

Article

Effects of Soccer Training on Body Balance in Young Female Athletes Assessed Using Computerized Dynamic Posturography

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Abstract: The aim of this study was to determine the effect of regular soccer training on the balance system for young women. Computerized dynamic posturography of female footballers ($n = 25$) and control group ($n = 50$) was assessed during three tests: Sensory Organization Test, Motor Control Test, and Adaptation Test. Statistically significant differences between the groups was found in Composite Equilibrium Score with higher values, indicating better postural stability, for footballers. Regular trainees also showed better usefulness of vestibular system while maintaining balance. Weight symmetry of the lower limbs during Motor Control Test also showed statistically significant differences between the groups. This study shows that female footballers have better postural stability than their inactive peers and that regular workouts may improve the balance system.

Keywords: posture stability; balance; football; exercise; training

1. Introduction

Football is the most popular sport discipline with around 200,000 professional players and 240 million amateur players. It is responsible for almost 10% of sports injuries requiring medical attention in adolescents [1,2]. This discipline requires players to have unprecedented coordination to cope with rapidly changing external conditions. With regular practice a player acquires precision in movement and more muscle mass. Frequent training helps the player acquire the ability to execute appropriate strategic movements to effectively target his/her opponent's goal and to prevent serious injuries. To evaluate motor coordination a test was adopted many years ago to measure maximum rotation to the left and right when jumping in the air with both feet [3]. In modern training it is necessary to constantly monitor the sportsperson's coordination and balance [4,5]. Presently there are many different methods to assess training progress, physical activity, and body postural stability, but the most important conditions in which football players should be assessed are dynamic conditions. Postural stability in athletes has been reported widely in several sports disciplines [6,7]. That suggest that the type of sport and repetitive training may affect the balance system control. Some researchers found that football players were better than other athletes [6,8] and that the level of playing experience influences postural control performance and adopted motor strategies [9].

The human body's static and dynamic balance is maintained by the posture control system, which coordinates the stimuli received by the vestibular system, the visual system, and proprioceptors, and also provides a selection of optimal postural responses aimed at preventing falls [10,11]. The posture control system tracks the position of the center of gravity (COG) over an area defined by the outline of the human feet, thus guaranteeing a stable posture [12]. The body's multi-segment construction, the height of the COG above the base of support (BOS), and a relatively small BOS, results in the

human body being unstable when in an upright position. The balance control system therefore needs to constantly analyze and counterbalance all the destabilizing factors through proper stimulation of the relevant muscle groups [12,13]. The central nervous system watches over the appropriate choice of reaction and the stimulation of the appropriate muscle reflexes. To correct posture, it adapts a movement strategy based on its analysis of linear and angular accelerations of individual body segments. Stability control of body posture depends on many factors, which includes a range of movements in the joints, muscle strength, speed and precision of movement, and the ability to perceive body positioning in space (“body sense”) [14].

Computerized Dynamic Posturography (CDP) allows the individual components of the human balance system to be evaluated. During CDP, signals from appropriate senses involved in maintaining balance are evaluated. The postural response time and the reaction time to unexpected support platform changes, with an appropriate motor response, is also determined as well as the efficiency of adaptive mechanisms [15]. CDP is the gold standard to differentiate between sensory, motor, and central adaptive impairments to postural control [16]. In football it can be an opportunity to track the rehabilitation of postural control impairment after anterior cruciate ligament injury, which is one of the most common in this sport [17].

The aim of this study was to compare the behavior of the balance system between two groups of young women and to determine the effect of regular practice. One group consisted of young female footballers who train regularly and the other, a group of peers who do not participate in any regular sporting activity. We hypothesize that football players would show better postural balance performance.

2. Materials and Methods

2.1. Participants

The study group consisted of 25 young (age = 18.9 ± 4.5 year) female footballers from AZS-PSW Biała Podlaska, a club in the Polish Women’s Football League. Each footballer in this study group has been attending training sessions for at least 6 years with five training sessions per week of 90 min duration. The control group consisted of 50 students (age = 20.7 ± 1.2 year) from the Medical University of Lublin, who had declared a lack of sporting activity. Both groups were chosen such that there were no statistically significant differences between them in height, weight, or body mass index (BMI) (Table 1). All subjects participating in the study had the same functional preferences (right-sided handedness, footedness, and eyedness) and same postural lateral preferences (hand-clasping, arm-folding, leg-crossing, and stair climbing) [18].

