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An assessment of static and dynamic balance effectiveness in one-leg stance of young footballers

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ABSTRACT

Purpose. Balance allows multidirectional lower limb movements that improve technical football skills and reduce injury caused by match activities. This study aimed to evaluate the static and dynamic balance of preferred and nonpreferred legs during unipedal stance in young footballers and investigate correlations between the two types of balance across each parameter.

Methods. Forty-three youth players (mean age = 15.81 ± 1.33 years, height = 179.50 ± 6.14 cm, body mass = 69.73 ± 9.35 kg) were involved in this study. Static balance was assessed via ellipse area (EA), perimeter length (P), anterior-posterior deviation (APD), medial-lateral deviation (MLD), trunk deviation (TD), average anterior-posterior speed (AAPS), and average medial-lateral speed (AMLS). The total stability index (TSI) and trunk total deviation (TTD) dynamic parameters were also examined.

Results. None of the static balance parameters showed significant differences between standing on the preferred and nonpreferred legs. Similarly, no meaningful distinctions were observed between the preferred and nonpreferred legs in terms of dynamic balance parameters. Overall, static and dynamic balances indicated no correlation, although minor connections were found between parameters: TTD and EA ($r = 0.332$; $p = 0.03$), TTD and MLD ($r = 0.335$; $p = 0.02$), and TTD and TD ($r = 0.423$; $p = 0.01$)

Conclusions. The balance evaluation in young football players should incorporate dynamic and static assessments because the postural control outcomes in these two tasks are independent. Participants underwent testing for both static and dynamic balance, revealing no noticeable differences between their preferred and nonpreferred legs.

Key words: postural stability, unipedal stances, youth footballers

Introduction

Balance refers to the physiological capacity of the human body to maintain the centre of gravity on the base of support [1] to prevent falling. The complex task comprises sensory, central, and motor components that integrate somatosensory, vestibular, and visual inputs to change muscle activity and joint position to maintain the centre of mass inside the support base [2, 3]. Because the human body is unstable, a postural control system must be employed to stand upright. The proficiency of postural balance is affected by morphology, muscle strength, power, proprioception, and hemisphere laterality [4, 5]. Moreover, other factors, such as anthropometry, age, sex, and activity level, influence the postural control [6, 7]. Maintaining static or dynamic balance is a prerequisite for successful human movement [8] and improves sports performance [9–11]. Static balance pertains to vertically sustaining the centre of gravity in alignment with the support base, with minimal movement [12] or unperturbed environments [13]. In contrast, dynamic balance refers to maintaining or re-establishing equilibrium through rapid and successive position changes [14, 15].

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Promoting balance is one of the most important aspects of a successful football performance [16], such as duelling opponents, postural control on slick grass, adjustment to the ball's orbit, moving around, and changing direction [17]. Early researchers recognised the significance of balance ability in football for enhancing specific skills, reducing injuries [11, 18, 19] and minimising falls during a match [4, 20]. The preferred leg is used for most techniques in football, ranging from shooting, passing, juggling the ball in the air, dribbling, and receiving the ball [21, 22], while the non-preferred leg is employed for supporting the body weight [23, 24].

Numerous studies across diverse samples have revealed significant differences between the left and right lower extremities in unilateral positions [25], emphasising a bilateral asymmetry in the control of equilibrium across the preferred and non-preferred legs [26]. Some authors declared no difference between the preferred and non-preferred legs, whereas others disagree [5]. In football, the consistency of players' employment of the dominant leg preference often leads to the emergence of bilateral asymmetry [27, 28] as a result of quadriceps muscles being primarily used concentrically in kicks, jumps, and passes in football [29, 30].

