the ball of the foot for the maximum possible time, with the trial concluding if the heel of the involved leg touched the floor, hands came off the hips, or the opposite foot was removed from the stance leg. Prior to formal testing, each participant underwent six practice trials on each leg to minimize the learning effect without compromising the ability to perform the test (Robinson & Gribble, 2008). The analysis focused on the best of the three trials, as per the methodology outlined by McCurdy and Langford (2006).

Dynamic balance assessment for each athlete involved the Y–lower body dynamic balance test (Y-LBDBT), a modified version of the three-direction star excursion balance test (SEBT) (Fullam et al., 2014). The "Y" configuration was created by securing three tape measures on the ground: one directed anteriorly (A) to the apex, and the other two positioned at 135° to this in the PM and PL directions (Fullam et al., 2014). Each tape length measured 2.5 m. Participants were instructed to stand barefoot in the center of the Y, with an equal part of the stance foot positioned anteriorly and posteriorly to the middle of the Y, maintaining this fixed position for all three reach attempts. During each attempt, participants performed maximal reaches along the three vectors with the opposite leg, ensuring the base of support was not compromised (Fullam et al., 2014; Bird & Markwick, 2016). Prior to formal testing, each participant completed six practice trials in each of the three directions.

The test began with the participant standing on the center of the "Y." While maintaining a single-leg stance, the participant reached forward with the free leg in one of three directions (A, PM, or PL) and then returned to the starting position. The stance leg was the one being measured, and the reach was named based on the directional relationship to the stance leg. The participant lightly touched the ground with the toes of the most distal part of the reaching leg without bearing weight on it and returned to the starting standing position. A piece of tape marked the most distal reach position for accurate repositioning between trials. The participant started with the right foot on the center of "Y" and performed three attempts while reaching in the A direction. The best of the three reach attempts (the maximal distance from the starting point to the point of maximum reach at the toe) was recorded as the score for the right A reach (in cm). Then, the participant placed the left foot on the center of "Y" and repeated with the opposite leg. Alternating stance legs between trials ensured adequate rest for accurate results. The testing sequence included: 1) right A reach (three trials); 2) left A reach (three trials); 3) right PM reach (three trials); 4) left PM reach (three trials); 5) right PL reach (three trials); 6) left PL reach (three trials). Three trials in each direction for each foot were collected, and the maximal reach in each direction was used for analysis, following the primary methodology outlined by Fullam et al. (2014) using the Y–LBDBT method.

The right leg length was assessed using a tape measure, extending from the anterior superior iliac spine to the furthest point on the medial malleolus while the participant was in a supine position. Subsequently, the maximal reached distance in each of the three directions was divided by the leg length and multiplied by 100 (Bird and Markwick, 2016). This process yielded normalized reaching distances presented as a percentage (%) of the participant's leg length. The average normalized reaching distance or the normalized composite score for all three directions was then calculated as a percentage (%) of the leg length.

Statistical Analysis

The required sample size was determined to be 84 participants, calculated using the G*power program, software version 3.1.9.7, to achieve 80% power, with alpha set at 0.05 and a substantial effect size of 0.4 (Faul et al., 2007). With the number of participants at 97, the sample size was deemed sufficient to perform the study.

The data pertaining to height, body mass, leg length, body mass index (BMI), age, training experience, and results from both static and dynamic balance tests showed a normal distribution across the four participant groups. Normality was assessed using quantile–quantile plots for each variable. Mean values and standard deviations for each characteristic within the four participant groups were calculated.

Statistical significance was set at $p < 0.05$, and a three-way ANOVA was employed to explore the outcomes of the SSBT, Y-LBDBT in anterior, posteromedial, and posterolateral directions, and the Y-LBDBT normalized reaching distance composite score. The factors considered were leg (right and left), group of participants (control and TS), and sex (male/female). Post-hoc analysis, utilizing pairwise contrasts with

Bonferroni corrections, was conducted to examine significant effects. Furthermore, to assess potential correlations between SSBT and Y-LBDBT normalized reaching distance composite scores across subjects, we calculated the Pearson correlation coefficient.

Results

There were no significant differences in the mean anthropometric characteristics between the groups of males and females. Table 1 presents the mean anthropometric characteristics of the participants.