Table 1. Characteristics of female footballers and the control group.

	Footballers (n = 25)		Control Group (n = 50)		<i>p</i>
	M	SD	M	SD	
Height [cm]	167.47	4.28	168.04	5.33	0.726
Body weight [kg]	62.00	5.17	61.72	5.55	0.873
BMI [kg/m ²]	22.06	1.65	21.86	1.51	0.672

M = mean, SD—standard deviation, *p*—probability value.

2.2. Procedure

The study was conducted with the approval of the Bioethics Committee at the Medical University of Lublin (KE 0254/195/2011). At the beginning, participants were informed about the purpose of the study and asked to complete a questionnaire and to sign the consent for the study. The questionnaire included questions about general health: all diseases or health problems, surgeries or hospitalizations, brain injuries, loss of consciousness episodes, bone/muscle/joint injuries as well as any medication or

drugs (including alcohol) taken in the past month. Another part of the questionnaire was about physical activity: what sport or physical activity the participant undertakes, for how long, and how many times per week. Afterwards each participant was accurately weighed and measured, and a short lateralization preference test was performed (e.g., which hand the participant uses for drawing/throwing a small object, which leg for kicking a football or stepping onto a chair, and which eye for looking into a bottle or a door viewer). The final stage of the study was a posturographic examination during which the participant stood barefoot on the posturographic platform and was secured with a special harness.

2.3. Instruments

Posturographic tests were performed using an Equitest posturograph manufactured by NeuroCom International®. The device consists of a dynamic force plate, visual surround, and a computer with software. Both the force plate and visual surround are moveable ($\pm 10^\circ$ rotation for both and a maximum angular velocity of $50^\circ/\text{s}$ and $15^\circ/\text{s}$, respectively). The study protocol included the following tests: Sensory Organization Test, Motor Control Test, and the Adaptation Test.

The Sensory Organization Test (SOT) evaluates the usefulness of signals coming from the different senses involved in maintaining body balance. This test is performed using six sensory stimulation conditions, during which visual stimuli are changed and a rotation of the foot support platform, or movements of the visual surround, are introduced. During the first three tests (SOT1–SOT3) the foot support platform is stationary while the visual information is varied: SOT1—eyes open, SOT2—eyes closed, SOT3—moving visual surround. During these tests, analyzing postural stability determines the usefulness of the visual signal and the patient's ability to suppress visual stimuli which are contrary to reality. The next three tests (SOT4–SOT6) are performed with a moving foot support platform, which interferes with the information received by the proprioceptive system. As with the previous three tests, visual information is varied: SOT4—eyes open, SOT5—eyes closed, SOT6—moving visual surround. Two final trials evaluate the usefulness of the vestibular system, whose role increases significantly in the case of incorrect or missing stimuli from the remaining systems involved in posture control. During SOT, the Equilibrium Score (ES) that quantifies the COG sway or postural stability under each of the 3 trials of the 6 sensory conditions is evaluated. A score of 100 represents perfect balance (no sway) and a score of 0 indicates a fall. During SOT, Composite Equilibrium Score (CES)—a weighted average of all 6 individual scores ES—the body's COG displacement in the anterior–posterior direction, as well as the motor strategy (MS)—correctness of the selected postural strategy—is also assessed. A score near 100 indicates a full ankle strategy while a score near 0 indicates a full hip strategy with maximum shear force. In addition the Sensory Analysis (SRS) that determines a patient's ability to use input from the somatosensory (SOM), visual (VIS), vestibular (VES) system to maintain balance as well as the degree to which the patient relies on visual information whether it is correct or not (PREF) is assessed [19,20].

The Motor Control Test (MCT) is performed for 6 conditions using the foot support platform capable of forward and backward movements through small, medium, and large displacements. A series of three trials is performed for each condition during which the patient's ability to perform corrective movements is evaluated in response to unexpected changes in the foot support platform. The MCT analysis the Latency Response (L)—the time between start of platform movement and start of postural response—the Amplitude (A) of the postural response and the Weight Symmetry (WS)—a nondimensional quantity with a score of 100 indicating that weight is borne equally by the two legs. The WS score decreases to zero or increases to 200 when all the weight is borne by the left or right leg, respectively.

