Comparison of Static and Dynamic Balance at Different Levels of Sport Competition in Professional and Junior Elite Soccer Players

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Abstract

Jadczak, Ł, Grygorowicz, M, Dzudziński, W, and Śliwowski, R. Comparison of static and dynamic balance at different levels of sport competition in professional and junior elite soccer players. *J Strength Cond Res* 33(12): 3384–3391, 2019—The purpose of this study was to compare body balance control and balance recovery strategies of professional football players, representing various sports levels in static (eyes open, eyes closed) and dynamic conditions, both on the dominant and nondominant leg. Three groups of professional and junior elite soccer players were investigated: a PRO group ($n = 52$), a U-21 group ($n = 55$), and a U-19 group ($n = 47$). The study of body balance control was performed using a Delos Postural Proprioceptive System measurement tool. The analysis of the results showed an effect of group ($p < 0.01$) and leg significance ($p < 0.95$) in the dynamic test. Three-way analysis of variance (3 [group] $\times$ 2 [leg] $\times$ 2 [eyes]) of static test data showed that the main effect of eyes ($p < 0.0001$), group ($p < 0.0001$), and leg ($p = 0.0092$) and the 2-way interaction of eyes $\times$ group ($p = 0.0003$) were significant. To represent statistical significance, the cutoff value was set to be $p \leq 0.005$ for all measures. Our results indicate the importance of evaluation and monitoring of dynamic and static balance on both legs, which allows for a comprehensive comparison of body balance control and the balance recovery strategy depending on the represented sport level. Our study indicates that the higher the sport level of football players (the PRO group), the better their balance, which may indirectly contribute to the prevention of injuries and more effective performance of any actions directly related to the game.

Key Words postural control, supporting leg, unipedal stance

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Introduction

Soccer is the world's most popular sport and the fastest growing team sport in the United States, especially within the younger populations (16). Because of its enormous popularity, multiple studies have been conducted to understand the fundamental skills required by a soccer player. During recent decades, soccer has become progressively more athletic, and the capacity of soccer players to produce varied forceful and explosive actions has become crucial in many game situations (26,33). Soccer is a sport that requires extremely high technical abilities, which are reflected on the pitch in the performance of such elements as passes, aerial duels, dribbling, feigns, receiving the ball from a player of the same team, interception of the opposition pass, and shots on goal. All these actions are performed very often in motion at a high speed, with opposition pressure, changed flight path of the ball, and in conditions of significant surface instability (6,13,15). Taking into account the complexity of the actions during the game, soccer requires that players have the ability to maintain balance on 1 leg, both in static and dynamic conditions, and thus, soccer players have better stabilization in a 1-legged stance (27,33). On the one hand, there is a strong visual dependence related to ball control, which forces players to lower their gaze, while simultaneously watching other players on the pitch (12). Earlier studies showed that static and dynamic balance in highly trained dancers, gymnasts, and football players is significantly better than in untrained people (4,10,24). In contrast, Bressel et al. (8) proved that in dynamic test (DT) and static test (ST), footballers exceed basketball players, yet do not differ from gymnasts. Maintaining appropriate balance seems to be effective in executing neuromuscular control (41), while being a distinguishing factor of professional football players (21,31).

In light of the current studies, there remain inconsistencies regarding whether players representing a high sporting level in various sport disciplines demonstrate a different strategy of body balance control (eyes closed or eyes open, 1-legged or 2-legged stance). No clear evidence exists to indicate that the assessment of balance with the eyes closed is more effective than tests performed with the eyes opened. However, training subjects usually have a better developed sense of balance than nontraining subjects (10), and the higher the sporting level they represent, the more stable the posture they are characterized by (31). Paillard et al. (29) demonstrated that judo athletes at the top sporting level were more dependent on visual information during posture control. Moreover, more experienced players generally use unique sensory information in posture organization depending on the demands posed by each discipline (20). A strong visual dependence in relation to the ball and other players was also noted in rugby players (7). Similarly, Romero-Franco et al. (36), when studying the effect of proprioceptive training on center-of-gravity control, noted an improvement in balance in sprinters when exercises were performed with eyes opened. This visual dependence is documented in other sport disciplines, including soccer (20).