Table 1. Anthropometric characteristics of the participants (mean ± SD)

Participant groups	Number of participants	Mean age (years)	Mean height (cm)	Mean body mass (kg)	Body mass index (BMI) (kg/m^2)	Leg length (cm)
Team sports (males)	30	21.7 ± 2.8	181 ± 7	77.8 ± 9.9	23.6 ± 2.5	93 ± 9
Controls (males)	17	20.5 ± 1.4	180 ± 5	81.7 ± 18.9	24.9 ± 4.8	95 ± 8
Signif. difference		p = 0.136	p = 0.581	p = 0.436	p = 0.309	p = 0.251
Team sports (females)	25	20.6 ± 1.0	171 ± 8	62.3 ± 7.4	21.4 ± 2.0	90 ± 8
Controls (females)	25	21.1 ± 2.1	168 ± 6	62.7 ± 8.5	22.1 ± 2.2	90 ± 7
Signif. difference		p = 0.318	p = 0.218	p = 0.838	p = 0.189	p = 0.492

The ANOVA analysis of the SSBT revealed no significant main effect of the leg ($F_{1,178}$ = 0.212, p = 0.646) and no main effect of the group ($F_{1,178}$ = 0.037, p = 0.847), with no observed interactions. However, a significant main effect of sex was identified ($F_{1,178}$ = 29.835, p < 0.001). Pairwise contrasts indicated notable differences in SSBT performance between both sexes. Static balance, as measured by the mean standing duration, was significantly superior in all groups and for both legs among male participants compared to females (p < 0.001). Specifically, MTS players exhibited a mean standing duration of 53 ± 20 s and 50 ± 21 s on the right and left leg, respectively, while the MCG participants had durations of 50 ± 19 s on the right leg and 51 ± 22 s on the left leg. FTS athletes displayed mean standing durations of 36 ± 22 s on the right leg and 32 ± 22 s on the left leg, with similar values observed in the FCG participants of 34 ± 22 s on the right leg and 34 ± 21 s on the left leg. The three-way ANOVA conducted on the Y-LBDBT, considering all three directions (A, PM, PL) and the normalized composite reaching distance, revealed the anticipated main effect of TS or CG group (Y-LBDBT-A, $F_{1,178}$ = 39.150, p < 0.001; Y-LBDBT-PM, $F_{1,178}$ = 52.156, p < 0.001; Y-LBDBT-PL, $F_{1,178}$ = 80.344, p < 0.001, Y-LBDBT composite score, $F_{1,178}$ = 88.266, p < 0.001) without any other main effects or interactions. Pairwise comparisons demonstrated that Y-LBDBT (in all directions and composite score) was significantly higher in the TS groups of male or female athletes compared to the CGs of male or female athletes in both the right and left legs, respectively (Figure 1).

Despite the mean leg length not showing a significant difference in male and female TS athletes (p = 0.069), the results of absolute reaching distance (cm) varied. The composite reaching distance was notably larger in males standing on the right leg at 93.9 ± 11.5 cm than for females at 88.7 ± 10.1 cm (p = 0.047). Similarly, in males standing on the left leg, the reaching distance was significantly larger at 92.6 ± 11.5 cm than for females at 87.6 ± 9.8 cm (p = 0.049). In the posterolateral (PL) direction, standing on the right leg the male TS players exhibited a significantly larger reaching distance at 100.0 ± 12.1 cm than the FTS group at 94.4 ± 10.1 cm (p = 0.037). However, the other reaching distances of male and female TS athletes did not show significant differences (p > 0.05).

The mean leg length in males and females from the CG differed significantly (p = 0.020). Despite this observed difference, the absolute composite reaching distance did not show a significant difference when standing on the right leg, with males at 81.3 ± 10.5 cm and females at 77.8 ± 13.7 cm (p = 0.175), or when standing on the left leg, with males at 80.8 ± 11.4 cm and females at 75.1 ± 11.2 cm (p = 0.060). In the PM direction, the reaching distance standing on the left leg was 86.8 ± 15.1 cm in males of the CG, which was larger than in females at 75.7 ± 17.7 cm (p = 0.018). Additionally, for standing on the right leg in the PL direction, males exhibited a larger reaching distance at 89.5 ± 13.7 cm than females at 78.7 ± 15.7 cm (p = 0.012).