In the Adaptation Test (ADT), the patient is subjected to two series of sudden platform perturbations, one of which causes dorsiflexion (ATU) while the other causes plantarflexion (ATD) in the ankles. Each series consists of five trials. During subsequent trials, the patient should maintain a vertical posture, minimizing with every subsequent trial the amount of energy required to rebalance the body. This sway energy (SE) is determined after each platform perturbation and indicates the amount of COG displacement during each trial.

2.4. Data Analysis

Statistical analysis was performed using the STATISTICA 10 (StatSoft) computer program. To verify the normality of the data the Shapiro–Wilk test was used. Because normality tests failed to confirm that all the parameters variables studied had normal distribution (most probable reason for not normal distribution in footballers group was the small number of participants), all variables were analyzed with non-parametric statistics—the Mann–Whitney U-test—for differences between groups. Statistically significant changes were those with a statistical significance level of $p < 0.05$.

3. Results

The SOT results are shown in Figures 1–3. ES analysis (Figure 1) shows statistical significance ($p < 0.05$) for the CES, with higher values for footballers. Of the six SOT conditions, COG displacement differed significantly between the groups only for conditions ES5 and ES6 which provided conflicting information to the sense organs, carried out on a moving platform with eyes closed (ES5) or a moving visual surround (ES6). These results reflect significant differences in the use of vestibular stimuli (VES) between people training regularly and those not performing any regular sport.

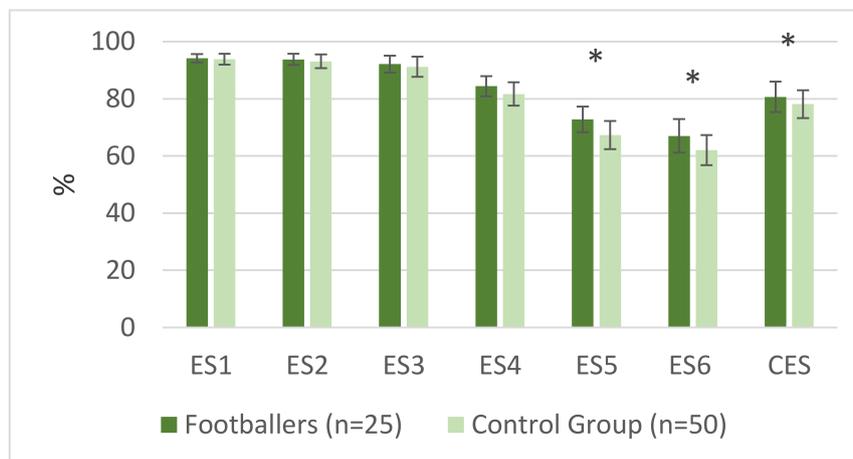


Figure 1. Sensory Organization Test—Composite Equilibrium Score (CES) and Equilibrium Score (ES) results (where the ES suffix refers to a particular SOT condition) for footballers and control group. The symbol * refers to a significant difference at $p < 0.05$.

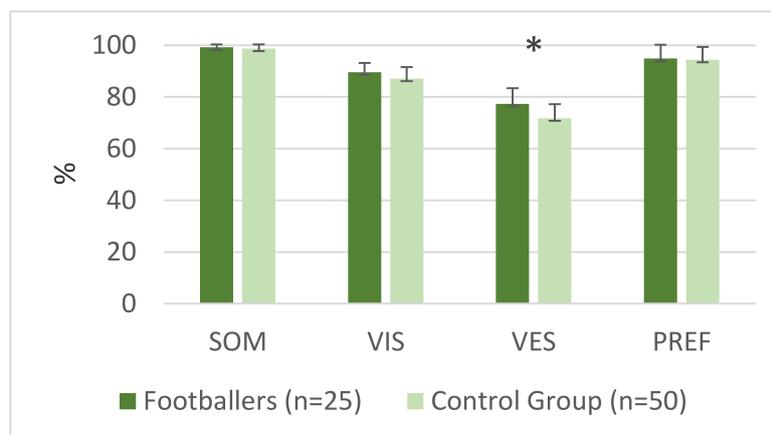


Figure 2. Sensory Organization Test—sensory analysis (SRS) results for the somatosensory system (SOM), the visual system (VIS), the vestibular system (VES), and visual preference (PREF) for footballers and control group. The symbol * refers to a significant difference at $p < 0.05$.