Physical training improves balance control while reducing body sway in ST (18) and DT (38). Thus, we can assume that trained persons will demonstrate better stability than nontrained, irrespective of the support leg, as was noted in basketball players in static conditions (19). Alternatively, professional gymnasts show good stability when performing balance exercises in DT in 1-legged stance (1) in line with their training, which develops balance in a way that is characteristic of this discipline (3,37). From this perspective, we assume that the specificity of training should affect the performance in line with the fact that movements performed by athletes during training relate to one body side (symmetrical or asymmetrical balance training). Gymnastic training increases balance control in women in comparison to nontraining women in dynamic conditions in 2-legged stance (10) and in static conditions in 1-legged stance (40). The latter study did not demonstrate differences between a dominant and nondominant leg in static conditions. However, the studies on soccer players show not only the asymmetry of gait changeability performed by right-handed players (25) but also differences between equilibration paths in the right and left legs (18), yet a strong asymmetry on the right side in dynamic motor tests (28). This leads to an assumption that the performance of soccer players may be asymmetrical. They should have better balance on the nondominant leg compared with the dominant one (15).

The few earlier studies of body balance in soccer players concerned the comparison of players representing very different sporting levels (9,31) or focused on comparisons of postural control skills between soccer and other sport disciplines (8,10,21). As there were no reports on balance abilities in soccer players representing top sporting level in youth (U-19 and U-21) and senior categories (PRO), we performed a comparison between these groups. Previous soccer knowledge and practice lead us to assume that players representing higher sporting level are characterized by a better posture control and balance recovery strategy in various conditions. Because of the above, in our study, we put forward the following research questions: (a) is there a difference between the sporting level and the ability of postural control both in static (with the eyes opened and closed) and in dynamic conditions between groups of professional and junior elite soccer players? (b) are there differences in postural control between the dominant and nondominant legs within a given group and between groups in players competing at different sporting levels? Our purpose was to use 2 types of platforms (stable and unstable) to document differences in standing balance abilities between the 3 groups of professional and junior elite soccer players.

METHODS

Experimental Approach to the Problem

The primary objective of this observational study was to compare the dynamic and static balance of professional and junior elite soccer players depending on the sporting level the players represent. Soccer players who competed at the level of Polish Extraklasa (top Polish league) were included in the PRO group. Players in the U-19 and U-21 groups were recruited from the leading soccer academy in Poland, according to the ranking of the Polish Football Association, and played in the top league in their age groups. To study mechanisms responsible for postural control (visual, vestibular, proprioceptive), static balance (on a stable platform) was measured both with visual control and without it. For the assessment of the balance recovery strategy (only with the eyes opened), an unstable platform was used (dynamic conditions). To find differences in the balance between lower limbs, the tests were performed on dominant and nondominant legs. This study used a cross-sectional study design, with measurements taken during the preseason period.

Subjects

Players were initially categorized according to their competitive sporting level. Fifty-two soccer players were included in the PRO group (mean age ± *SD*, 25.7 ± 3.9 years; height, 182.4 ± 5.9 cm; body mass, 78.0 ± 7.2 kg). Average training history in this group was 16.2 years. Fifty-five players were included in the U-21 group (mean age ± *SD*, 20.3 ± 0.6 years; height, 181.8 ± 6.7 cm; body mass, 75.6 ± 8.0 kg), and their mean training history was 10.6 years. The U-19 group included 47 players (mean age ± *SD*, 17.8 ± 0.9 years; height, 181.2 ± 7.4 cm; body mass, 71.2 ± 8.3 kg) with a mean training history of 8.5 years. In the starting season, all studied groups performed 5–6 training units in a weekly macrocycle. Foot dominance was determined using a self-report measure and in addition to a kicking-ball test. All players in the PRO group and the majority of players in the U-19 and U-21 groups had professional soccer contracts. The study excluded players who had a history of cerebral concussion, vestibular disorders, injury to either ankle or lower extremity injuries for 3 months before testing, ear infection, upper respiratory infection, or head cold at the time of the study and previous balance training. All participants or their parents or guardians (for players younger than 18 years) were verbally