Previous research has examined postural balance in football players, including static and dynamic balance performance by playing position [9], balance differences among athletes of various sports [23], and static and dynamic balance in age groups [31] To the best of our knowledge, there were limited studies evaluating static and dynamic balance that focus on young footballers. Therefore, this study aimed to assess the static and dynamic balance of preferred and nonpreferred legs during unipedal stance in young footballers. The second aim was to investigate correlations between the two types of balance in each parameter. We hypothesised that we should not see any differences in the two legs' capacities for maintaining balance in a single-leg stance. Furthermore, there was no connection among variables related to static and dynamic balance.

Materials and methods

Study design and participants

This study employed a cross-sectional design. All participants were thoroughly informed about the methods and provided written informed consent before participation. Consent was obtained from the coaches and parents on behalf of the adolescent participants. Data collection was conducted in Latvia on March 2023, at the onset of the beginning of the season. Forty-three young male football players from different football clubs in Riga city, who had regular training and competition timetables, were selected. These players had a mean age = 15.81 ± 1.33 years, height = 179.50 ± 6.14 cm, body mass = 69.79 ± 9.35 kg, body mass index = 21.59 ± 2.39 kg/m^2, training experience = 9.48 ± 2.48 years, and completed an average of 8.4 ± 2.1 hours of training per week. The reported training hours and experiences reflect the participant's regular training sessions pertinent to physical changes and physiological adaptations. Moreover, focusing on chronological and biological age was essential for functional performance assessment, especially when evaluating preferred or nonpreferred leg usage in young footballers.

Inclusion criteria for the young football players were: (1) age from 14 to 16 years; (2) participants perform balance exercises during the training season to integrate the training models with the specific demands of football games, such as (a) Squats on one/both legs standing on a BOSU ball; 4 × 10, time recovery 30 s; (b) Multidirectional leg swinging while standing on one foot on a BOSU ball; 4 × 10 per limb, time recovery 30 s. The type of balance training model aligns with the specific qualities and demands of the football game. The critical training components focused on improving the lower limbs' coordination, strength, and stability by combining other training programs. Players who experienced painful legs during the investigation had lower extremity or back injuries, had previous surgery in the year before the study, had vestibular disorders, had treatment for the inner ear, or had a concussion within three months preceding the study start were excluded after direct inquiry.

Assessment procedures

Before undergoing postural balance tests, players identified their preferred and non-preferred lower limbs using the 'Waterloo Footedness Questionnaire-Revised' (WFQ-R) [32]. Participants were warmed up for 10 min by cycling on a cycle ergometer (Wattbike Pro Ltd, Nottingham, UK) at 55–65 revolutions per minute and performing static and dynamic stretches for their lower extremities and core muscles. To assess the anthropometric characteristics of the adolescent football players, we used a SECA 220 stadiometer (SECA Deutschland, Hamburg, Germany) to measure the height with a precision of up to 1 mm, and SECA 874 scale (SECA Deutschland, Hamburg, Germany) for body mass measurement with a precision of up to 0.05 kg.

To evaluate static and dynamic balance, we used a ProKin 252 stabilometric platform (TecnoBody, Dal-

