Gait & Posture 74 (2019) 148–153

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Analysis of static balance performance and dynamic postural priority according to playing position in elite soccer players

Łukasz Jadczak[a,*], Monika Grygorowicz[b,c], Andrzej Wieczorek[a], Robert Śliwowski[a]

[a] Department of Theory and Metodology of Team Sports Games, Poznan University of Physical Education, Królowej Jadwigi 27/39, 61-871, Poznań, Poland
[b] Poznan University of Medical Sciences, Department of Physiotherapy, 11 Smoluchowskiego Street, 60-179 Poznan
[c] Rehasport Clinic, FIFA Medical Centre of Excellence, Sports Science Research Group, 20 Gorecka Street, 60-201 Poznan

ARTICLE INFO

Keywords:
Professional athletes
Single-leg balance
Delos Postural System

ABSTRACT

Backgrounds: Balance performance and postural priority are important components of motor skill development. No published reports have investigated the differences in static balance abilities and postural priority among professional soccer players according to field position.
Research question: We hypothesized that static balance as well as dynamic postural priority is influenced by playing position in professional soccer players.
Methods: The study covered a group of 101 elite professional soccer players who were divided into six subgroups according to playing positions: goalkeepers (G) (n = 10), central defenders (CD) (n = 15), external defenders (ED) (n = 15), central midfielders (CM) (n = 23), external midfielders (EM) (n = 15) and forwards (F) (n = 23). All participants completed the Delos Postural System Test using the standard protocol. The tests were performed unilaterally on non-dominant (NL) and dominant leg (DL) under static conditions (with open and closed eyes) standing on a stable platform and under dynamic conditions on an unstable base.
Results: In the static test with open eyes (ST OE) there were no statistically significant differences between the legs and positions. In the static test with closed eyes (ST CE), the differences are statistically significant only between positions. Players on the CM position have significantly higher differences than G. In the dynamic postural priority test (DPPT) there is a difference between positions and legs. In fact, the statistically higher differentiation refers to players in the CM position relative to ED, CD, EM and F. We noticed a significantly greater difference in the NL compared to the DL.
Significance: Static balance performance and postural priority varied with playing position in elite soccer players. Midfield players have better postural priority than players in other positions. Professional soccer players present greater balance postural priority on the non-dominant leg.

1. Introduction

Soccer is the world's most popular sport and many studies have attempted to define the characteristics of successful soccer players [1,2]. Within a match, players are required to tackle, kick, jump, dribble, and head balls in intermittent actions, usually with a change of activity every 4–6 s [3]. It has been suggested that soccer game activities may be directly related to the player's position on the field [4]. Athletes may develop certain physical characteristics based on the demands of their specific positions [5]. So far, researchers have concentrated on the relationship of the player's position on the field with physical fitness in the area such as: aerobic and anaerobic performance [6], jumping [7], running distance [8] or isokinetic strength [9,10]. It was also attempted to determine the anthropometric characteristics of soccer players depending on their position on the field [6,7]. We have not found any studies in the literature examining static balance performance and dynamic postural priority according to playing positions in soccer. Precise measurement of body balance and postural strategy can indicate an appropriate player profile in a position and consequently implement appropriate training programs.

Recently, researchers have identified balance ability in sport as an important aspect of performance [10,11]. These studies focused primarily on the search for a balance between the sport level [12], the assessment of balance between different disciplines [13] and the impact

* Corresponding author at: Department of Theory and Metodology of Team Sports Games, Poznan University of Physical Education, 27/39 Krolowej Jadwigi St., 61–871, Poznan, PL, Poland.

E-mail addresses: jadczak@awf.poznan.pl (Ł. Jadczak), monika.grygorowicz@rehasport.pl (M. Grygorowicz), wieczorek.awf@wp.pl (A. Wieczorek), robertsliwowski@wp.pl (R. Śliwowski).

https://doi.org/10.1016/j.gaitpost.2019.09.008
Received 18 December 2018; Received in revised form 6 August 2019; Accepted 4 September 2019
0966-6362/

of balance control on injuries in sport [14]. The last few years have shown increasing numbers of balance studies with soccer players, indicating that better postural control can help to improve not only performance, but also technical skills in soccer [15]. Balance interventions with athletes have improved measures of athletic performance including agility and vertical jump height [16]. This may suggests that improved balance, or underlying postural control, may elicit an improved rate of force development in the muscles [17]. Moreover, researchers have proposed that improved balance could decrease the amount of musculature involved in stabilization, allowing more muscles to contribute to force production in a given movement [18]. During a soccer game, players often perform different actions, many of which are unilateral, such as kicks, passes and movements to change the running direction, in order to achieve greater success in carrying out these actions. Most soccer players prefer to use the DL (dominant leg) for kicking the ball to be more accurate and the NL (non-dominant leg) to support body weight. Many drills (shooting, passing, and stopping) are executed in a few seconds whilst standing on the non-dominant leg. Other researchers have also demonstrated better unilateral balance in soccer players when compared to untrained subjects, basketball players, and swimmers [19]. Hence, the stability of the supporting foot turns out to be critical to shoot as accurately as possible. Some results suggest that the position or function performer in the field can also promote asymmetries in muscle function between lower limbs, which could impair performance during game actions [20]. Therefore, soccer players' postural control should be evaluated in unipedal stance to respect the specific conditions of soccer.