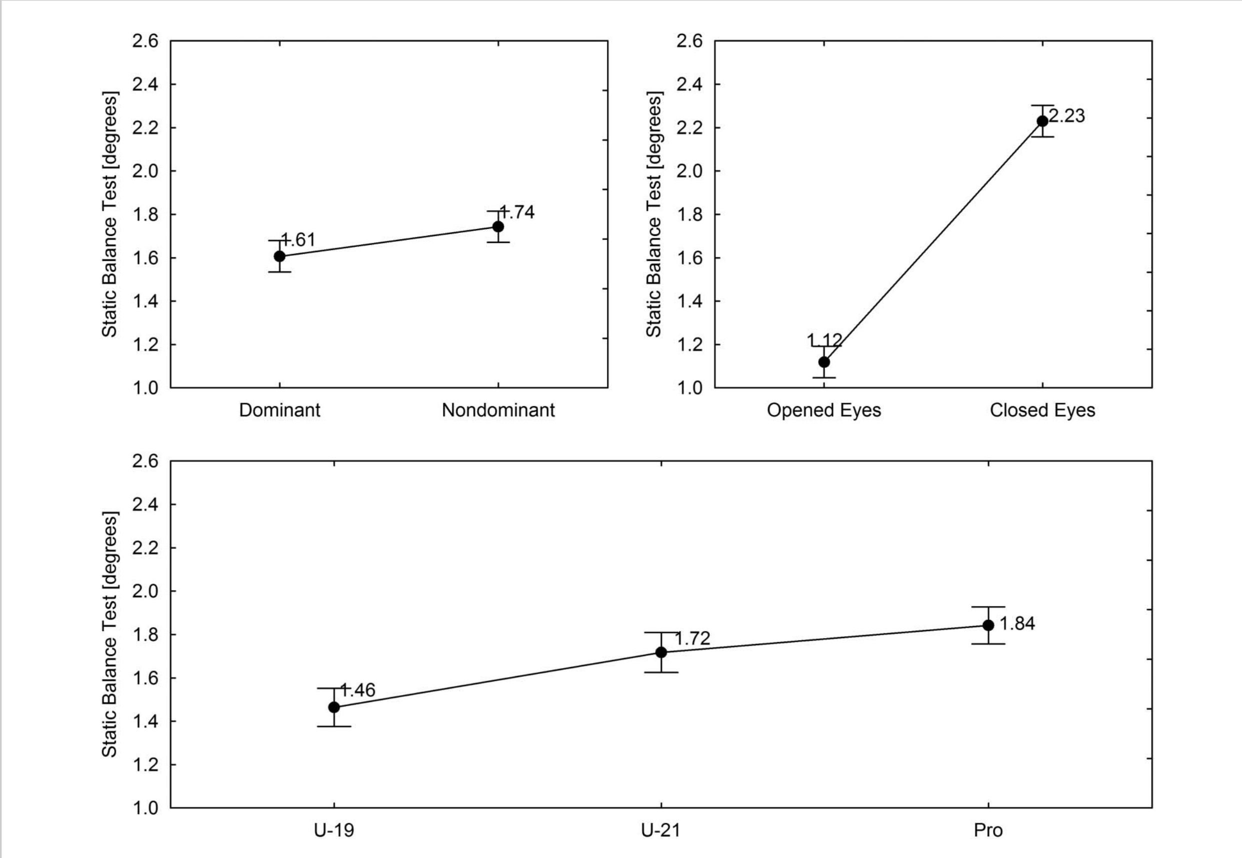

Figure 1. Results with mean values and 95% confidence interval for legs, eyes, and groups in the static balance test.

informed of the purpose, procedures, and risks associated with the study, their freedom to withdraw at any time without prejudice, and if they or their parents or guardians agreed, they signed the consent form. The study was performed according to the Declaration of Helsinki and the ethical approval for the study was granted by the Bioethical Committee at the Poznań University of Medical Sciences (629/13).