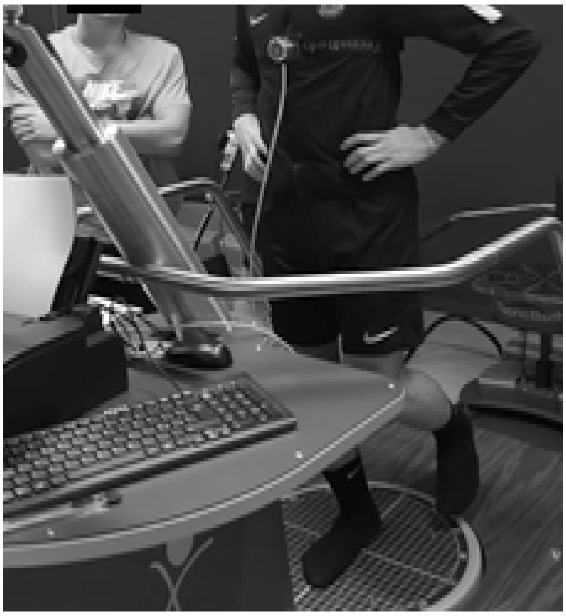


Figure 1. Static and dynamic balance assessment

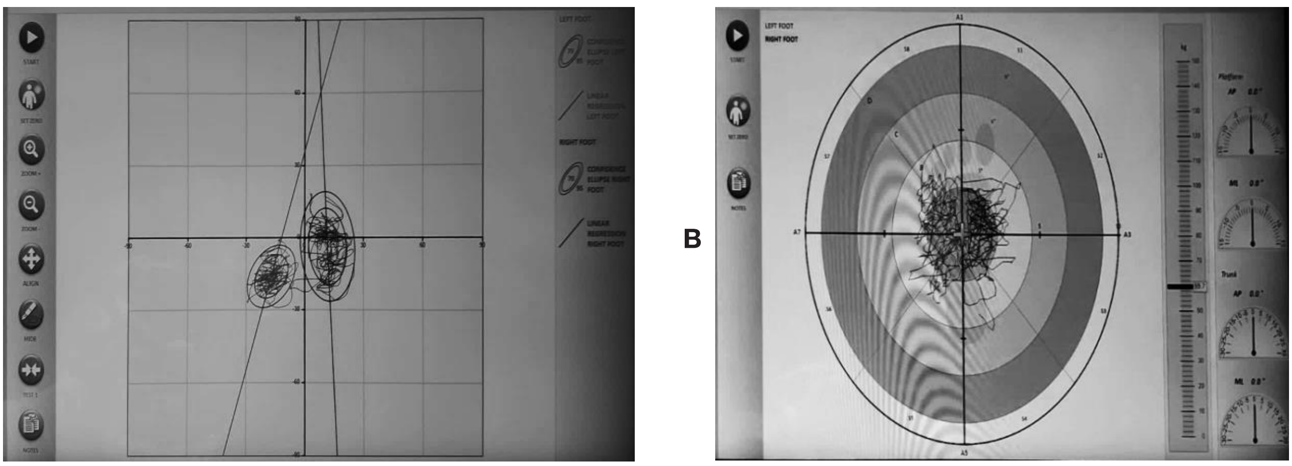
mine, Italy). The trunk sensors were attached to the chest in the middle of the sternal bone. The longitudinal axis of the foot was determined by establishing a tangent line connecting the midpoint of the middle toe with the central point of the heel. The supporting leg produced a knee flexion of 30°, while the contralateral leg demonstrated a knee angle of 45° in a bent position [33]. The participants' hands were set on their hips and instructed to direct their attention toward a screen in front of them (see Figure 1).

The participant performed three practice trials of standing on each leg before formal testing to decrease the learning effect on the measurements. The trial sessions were completed on days 1 and 2, with at least a 30-minute break between balance tests. The formal test was conducted on days 3 and 4, with a time lag of 48 hours after the trial. Based on previous test protocols [34, 35], two trials were performed, one on each lower extremity with eyes open for a 30-s test duration. If subjects failed to complete the 30 s without error, they were given one additional trial to complete the test. In this study, all players succeeded in the first trial, and the best score was used for analysis. Regarding data acquisition, after the subject conducted the test, the results of both the right and left legs were displayed on the Prokin 252's screen (see Figure 2 A, B). The investigator then saved and captured the test results using a camera phone to ensure no data was lost. In addition, this study provides a form for collecting the results of the static and dynamic balance tests.

Static balance test

Players were instructed to maintain a balanced one-leg stance, looking straight ahead at a screen for 30 s with their eyes open and focusing on a stationary target. When these measures were done, the device presented data of the parameters: ellipse area (EA) of the body centre of gravity movements, perimeter (P) of the centre of gravity, distances of sway in the anterior-posterior deviation (APD), medial-lateral deviation (MLD), and trunk deviation (TD), average anterior-posterior sway speed (AAPS), and average medial-lateral sway speed (AMLS). The total length of the circumference of the disorganised lines of the centre of gravity sway was used to determine the player's body sway area's perimeter (P). Shorter perimeter lengths (P) indicate better postural balance [36]. Furthermore, the area of the body's centre of gravity sways (ellipse area) was an established elliptical form that covered at least 90 or 95 percent of the chaotic sway lines. Balance performance is better with smaller ellipse areas (EA) [37].