The absolute difference between the mean reach distances of the right and left legs was 4.8 cm (or 5%) only in the PM direction within the MCG, surpassing the critical threshold of 4 cm associated with an elevated injury risk as indicated by Gonell et al. (2015).

The mean normalized reaching distance of the Y-LBDBT (in %) for each of the three directions (A, PM, PL) and the normalized composite reaching distance score were notably higher in the FTS athletes compared to the FCG) in both the right and left legs, respectively (Figure 1).

ANOVA results indicated no significant main effect of the leg, and the differences in mean normalized reach distances between the right and left legs in all directions (A, PM, PL) and the composite score did not reach statistical significance (Y-LBDBT-A, $F_{1,178}$ = 0.737, p = 0.392; Y-LBDBT-PM, $F_{1,178}$ = 0.051, p = 0.822; Y-LBDBT-PL, $F_{1,178}$ = 0.318, p = 0.574; Y-LBDBT-norm, $F_{1,178}$ = 1.116, p = 0.29). Figure 1 illustrates the mean normalized reach distances and composite scores for the right and left legs for all four groups.

Furthermore, no significant correlation was identified between the results of the SSBT and the normalized reaching distances composite score of the Y-LBDBT in both the right and left legs for all groups. The correlation coefficients ranged from 0.0006 to 0.051, with probability levels (p) ranging from 0.908 to 0.278.