Procedures

The tests were performed in the Biomechanical Assessment Laboratory at the Rehasport Clinic in Poznań. The laboratory is certified by International Federation of Association Football, as a Medical Center of Excellence. The results were collected from 2009 to 2015. Each player was tested once in the same stage of the season (before the start of the Polish Ekstraklasa competition, in the summer, i.e., July-August) by the same research team and under the same research conditions. All tests were carried out in the same order for each player and took place between 9 AM and 12 AM. All tests were performed in ambient temperate conditions (≈22° C and 35% relative humidity) and were kept constant across testing sessions. For 2 days before the tests, the players were not subjected to intensive training. There was no specific advice regarding nutrition, but they were advised to eat a similar meal before each testing session. Before every test, the participants filled in questionnaires in which they assessed whether they experienced any musculoskeletal pain or any discomfort, in particular within the legs. To establish postural stability, a ST and a DT were performed using the Delos Postural Proprioceptive System (Delos, Turin, Italy), which is composed of the electronic postural reader Delos Vertical Controler (DVC), Delos Postural Assistant (DPA), Delos Equilibrium Board (DEB), and the Postural System Manager (a computer and software for visualization and analysis of DVC and DEB data). The electronic postural reader–DVC– is an oval-shaped device (7 × 4.5 × 2.5 cm in size) recording and visualizing in real time the lateral lean and anteroposterior movements of the trunk. It is applied to the sternum and measures the trunk inclination in the frontal (x) and sagittal plane (y) by means of a 2-dimensional accelerometer unit. The DPA is a supporting bar with an infrared sensor that assesses the longest uninterrupted period during which the subject did not have to support the hands on the bar for balance. The electronic rocking board, DEB, has a single degree of freedom, and it allows the assessment of proprioception of the extremities based on inclination of its movement. The rocking board of the Delos Postural System is equipped with an

Table 1. Mean ± *SD* of dynamic test of group scores (in percent) for dominant and nondominant legs.*†

Group	Leg (%)‡		Effects		
	Dominant	Nondominant	Group	Leg	Group × leg
U-19	44.31 ± 9.06	47.33 ± 8.69	<0.0001	0.0054	0.9925
U-21	46.42 ± 9.98	49.32 ± 9.99			
PRO	59.40 ± 8.13	62.10 ± 7.60			

*$p \leq 0.05$ statistically significant value, and $p \geq 0.005$ statistically insignificant value.
†The results increase with the level of sport competition.
‡Mean values for dominant and nondominant leg show significant differences between PRO and U-21 and U-19 ($p < 0.001$).

accelerometer connected wirelessly (Bluetooth system) to a personal computer. The data from the postural reader are a stream of acceleration samples taken by converting the sensor outputs into digital domain (21). The output signal is sampled at 100 Hz. The analyzed output signals are the inclination angles of the rocking board, as a function of time, and the related direction of the inclination. The maximum width of inclination is within a 30° angle (i.e., $-15° \leq \alpha \leq 15°$). The requested accuracy is 0.5°. Postural priority was used as the main outcome because it is confirmed to be a valuable parameter in postural control assessment. It is calculated as a product of mean deviation of the DEB platform (in degrees) from the vertical axis and the subject's deviation from a resultant of mean axes (also in degrees), measured by means of the accelerometer. Directly before the test, a participant performed a 10-minute warm-up session on a Monark 874 E ergometer (Monark 874 E ergometer, Monark Exercise AB, Vansbro, Sweden) without a load and with a pedaling speed of 50–60 revolutions per minute. First, a ST with the eyes opened and closed was performed, followed by a DT. Participants were barefooted. The better of 2 attempts of each participant was taken into consideration.