A



B

Figure 2. Sample of the results of (A) the static balance test and (B) the dynamic balance test on the unipedal stance with a duration 30 s

Dynamic balance test

The dynamic balance test is the system's movable dynamic balance platform that uses air piston servo motors to measure the body's centre of gravity sways in unstable conditions in all directions at 15°. The participant had to maintain balance in a one-leg stance on the platform with their preferred or non-preferred leg while their hands were on their hips and their eyes were open. The subject was tested with a single-leg stance on an unstable surface for 30 s on each leg. After these tests, the device displayed the parameters of total stability index (TSI) and trunk total standard deviation (TTD). The TSI value of 0–0.83 was categorised as the norm for athletes, while the norm for healthy participants was 0.84–2.32, and poor postural control if it exceeded 2.33. Trunk position sense was worse if its value was higher [38].

Statistical analysis

The statistical examinations were conducted using the SPSS 26.0 for Windows software program (SPSS Inc., Chicago, IL, USA), with a significance level of $p <$ 0.05. The mean values and standard deviations for each characteristic were calculated. The Shapiro–Wilk and Levene tests assessed the equality of error variances, with a significance level of $p > 0.05$. However, only the MLD parameter had a normal distribution, while the EA, P, APD, TD, AAPS, AMLS, TSI, and TTD parameters revealed no normal distribution. Therefore, the Mann–Whitney (non-parametric) test was used to compare the footballers' static and dynamic balance abilities on the preferred and non-preferred legs. Furthermore, effect sizes (ES) from the Mann–Whitney comparisons were evaluated using partial eta-squared (η_p^2). Small, medium, and large ES were defined as 0.01, 0.06, and 0.14, respectively [39]. On the other hand, Spearman's correlation rho was used to assess the relationship between static and dynamic balance parameters.

Results

The results of the WFQ-R questionnaire revealed that 39 of the football players used their right leg as the dominant, while 4 players used their left leg as dominant. The data in Table 1 was obtained from the best value of each parameter during 30 s of preferred and non-preferred leg stances with the eyes open. Static balance of the preferred and non-preferred leg for the parameters EA ($Z = –0.816$, $p = 0.414$, $\eta^2 = 0.004$), PA ($Z = –0.428$, $p = 0.669$, $\eta_p^2 = 0.002$), APD ($Z = –0.350$; $p = 0.726$; $\eta_p^2 = 0.001$), MLD ($Z = –0{,}890$; $p = 0.437$; $\eta_p^2 = 0.013$), TD ($Z = –0.808$; $p = 0.419$; $\eta_p^2 = 0.017$), AAPS ($Z = –0.229$; $p = 0.819$; $\eta_p^2 = 0.000$), and AMLS ($Z = –0.967$; $p = 0.333$; $\eta_p^2 = 0.013$) showed no statistically significant differences at $p > 0.05$.

In the same way, the dynamic balance results revealed no significant differences between the preferred and non-preferred leg for the parameters: TSI ($Z =$ $–0.337$, $p = 0.736$, $\eta_p^2 = 0.000$) and TTD ($Z = –0.268$, $p = 0.789$, $\eta_p^2 = 0.001$) at $p > 0.005$.