Numerous studies have analyzed various motor control and orientation in space strategies by examining the coordination of the movement of the eyes, head, body, and limbs during a locomotor task [21]. Romero-Franco et al. [22] studied the effect of a proprioceptive training program on center of gravity control in sprinters and stated that improvement in balance was reported when exercises were performed with eyes opened. This dependency on vision has been documented in other sports such as rugby players and high jumpers [21]. Despite the existence of certain discrepancies as to whether high-level athletes demonstrate different postural control strategies (eyes open or closed and single- or double-leg stance) compared with others competing in different sports, it has been reported that static balance (on stable base) or dynamic postural priority (on unstable base) with eyes opened and closed, is of utmost importance for optimizing and developing the athlete's fundamental motor skills in soccer [23].

Taking into account the current results of the research, the purpose of our study was to provide insight into the static balance profile and dynamic postural priority of a large group of elite soccer players and to identify differences among the different playing positions. We hypothesized that this profile would show significant differences among the positional roles of the players.

2. Methods

2.1. Participants

The study covered a group of 101 elite professional soccer players of Polish Ekstraklasa (the top division in Poland). The participants had at least three years of experience playing soccer at a professional level with regular training on a given position. The players were divided into six subgroups, according to playing positions: goalkeepers (G) (n = 10), central defenders (CD) (n = 15), external defenders (ED) (n = 15), central midfielders (CM) (n = 23), external midfielders (EM) (n = 15) and forwards (F) (n = 23). The analysis was conducted on values collected only from players who played at least 50% of official club matches in the season preceding the study. Foot dominance was determined using a self-report measure and in addition to a kicking-ball test. The study excluded players who had a history of cerebral concussion, vestibular disorders, injury to either ankle, lower extremity injuries for 3 months before testing, ear infection, upper respiratory infection, or head cold at the time of the study. All participants were verbally informed of the purpose, procedures, and risks associated with the study, their freedom to withdraw at any time without prejudice and if they agreed, they signed the consent form. The study was carried out 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).

2.2. Instrumentation

The tests were performed in the Biomechanical Assessment Laboratory at Rehasport Clinic in Poznań. The laboratory is certified by FIFA, as a Medical Centre of Excellence. The results were collected from 2011 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 10 a.m. and 12 p.m. All tests were performed in ambient temperate conditions (≈ 21 °C and 30% relative humidity) and were kept constant across testing sessions. For two days before the tests, the players were not subjected to intensive training. Before every test, the participants completed questionnaires in which they assessed whether they experienced any musculoskeletal pain or any discomfort, in particular within the legs. In order to establish postural stability, a static test (ST) and dynamic postural priority test (DPPT) were performed using the Delos Postural Proprioceptive System (DPPS, 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 (PSM) (a computer and software for visualization and analysis of DVC and DEB data) [14]. Immediately prior to the test, participants performed a 10 min warm-up session on a Monark 874 E ergometer (Sweden) without a load and with a pedalling speed of 50–60 rpm. First, the ST with OE and CE was performed, followed by the DPPT. Participants, barefooted, were unfamiliar with DPPS and asked to minimize amplitude of the postural cone. The subject was looking at a display that showed the countdown before each trial, the eye condition requested, and which foot was to be used as support. No feedback on postural stability was given during the tests. The better of two attempts of each participant was taken into consideration [24].

2.3. Procedures

The ST includes six trials: two with the EO and four with the EC, each lasting 20 s. 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 non-supporting 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 in order to maintain a stable posture [14,24]. None of the subjects needed to use the support of the sensor bar.

In the DPPT an unstable platform designed to permit only lateral movements was also used. First, the tested person performed four trials, two on each leg, alternating with hands alongside the body. The following four 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 s long with 20 s breaks after each trial. The break between series was 60 s long. The so-called Postural Priority index was calculated, which is the quotient of the mean inclination of the DEB platform from the horizontal plane (in degrees) and the postural instability calculated as the average of the absolute shifting around the resultant average axis (also in degrees, measured using an accelerometer in sternal position) [24]. None of the subjects needed to use the support of the sensor bar.

2.4. Statistical analysis

All statistical analyses were conducted using STATISTICA 10.0 for Windows Version (SPSS Inc., Chicago, IL, USA). All results are reported as means and standard deviations (mean ± SD) calculated by conventional procedures, unless otherwise stated. The normality of the variables was tested with the Shapiro–Wilk Test, and the coefficients of asymmetry and kurtosis were found. For all balance variables (ST with OE and CE, DPPT) differences between legs (DL and NL) were tested using the T-test, if the normality condition was not met, the differences were tested with the non-parametric U Mann-Whitney test.