Assessment of Static Balance. The ST includes 6 trials: 2 with the eyes opened (EO) and 4 with the eyes closed (EC), each lasting 20 seconds. A player was asked to stand with bare feet alternatively on the left and right foot with a 15-second break between each trial. The nonsupport leg was relaxed and did not touch the tested leg or the surface. The hands were hanging loosely alongside the body to enable holding the DPA and returned to the starting position when the sway was too big and could cause a fall. The accelerometer showed information about the body sway from the x–y axis to 0.1°, and the software, with the help of the DPA, calculated the time of support and frequency with which the participant had to use it to maintain a stable posture. The value of deviation from the vertical was assessed as follows:

- 0–1° deviation–very good control
- 1.1–2.5° deviation–good control
- 2.6–5° deviation–satisfactory control
- 5.1–9° deviation–passable control
- >9° deviation–unsatisfactory control
- >10% is hands resting on the DPA–test not passed because of insufficient neuromuscular control to allow the participant to stand on 1 leg during the trial without hand support.

Assessment of Dynamic Balance. In the test performed under dynamic conditions, an unstable platform designed to permit only lateral movements was also used. First, the tested person performed 4 trials, 2 on each leg, alternating with hands alongside the body. The following 4 repetitions required the subject's arms to be held behind his or her back to minimize the attempts to maintain stability using the upper limbs. Each trial was 30-second long with 20-second break after each trial. The break between series was 60-second long. The so-called postural priority index was calculated, which is the quotient of the mean deviation of the DEB platform (in degrees)

Table 2. Mean values and *SD* in the static test between the groups for the eyes opened and eyes closed.

Eyes	Group (°)*			*F*	*p*
	U-19	U-21	PRO		
Opened eyes	1.10 ± 0.41	1.20 ± 0.41	1.05 ± 0.34	3.78	0.0238
Closed eyes	2.33 ± 0.75	2.49 ± 0.98	1.87 ± 0.71	15.56	<0.00001

*Two-way interactions between the group vs. eyes.

from the vertical axis and deviation of the participant from the resultant mean axis (also in degrees, measured using an accelerometer). The values of the indicator describe the posture control:

>60% correct visual-proprioceptive posture control
40–60% disturbed visual-proprioceptive posture control
<40% vestibular control (emergency control).

If a participant supported himself or herself with his hands (emergency strategy) for a time equal or greater than 25% of the duration of the trial, stabilization was considered insufficient to pass the test.

Statistical Analyses

Statistical analysis was performed using the STATISTICA 10 software (StatSoft, Inc., Tulsa, OK, USA). To represent statistical significance, the cutoff value was set to be $p \leq 0.005$ for all measures. Figure 1 presents the results with mean values and 95% confidence interval for legs, eyes, and groups in the ST. Mean ± *SD* were calculated for the dominant and nondominant legs in the 3 studied groups in the DT and for the eyes opened and eyes closed in the ST. Two-way factorial analysis of variance (ANOVA) design with 3 (group) × 2 (leg) was performed for the comparison of legs between the groups in the DT. Three-way ANOVA design with 3 (group) × 2 (leg) × 2 (eyes) was performed to compare whether the differences were statistically significant between the groups for the dominant and nondominant legs, both with the eyes opened and closed. Tukey's post hoc test was used to identify specific differences in the ST and DT. Using Cohen's (1988) criteria, an effect size between ≥0.20 and <0.50 was considered small, ≥0.50 and <0.80 medium, and ≥0.80 large.

Results

Dynamic Balance Performance

The tests for each group were performed on the same day, both for the dominant and nondominant legs. The analysis of the results showed the effect of significance of group ($p < 0.01$) and leg ($p \leq 0.05$) in the DT. The post hoc test showed statistically significant differences between the PRO and the U-21 groups and between the PRO and the U-19 groups ($p < 0.0001$). For legs, the post hoc test showed significant differences at the level of $p = 0.0053$. The PRO group had the highest result in the DT. The result for the nondominant leg was higher than that for the dominant leg. There was no group × leg ($p > 0.05$) interaction (Table 1). In the DT there was a small effect size ($d = 0.26$) between the legs, whereas between the groups, a large effect size was noted and amounted to $d = 1.76$ between the PRO and U-21 groups and $d = 1.42$ between the PRO and U-19 groups.