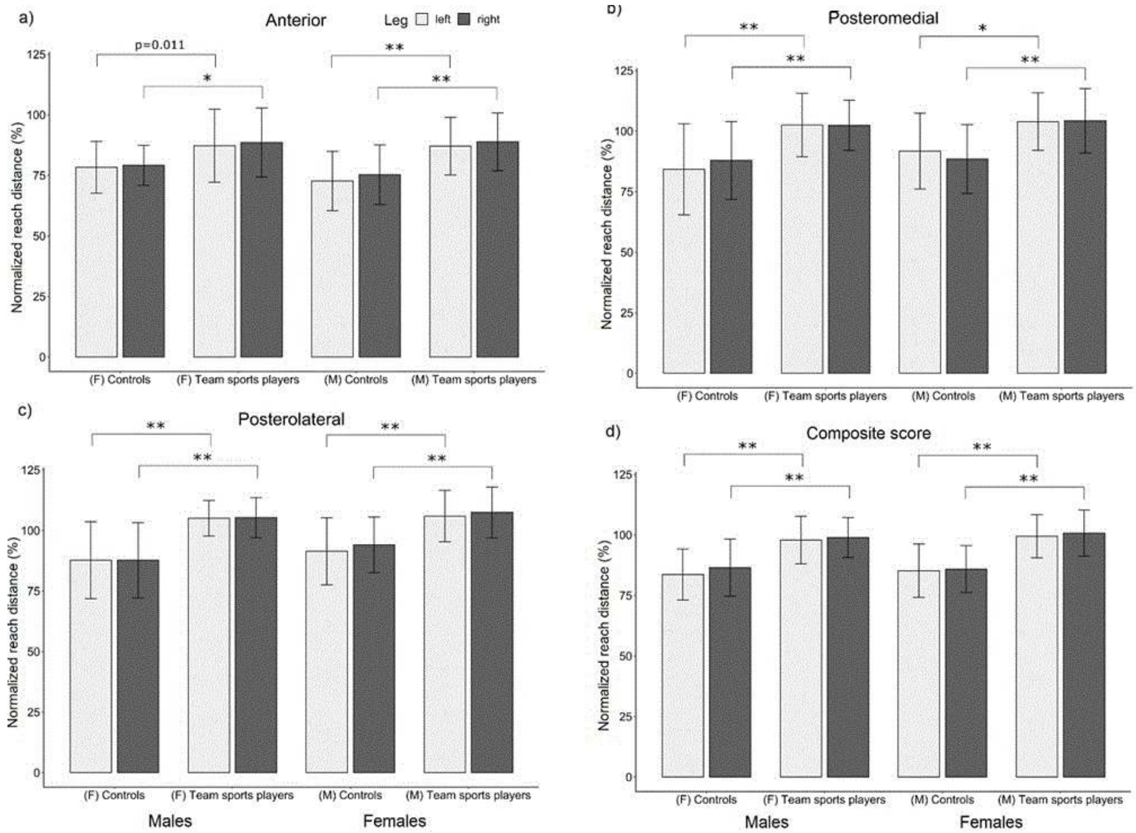

Figure 1. Normalized reaching distances from the Y-lower body dynamic balance test (Y-LBDBT) in the anterior (a), posteromedial (b), and posterolateral (c) directions and the composite score (d) in % (SD) in the four participant groups (male control group (MCG) and team sports (MTS) players; female control group (FCG) and team sports (FTS) players), * $p < 0.001$, ** $p < 0.001$.

Discussion

According to our findings, there were no significant differences in the results of the SSBT between the TS and CG, both in males and females. However, static balance was influenced by the athlete's sex, with males in both groups exhibiting higher static balance than females.

The normalized leg reach distances in three directions and the composite score of the Y-LBDBT were significantly greater in the TS groups of both males and females compared to the CG of both sexes. Dynamic stability normalized results did not show significant differences between males and females in both the TS and CG.

Notably, a substantial side-asymmetry of dynamic stability (4.8 cm) was observed only in the CG, specifically in the PM direction for males, exceeding the 4-cm cut-off value associated with a higher injury risk, according to Gonell et al. (2015). However, using Y-LBDBT scores alone is not recommended for predicting injury risk (Lai et al., 2017).

The correlation analysis revealed no significant relationship between static and dynamic balance in all four groups. These results align well with the findings of Sell (2012) and Pau et al. (2015), supporting the notion that static and dynamic balance are distinct characteristics in athletes, and a significant correlation between these balance conditions is not evident. Therefore, decisions about dynamic stability should not be solely based on static balance measurements.

The trainability of both static and dynamic balance performance has been established in numerous studies. For instance, Benis et al. (2016) demonstrated that an 8-week neuromuscular training program (focusing on core stability and plyometric exercises incorporated into a 30-min warm-up session twice per week) significantly improved dynamic balance and lower limb stability in the Y-LBDBT. Notably, this program progressed from stable to unstable positions, intensifying the demands on lower extremity strength and core stability, although exercises emulating the Y-LBDBT were not included. In our study, we did not observe significant differences in static balance performance between same-sex athletes from both groups (TS and CG). This lack of distinction could be attributed to the predominant experience in dynamic balance training among TS athletes and the potential ceiling effect of static balance trainability in healthy, experienced athletes, as noted by Holm et al. (2004) and Kovacs et al. (2004). The trainability of dynamic balance has been supported by several studies, including those by Plisky et al. (2009), Filipa et al. (2010), Chaabene et al. (2021), and Aloui et al. (2021). Chaabene et al. (2021) reported significant improvements in Y-LBDBT results in young female national-level handball players following 8 weeks of balance exercises as part of a comprehensive training program before strength and plyometric exercises. Likewise, Asadi et al. (2015) demonstrated that an integrated plyometric program within regular basketball practice led to substantial enhancements in players' performance in the star excursion dynamic balance test. Furthermore, Aloui et al. (2021) found that incorporating loaded plyometrics with short sprints and change-of-direction training twice per week for 8 weeks significantly improved vertical jump height, 10-m sprinting time, change-of-direction ability, and dynamic balance performance in the Y-LBDBT absolute values in three directions while standing on both the right and left leg in young football players.

Filipa et al. (2010) conducted investigations wherein male and female TS athletes were combined into the same group, establishing identical norms irrespective of the athlete's sex for Y-LBDBT normalized results as a percentage of leg length. Chimera et al. (2015) reported similar overall Y-LBDBT scores for both male and female athletes, aligning well with our findings. In our study, the Y-LBDBT normalized test data showed no significant differences between MTS and FTS athletes and the respective CGs.