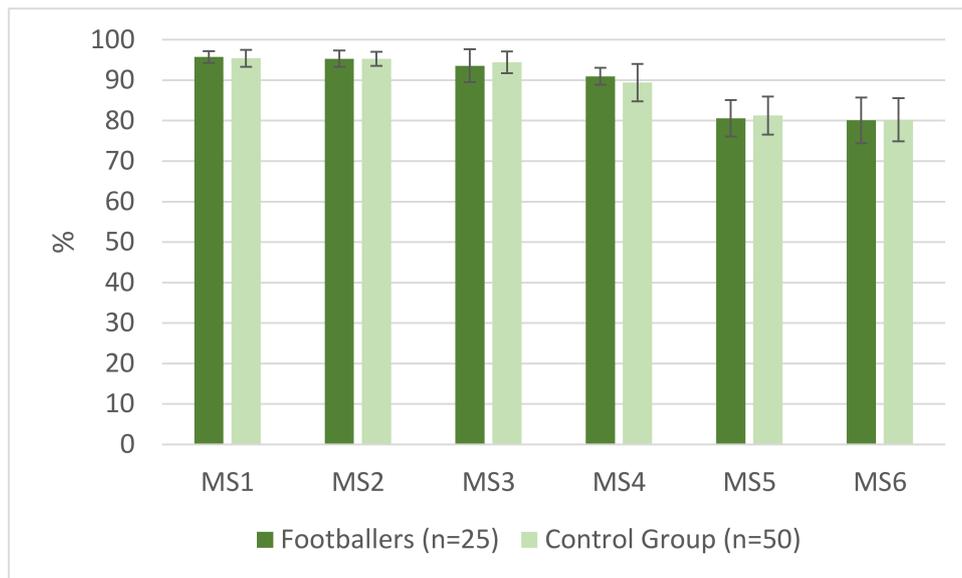


Figure 3. Sensory Organization Test—motor strategy (MS) for particular SOT conditions for footballers and control group.

The usefulness of the signals from the other sensory organs involved in the control of body balance (VIS, SOM, and PREF) did not highlight any significant differences between the two groups (Figure 2).

There was no impact on the selection of an appropriate motor strategy (MS1–MS6) by people playing football (Figure 3).

During MCT, statistically significant differences between the two groups were found in the symmetry of loading of the lower limbs during all the trials (Figure 4). Football players were characterized by disproportionate distribution of body weight with a predominance of left leg.