Static Balance Performance

Three-way ANOVA (3 [group] × 2 [leg] × 2 [eyes]) of ST data showed that the main effect of eyes ($p < 0.0001$), group ($p < 0.0001$), and leg ($p = 0.0092$), and the 2-way interaction of eyes × group ($p = 0.0003$) was significant. However, the 2-way interactions of leg × eyes ($p = 0.34$), leg × group ($p = 0.41$), and 3-way interaction of leg × eyes × group ($p = 0.95$) were not found to be significant (Figure 1).

Interactions of groups with eyes were significant ($p = 0.0003$) (Table 2). Tukey's post hoc test showed statistically significant differences for the eyes opened between the PRO and the U-21 groups ($p = 0.1867$) and for the eyes closed between the PRO and the U-21, and the U-19 groups ($p < 0.0001$). The PRO group had the best results for both the eyes opened and eyes closed. In the ST with the eyes opened, there was a small effect size ($d = 0.40$) between the U-21 and PRO groups, and with the eyes closed, there was a medium effect size between the U-21 and PRO ($d = 0.72$) and between the U-19 and PRO groups ($d = 0.63$).

Discussion

The purpose of this study was to compare the static and dynamic balance at different levels of competition in highly trained soccer players in the U-19, U-21, and PRO categories. For the assessment of the above parameters, we used the Delos Postural Proprioceptive System, which provides a reliable means for assessing neuromuscular control by quantifying the ability of a person to maintain static and dynamic postural stability on a stable and unstable surface (35). The results of our study indicate the PRO group as the one with the highest results in the DT. Also, in the ST, the PRO group had the best results both for the eyes opened and for the eyes closed. Better results in the DT were obtained for the nondominant leg compared with the dominant leg. Regression analysis showed that the specific contributors to the prediction of the level of competitive success in U-19, U-21, and PRO categories were balance sensitivity scores for the dominant and nondominant legs. These findings suggest that having good balance ability both in static and dynamic conditions for both legs is important for sporting success.

Previous studies reported that long-term practice of a high-skill sport activity can improve balance (27,31). Our findings also revealed that the long-term practice soccer players (group PRO) had a better balance sense than the other groups (U-19 and U-21). This was related to their better single-leg standing balance both in ST (closed eyes) and DT. Improved balance sense among the PRO category soccer practitioners may result from the fact that players have a better awareness of body posture, which contributes to the appropriate positioning of leg joints, which could have directly improved the acuity of joint repositioning (32). Repeated appropriate positioning of individual body parts in space, which takes place in soccer training, might have developed a better internal model of verticality (i.e., a better knowledge of the orientation of the body's axis and verticality) (31). The players in the PRO group may have improved the cortical representation of certain joints, leading to enhanced joint proprioception. Perhaps, these neurophysiological changes have not yet occurred in the U-19 and U-21 groups, which may be linked to a shorter training history. In our study, the training history of the PRO category was definitely the longest (16.3 years), compared with the U-19 and U-21 categories (8.5 and 10.6 years, respectively). The number of training hours was similar in all groups; however, the total number of training hours throughout a players' career was largest in the PRO group. Paillard et al. (30), who studied surfers, reported similar conclusions, which in their opinion could be linked either to the amount of training influencing the postural adaptation as a result of certain motor program acquisitions, which included specific postural adaptations, or to better intrinsic qualities (natural predispositions). In another study, Paillard et al. (31) showed that national soccer players' postural control was better than that of regional players, suggesting that national players possessed a greater sensitivity of sensory receptors or better integration of information than regional players (or both). Our results also suggest different body posture control strategies between the groups. During easy unipedal tasks of balance, both in static and dynamic conditions, players of the U-19 and U-21 groups use proportionally more short-loop (proprioceptive) information than the PRO players. Alternatively, players in the PRO group use proportionally more long-loop (vestibular) information, which probably contributes to more efficient vestibular or interoceptive (or both) input than U-19 and U-21 players. Thus, in easy tasks, players in the PRO group do not stimulate too much proprioception, using a better efficiency of the vestibular system, as opposed to the U-19 and U-21 group players. In soccer, because we are dealing with complex motor tasks (hitting the ball while it is in the air or while standing on 1 leg), which require stimulation of short neural loops, the PRO players could initially use mainly proprioceptive information for effective regulation of body balance. Similar results were reported by Era et al. (11), who showed that international-level rifle shooters were more stable than national-level shooters.