However, in contrast to our results, Alnahdi et al. (2015) observed greater Y-LBDBT normalized reach distances in males compared to females across all three reach directions and test composite scores for both legs. Notably, their reported normalized reach distances were comparatively smaller than those in our TS groups. For instance, our data showed a mean composite score of 100–101 ± 9% in males, whereas Alnahdi et al. (2015) reported 95 ± 7%. Similarly, our test composite score for females in the TS group was 98–99 ± 8–10%, while Alnahdi et al. (2015) indicated a mean value of 85 ± 6% for females. The data from Alnahdi et al. (2015) for males (95 ± 7%) were higher than the results from our MCG (85–86 ± 10–11%). Nevertheless, the Y-LBDBT results for females (85 ± 6%) from Alnahdi et al. (2015) were consistent with our findings in the FCG (84–87 ± 11–12%). Gorman et al. (2012) also determined that males perform better than females in normalized reach distance tests, but Gribble et al. (2009) found that females perform better in the same test. These contradictions in the Y-LBDBT results between male and female TS athletes observed by various researchers could be attributed to differences in anthropometric characteristics, sport specialization, performance levels, and the extent of balance training (hours) included in the training programs of the participants.

Schwiertz et al. (2020) found that 14-year-old male football players exhibited significantly higher Y-LBDBT results, with a normalized reach distance composite score of 103.8 ± 8.1% compared to a CG of non-sport-active 14-year-old males (normalized reach distances composite score of 93.2 ± 9.6%). These football player results were consistent with our male TS group data (100–101 ± 9%). The adolescent CG's results fell between our two male participant groups, with our CG displaying mean normalized composite score reach distances of 85–86 ± 10–11%. This discrepancy might be attributed to differing physical activity levels among adolescent and adult males in the CGs.

Similarly, Thorpe and Ebersole (2008) established that collegiate female football players outperformed female non-football recreational athletes in both anterior and posterior reach directions. Hence, sports training and performance levels play a crucial role in influencing the dynamic balance of athletes engaged in specific sports, driven by the inherent sports-specific movement patterns.

Plisky et al. (2006) observed that female athletes with a composite reach score of less than 94% of leg length faced a higher risk of injury. Additionally, Butler et al. (2013) identified that Y-LBDBT composite scores below 89.6% increased the risk of injury by three and a half times. Consequently, our female athletes in the TS group demonstrated a lower susceptibility to increased injury risk, given their mean composite reach score of 98–99%.

Limitations of this study included the small number of qualified male and female athletes from the same TS, leading to their inclusion in combined groups of basketball, volleyball, and football players. This could potentially result in overlooking differences in sport-specific movement patterns, affecting the side asymmetries observed in balance tests. For instance, football players who predominantly kick with their dominant leg might exhibit distinct balance characteristics between their dominant and non-dominant legs. Furthermore, the study solely employed the Y-dynamic balance test for the lower body, with no inclusion of other dynamic balance assessments.

Conclusions

Dynamic stability, as assessed by the Y-LBDBT, was considerably superior in both male and female TS players compared to participants in the CG. In contrast, static balance showed no discernible difference between TS and CG participants of the same sex. This lack of disparity in static balance performance might be attributed to its non-specificity for TS players, suggesting that the ceiling of trainability had been reached in participants from both groups.

Therefore, our hypotheses were partially validated: 1) dynamic balance performance, but not static balance performance, was superior in TS players compared to both male and female CGs; 2) static balance performance in both groups, along with the absolute composite score values from the Y- LBDBT in TS players, showed male superiority over females. However, the normalized Y-LBDBT distances in all directions and the normalized composite score showed no significant differences between sexes in either group.

The capacity to enhance dynamic balance in the Y-LBDBT is influenced not by sex but rather by the training regimen, incorporating sports-specific skill development exercises and the inclusion of balance and plyometric exercises. Conversely, long-term one-leg stance static balance performance is better in males than in females owing to their anthropometric characteristics, such as a larger muscle mass and higher ankle joint stiffness.

It would be interesting to assess the impact of long-term consistent balance training programs tailored to specific TS on athletes' balance performance. This evaluation could involve employing diverse balance tests and equipment in future studies.

Coaching recommendations: the Y-LBDBT is a valuable tool for assessing dynamic balance ability in TS players. Notably, both male and female athletes can achieve similar enhancements in normalized scores on the Y-LBDBT. In contrast, the SSBT does not offer specificity for evaluating static balance in TS.

Conflicts of interest

The authors declare no potential conflicts of interest related to the research, authorship, and publication of this article.

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