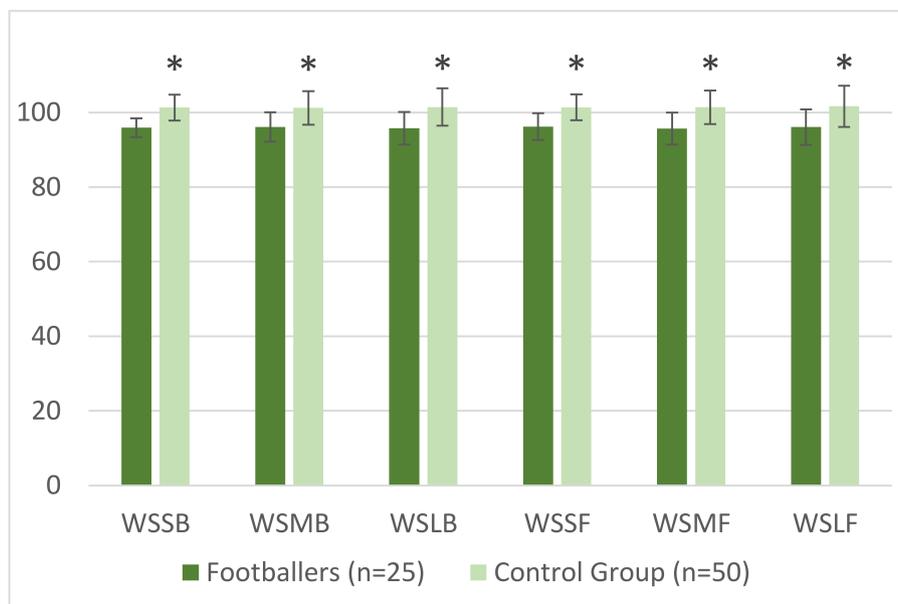


Figure 4. Motor Control Test—weight symmetry (WS) results for the lower limbs for small, medium and large platform transitions in backward (SB, MB, LB) and forward (SF, MF, LF) direction for footballers and control group. The symbol * refers to a significant difference at $p < 0.05$.

Postural response latencies (Figure 5) and their amplitudes (Figure 6) did not reveal any statistically significant differences between the two groups, which means that neither the reaction time nor the angular velocity of COG during the trials depends on the physical activity.

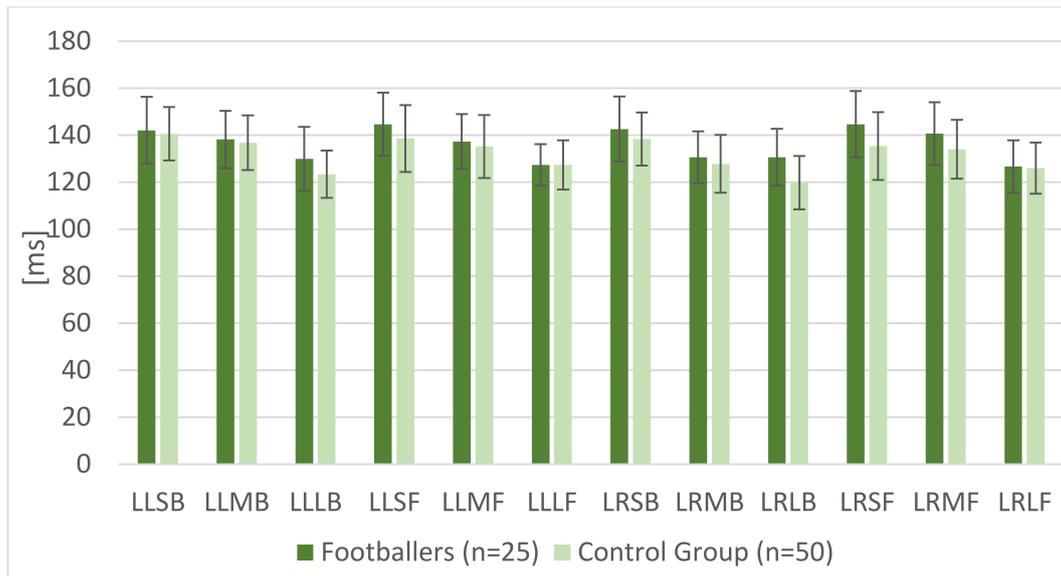


Figure 5. Motor Control Test—postural latencies for left (LL) and right (LR) lower limb for small, medium and large platform transitions in backward (SB, MB, LB) and forward (SF, MF, LF) direction for footballers and control group.