As has already been shown by other authors in judo, tae kwon do, and karate athletes, as well as dancers, shooters, and gymnasts (1,11,14,15,39), visual information is a determining factor in the postural regulation of soccer players. The results of the players in our tests in all groups confirm these findings and indicate the significant role of the visual factor in postural regulation. The study by Paillard et al. (31) indicates that the vision-by-group interaction for the center of foot pressure surface area and the center of foot pressure velocity was significant in static balance. Our findings show that the absence of vision significantly disturbed postural control for all categories of soccer players. This finding could be explained by the fact that postural regulation developed in terms of visual control with sports training is not always transferable to upright stance situations (1). For postural regulation, the reliance on visual cues increases for all groups, demonstrating the role of vision for maintaining better balance in soccer players. These findings are consistent with the literature (22,32,38) and our study in which the visual factor plays a significant role in body posture control and its lack significantly affects motor control.

In the literature, a preference for the use of the lower leg is described as being dependent on the role played by this limb. According to this, the dominant limb is a mobilizing limb, whereas the limb responsible for maintaining body posture during the activity performed by the dominant leg is defined as nondominant (23). Some authors could not reveal significant differences in balance ability between the dominant and nondominant leg in amateur soccer players in unilateral stance (5,17,34). However, in these studies, amateur soccer players (34) or children were studied or the number of participants was low (17), which could affect the results. Our study does not confirm this theory. In the DT, in all groups, the soccer players had statistically significantly better results in the nondominant leg, whereas in the ST, no statistically significant differences were noted, which may be because of the more dynamic nature of soccer play. Atkins et al. (2) indicated that for ground reaction force in all studied groups, the results were higher for the nondominant leg. Soccer training generates modifications in the central regulation of the nondominant leg balance control, and its specificity minimizes the action of the nondominant supporting leg proprioceptive sensory loops and could allow the sensory motor control to rely on purely biomechanical processes (18).

The results of this survey show that postural control improves with the increase in sporting level and denotes that higher ability in this is a distinctive feature of top soccer players. Good balance underlies coordinated movement control and the significant correlations between balance ability and competition level observed in the present study indicate that balance tests may be useful in the assessment of sporting level. For soccer players tested here, balance maintaining and control and adequate balance recovery strategy were found to be the single best predictor for sport-level achieved, predicting competition level.

Practical Applications

Postural performance and strategy were different between professional (the PRO group) and elite junior soccer players (U-19 and U-21 groups). In test conditions specific to playing soccer, the level of playing experience seems to influence postural control performance measures and strategies. In conditions specific to soccer, postural capabilities can be considered as one criterion of performance or ability.

The findings of our study make it possible to indicate to coaches the need to change postural regulation mechanisms from visual to vestibular and proprioceptive factors, which in the conditions of player's contact with a ball will allow a better visual control of the situation in the field. The finding of this study will also help coaches understand the significance of developing body balance on the same level, symmetrically in both lower limbs, as too large differences in this respect may lead to overload and even injuries.

For practical purposes, the results of this study will be of benefit to the practitioners seeking to identify postural profile. Coaches and strength and conditioning professionals are recommended to use a variety of exercises to improve balance, including both exercises with opened and closed eyes (on the dominant and nondominant legs) on progressively challenging surfaces to make decisions about tasks and sensory availability during assessment and training. This finding is important to make an appropriate adjustment for balance performance enhancement.

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