Data Table 2 was obtained from each parameter's average preferred and non-preferred leg during 30 s with the open eyes. Although small positive statistically significant correlations were determined between TTD and EA ($r = 0.332$; $p = 0.03$), TTD and MLD ($r = 0.335$; $p = 0.02$), and TTD and TD ($r = 0.423$; $p = 0.005$), in

Table 1. Static and dynamic balance value

	Non-preferred (means ± *SD*)	Preferred (means ± *SD*)	*Z*	*p*-value	Partial eta-squared
Static balance					
EA (mm²)	858.09 ± 383.88	905.56 ± 347.33	–0.816	0.414	0.004
PA (mm)	1580.02 ± 534.23	1622.02 ± 490.72	–0.428	0.669	0.002
APD (mm)	8.46 ± 2.83	8.58 ± 2.50	–0.350	0.726	0.001
MLD (mm)	5.39 ± 1.15	5.64 ± 1.02	–0.890	0.437	0.013
TD (°)	1.93 ± 0.90	1.72 ± 0.73	–0.808	0.419	0.017
AAPS (mm/s)	30.97 ± 11.36	30.98 ± 9.89	–0.229	0.819	–
AMLS (mm/s)	35.43 ± 11.81	38.31 ± 13.36	–0.967	0.333	0.013
Dynamic balance					
TSI (°)	2.35 ± 0.78	2.35 ± 0.90	–0.337	0.736	–
TTD (°)	2.72 ± 1.97	2.87 ± 2.09	–0.268	0.789	0.001

EA – ellipse area, PA – perimeter, APD – anterior-posterior deviation, MLD – medial lateral deviation, TD – trunk deviation, AAPS – average anterior-posterior speed, AMLS – average medial-lateral speed, TSI – total stability index, TTD – trunk total deviation

Table 2. Correlation between dynamic and static balance parameters

	EA (mm^2)	PA (mm)	APD (mm)	MLD (mm)	TD (°)	AAPS (mm/s)	AMLS (mm/s)
TSI (°)	0.136 0.386	–0.062 0.693	0.147 0.345	0.101 0.518	0.161 0.301	–0.006 0.969	–0.032 0.837
TTD (°)	0.332* 0.03	0.045 0.773	0.267 0.083	0.335* 0.028	0.423** 0.005	0.092 0.557	0.043 0.784

EA – ellipse area, PA – perimeter, APD – anterior-posterior deviation, MLD – medial lateral deviation, TD – trunk deviation, AAPS – average anterior-posterior speed, AMLS – average medial-lateral speed, TSI – total stability index, TTD – trunk total deviation
* indicates $p < 0.05$, ** indicates $p < 0.01$

general, no statistically meaningful correlation was determined between static and dynamic balance for the parameters: TSI and EA ($r = 0.13$; $p = 0.38$), TSI and PA ($r = –0.06$; $p = 0.69$), TSI and APD ($r = 0.14$; $p = 0.34$), TSI and MLD ($r = 0.10$; $p = 0.51$), TSI and TD ($r = 0.16$; $p = 0.30$), TSI and AAPS ($r = –0.00$; $p = 0.96$), TSI and AMLS ($r = –0.03$; $p = 0.83$), TTD and PA ($r = 0.04$; $p = 0.77$), TTD and APD (r = 0.26; $p = 0.08$) TTD and AAPS ($r = 0.09$; $p = 0.55$), TTD and AMLS ($r = 0.04$; $p = 0.78$).

Discussion

This research aimed to investigate the differences in static and dynamic balance characteristics between the preferred and non-preferred legs of young football players. The most important discovery made by this research was that the preferred and non-preferred legs did not significantly contrast in terms of static and dynamic postural balance assessment. The second objective was to investigate the associations between static and dynamic balance parameters. As a result, no statistically meaningful correlation was identified between the two balance characteristics.

Static balance was assessed using a test where the participants were required to maintain a one-leg stance for thirty seconds with their eyes open. Interestingly, no noticeable distinctions were seen between the preferred and non-preferred leg in terms of primary parameters of static balance, namely the ellipse area/sway area (mm^2) and perimeter/sway path lengths (mm). Other parameters, such as trunk deviation, anterior-posterior/mediolateral deviation, and anterior-posterior/mediolateral average speed, did not affect the preferred or non-preferred leg. In prior studies on the lower extremities, the static postural stability on one leg was assessed by measuring a specific area from the centre of pressure (COP) deviations. However, the COP-based parameters, such as sway area [40], COP excursion [41], 95% COP elliptical area, standard deviation [42], total path length area [40] and velocity anterior-posterior/mediolateral [43], did not confirm the existence of a preferred leg effect.