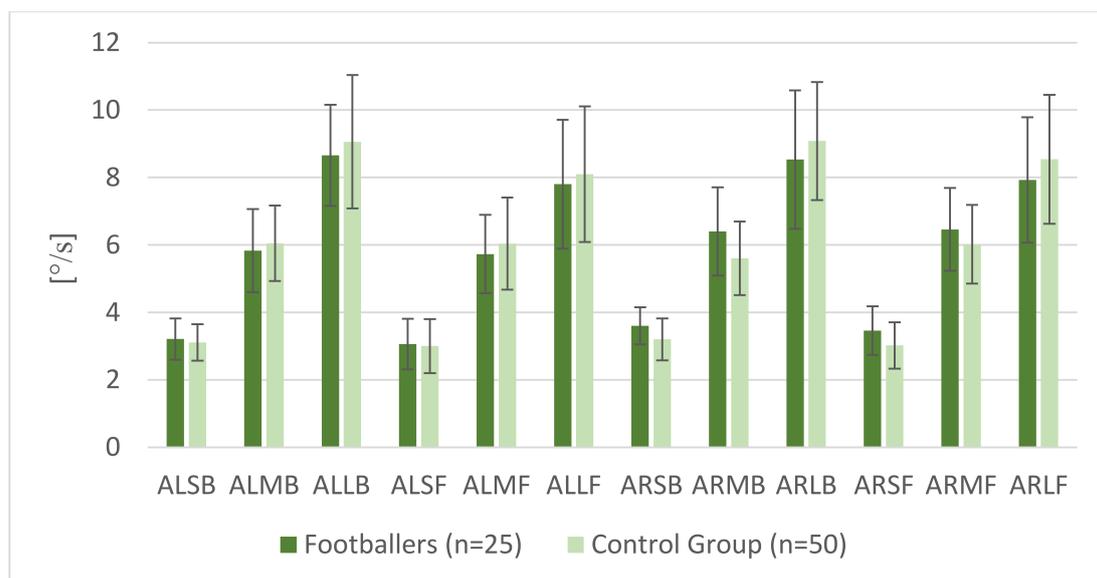


Figure 6. Motor Control Test—amplitudes of the postural responses for left (AL) and right (AR) lower limb for small, medium and large platform transitions in backward (SB, MB, LB) and forward (SF, MF, LF) direction for footballers and control group.

In the ADT there were no statistically significant differences between the measured parameters for both groups, which means that the adaptive postural response system is independent of physical activity. The results are shown in Figure 7.

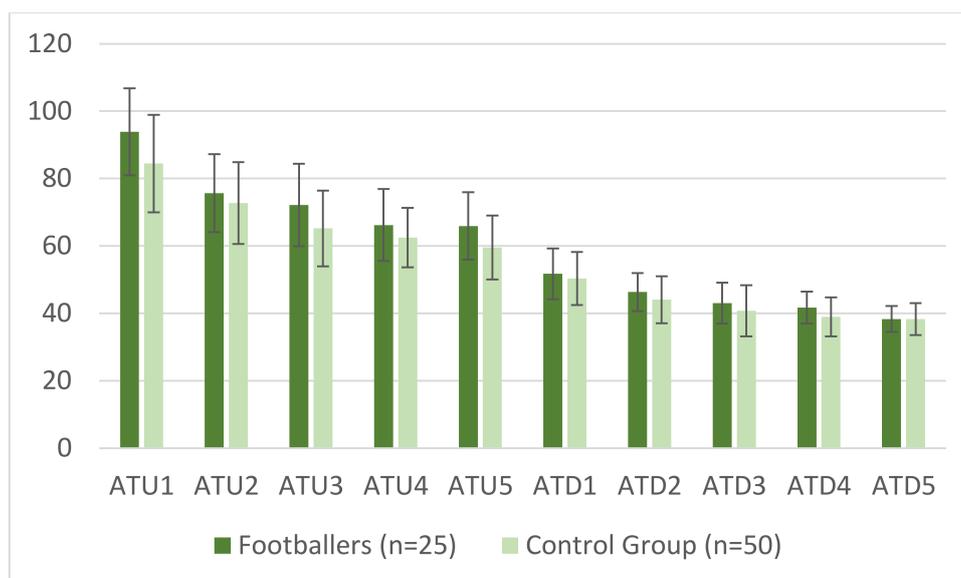


Figure 7. Adaptation Test—sway energy for 5 dorsiflexion (ATU) and 5 plantarflexion (ATD) condition for footballers and control group.

4. Discussion

Football is a sport discipline which, in addition to unprecedented coordination, requires exceptionally divided attention. The players must focus not only on the ball, but must also control their positions, the actions of the players in their team as well as those in the opposing team. They must analyze and foresee subsequent situations.

This study shows that professional footballers achieve significantly better results in the CES. The smaller COG displacements observed during all SOTs provides the evidence for the higher CES value for footballers who train regularly. The footballers also showed smaller COG displacements in the anterior–posterior direction for conditions which were inconsistent with the real signals from the somatosensory and visual systems. The footballers made better use of the signals from the vestibular system, which is the most reliable source of information regarding the positioning of the body’s COG [15]. An analysis of the symmetry of the distribution of body weight gives a higher load asymmetry in the lower limbs in the footballers, which arises from using the dominant leg during the game. This is probably the result of more symmetrical actions performed during training and matches, which are due to unexpected situations arising during the game. For both male [21] and female footballers [22], in particular when shooting at goal, which is an important technical skill, there is a clear asymmetry with the right leg being dominant. Barone et al. [23] suspects that sportspeople prefer to use one leg (dominant), because they have better standing balance on non-dominant one.

The regularity of exercising in the context of improving balance has been written about repeatedly. One of the few studies relating to female footballers showed that doing dynamic exercises during warm-up improves both static and dynamic balance [24]. Jakobsen et al. [25] observed postural control improvement after 12 weeks of football training and high-intensity interval running. Paillard et al. [9] paid attention to the fact that the players with more frequent and intensive training sessions showed better postural control, which may be due to greater sensitivity of sensory receptors or better integration of information. Both the general muscular exercises (that mobilizes the whole body) and local muscular exercises (that concentrates on a particular muscle group) can disturb postural control. General muscular exercises (especially running and walking, which are a big part of a football training) contribute to changing the effectiveness of sensory inputs: vestibular—decreases the sensitivity of orthotic organs—and proprioceptive—disturbs the senses of the force and limb position [26]. Söderman et al. [27] Baghbaninaghadehi et al. [28] have drawn attention to the importance of maintaining proper

body stability in team sports. This is an important issue, because footballers must have adequate stability, which is especially important when jumping up to head a ball. Brito et al. [29] found that the postural sway (represented by sway velocity) increased and the ankle proprioception decreased after a 45 min of a match. The authors suggest that prophylactic balance training should be performed following rather than before the practice session. Also, Gioftsidou et al. [30] observed improvement in the balance ability, especially in non-dominant lower limbs when the balance training was performed after the football training.

Mohammadi et al. [31] observed significant changes in both the static and dynamic balance parameters among young sportspeople who undertook a 6-week appropriately selected training schedule. According to the authors, an increase in the sportsperson's muscle mass was responsible for the changes. Results of this work also show better postural stability of young football players in dynamic conditions, which are more valuable than static ones, because they are the closest conditions to these on the football field. Interestingly, Pau et al. [32] observed dynamic balance impairment in young football players due to fatigue after the first half on football match. The impairment was observed in the increase in the time necessary to stabilize after landing from a single-leg jump.

On the basis of tracking professional players' COG trajectory while they were standing on one leg and then monitoring the time taken to stabilize their posture, Pau et al. [32] showed that they achieved significantly lower stabilization times while their center of pressure (COP) displacement surface area was significantly less than for their novice colleagues.

The assessment of the balance and dizziness following sports-related concussions is very important for making decisions about further training or removal from the team [33]. In addition, the study authors [34,35] have shown that the use of exercises to improve balance also has a positive effect on coping with stress and reduces the risk of injury during physical activity, which is extremely important in the effective use of a sportsperson during the game.

The findings of this study must be seen in light of some limitations. The first limitation is the sample size: because of the number of football players in the world it is difficult to deduce a general conclusion based on a small sample. The second limitation concerns the sample profile—using purely student sampling is also extremely limiting on the population. Another limit regarding the student population is the questionnaire and their truthfulness, especially in questions about alcohol, drugs, etc. Gribble et al. [36] observed that males were more adversely affected by fatigue than females. This may suggest that for future research the study group should consist of both sexes. In our research, only dynamic conditions were tested; however, Hrysonmallis et al. [37] and Pau et al. [38] paid attention to the fact that assessment of balance in football players should be performed with both dynamic and static tests, because postural control performance is not related in these two cases.

5. Conclusions

In conclusion, postural stability in young female footballers was found to be better than their inactive peers. The study showed better usefulness of the vestibular system as well as asymmetrical weight-bearing in regularly trainees.

Further research to explore the possibilities of use CDP in assessing the progress of training is needed. The Sensory Organization Test assesses the quality of the human balance system, which could help with evaluation of training effects. Also, the results of the WS may be useful for determination of the dominant leg, which is important when selecting the role the player can play on the field. More studies are needed to specify which exercises contribute to improving the balance and perhaps apply them in rehabilitation techniques.

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