The dynamic balance test measures the subject's capacity to respond effectively to the base of support displacements or external mechanical stimuli [14]. This experiment's findings indicated no statistically significant differences between the preferred and non-preferred legs in terms of the total stability index and trunk deviation parameters. Other studies found no differences in laterality among football players during a 60-second one-legged balance test and in earlier studies investigating dynamic balance across different sports [44–46].

Football players frequently favour their preferred leg for kicking and passing manoeuvres. Nonetheless, it was critical to recognise that, during regular training sessions, players face numerous situations where they must utilise both legs equally [47]. Furthermore, football coaches and trainers focus on technical and neuromuscular aspects to improve balance throughout puberty. The staff also considers designing a variety of exercises to remediate any imbalance and monitoring strength development to achieve high-level performance, physiological adaptation to level competition, and injury prevention of the lower limbs. Atkins [48] reported a 'trigger point' in early adolescence, where noticeable bilateral imbalances emerge. However, these differences tend to decrease as individuals progress through later adolescence.

The static and dynamic balance characteristics were attributed to similar structures, such as the cerebral cortex, basal ganglia, cerebellum, brainstem, and spinal cord. However, the lack of significance in the relationships may be attributed to the different roles these variables play under single- or dual-task conditions [49]. This study discovered no significant evidence supporting the correlation between static and dynamic balance. However, minor exceptions were observed regarding the relationships between TTD to EA, TTD to MLD, and TTD to TD. In line with the findings of Pau et al. [31], no significant associations were observed between the static and dynamic balance parameters, except for the relationship between vertical time to stabilisation and centre of pressure displacements in the anteroposterior direction. Several previous investigations on staff and students with no history of musculoskeletal disorders [50] and healthy adults [51] found no relationship among the parameters of both balances. It is essential to highlight that both types of balance tests propose distinct information that contributes to the comprehensive evaluation of young football players.

Assessment of the two types of balance performance can provide valuable insight into maintaining mobility and stability through the kinetic chain. Static balance tests are manageable, but poor static balance represents a risk factor for lower limb injuries. As in Pau's study [31], players may only partially represent their abilities to recover and maintain balance after a dynamic task, as is commonly experienced during training or competitions. Thus, these findings suggest that young footballers should have static and dynamic balance ability to improve their technique and mobilisation. The design of intervention training programs should prioritise the development of postural control among young players to enhance their careers in the future.

This study had some drawbacks that need to be acknowledged. First, the stages of puberty for young male footballers aged 14–16 years were not assessed, which is very important for understanding physiological development, improving physical performance, and preventing injury. Next, control groups (age, sex, untrained subjects or subjects with other sports specialties) were not included, which influences the value of the balance test. And finally, there was no training intervention that could modify the athlete strategies during the control of static postural balance in different sensory conditions. Future studies should include balanced training interventions and consider the maturity stage of the subjects.

Conclusions

Understanding the importance of maintaining postural control on the preferred leg is prominent for young football players' physical performance, skill development, and injury prevention. In investigating young footballers' static and dynamic balance, a notable lack of disparity was revealed between the performance of their preferred and non-preferred legs. The balance evaluation in adolescent football players should incorporate dynamic and static assessments, although outcomes in these two tasks are independent. Investigating kinematics and muscular activation could provide insights into how young players enhance their balance and whether postural control ability can be conditioned over the training season.

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Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee of the Latvian Academy of Sport Education (approval No.: 1/51813, date of approval: February 24th, 2023).

Informed consent

Informed consent has been obtained from the parents of all participants included in this study.

Conflict of interest

The authors state no conflict of interest.

Disclosure statement

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