For all balance variables (ST with OE and CE, DPPT) and variables of physical characteristics (body weight, body mass and age) differences between positions on the field (G, CM, ED, EM and F) were tested using one-way analysis of variance (ANOVA). Duncan post-hoc procedures were used to identify specific differences. For variables for which there was a statistically significant difference between legs and positions, a multivariate analysis of variance 2 × 6 was performed (leg x position). To describe differences related to balance, effect sizes were calculated as the difference between means divided by the pooled standard deviation. Using Cohen's (1988) criteria, an effect size ≥ 0.20 and < 0.50 was considered small, ≥ 0.50 and < 0.80 medium, and ≥ 0.80 large. Statistical significance was set at an alpha of 0.05 for all statistical procedures [25].

3. Results

The physical characteristics of the players demonstrate significant differences in their height ($F = 13.50$, $p \le 0.0001$) and weight ($F = 13.18$, $p \le 0.0001$) according to their playing positions. In contrast, age did not significantly differ between groups ($F = 0.53$, $p = 0.7512$) (Table 1). G are significantly heavier and higher than players in all other positions (in all cases $p < 0.0001$, except for CD $p < 0.001$). CD are significantly heavier than EM ($p < 0.0001$), ED ($p < 0.001$), CM ($p < 0.05$) and F ($p < 0.05$). On the other hand, F are significantly heavier than EM ($p < 0.05$) and ED ($p < 0.05$). In turn, CM are heavier than EM ($p < 0.05$). Generally, EM and ED have less weight and body height statistically than competitors in other positions, and G are characterized by a significantly higher statistically high body weight and height in relation to the athletes in other positions.

In ST, the differences between the legs occur only with the CE ($Z = -1.97$, $p = 0.0484$). Results indicate a better ST in NL (Fig. 1A). In DPPT, there are differences between legs demonstrating better results for NL ($t = 1.89$, $p = 0.0469$) (Fig. 1B). In ST CE, the differences in statistical significance occur between the G vs. ED ($p = 0.0139$) and G vs. CM ($p = 0.0021$) positions (Fig. 2A). In DPPT test, there are also differences between the positions of CM vs. ED ($p = 0.0028$), CD ($p = 0.0025$), G ($p = 0.0066$), F ($p \le 0.0001$), EM ($p \le 0.0001$) (Fig. 2B). Large effect sizes could be observed between positions in DPPT for CM vs. CD ($d = 0.83$), CM vs. F ($d = 1.03$) and CM vs. ED ($d = 0.95$); moderate for CM vs. ED ($d = 0.66$) and CM vs. CD ($d = 0.68$); and small in DPPT for legs ($d = 0.26$), G vs. ED ($d = 0.27$), G vs. CM ($d = 0.36$) and between legs at the CE ($d = 0.26$).

In the ST CE and DPPT, the differences are statistically significant between positions and leg. In ST CE, players on the CM position have significantly higher differences than G. The direction of differentiation was in favor of the players from the middle of the field. There was a trend to significance of differences between the legs. In DPPT, statistical higher differentiation refers to the players in the CM position relative to ED, CD, EM and F. Also in this case the direction of differentiation was in favor of the players from the middle of the playing field. We noticed a significantly greater difference in the non-dominant leg (NL) compared to the dominant leg (DL) (Table 2).

4. Discussion

The primary aim of this study was to compare balance profiles in elite soccer players across different field positions taking into consideration the influences of the leg. The principal finding of the present study was that static balance performance and dynamic postural priority varies significantly between players in different playing positions. In terms of the ST CE, players on the CM position have significantly higher differences than G. In relation to DPPT there is a difference in favor of players playing in CM position relative to ED, CD, EM and F. In the same test we noticed significantly greater difference in NL compared to DL (Table 2).

The characteristics of soccer players have been previously investigated, and little or no differences have been found in height and body mass across field positions [5]. In turn, Reilly et al. [26] found that relative heterogeneity in body size is a characteristic of elite soccer teams, so anthropometric differences were therefore expected between playing positions. The most common differences in terms of height and body mass relate to players in the G and CD positions. These players are characterized by higher values of these parameters, which may be due to the need to reach for the ball at the highest possible point, or to achieve a physical advantage in a direct fight with the opponent [7]. Our results are in agreement with this. In addition, our results are in agreement with ED and EM being lighter and shorter than other positions. This may be related to the longer distances run by players which play in side sections of the field and are required to be able to move as fast as possible with or without the ball. Players in central positions, both in defense and in midfield (CD and CM), might be heavier because they perform more defending activities and do not run as much as ED and EM. Also, the height difference between ED, EM and CD, CM may indicate that it is not necessary to be tall to play this position, since the main role of ED and EM is to assist forward players with passes and crosses, but not necessarily to participate in aerial balls. Anthropometric differences in various positions are confirmed in the study of Bloomfield et al. [27] when comparing elite soccer players from four European leagues, found differences between the age, height, body mass and BMI of players in different positions.

In their study, Ricotti et al. [11] indicate balance performance as one of the basic factors which permit to identify and discriminate top-level soccer players. Our results indicate that players at the top sporting

Table 1
Physical characteristics and ethnicity of the subjects (mean values ± SD).

	G (n = 10)	ED (n = 15)	F (n = 23)	EM (n = 15)	CD (n = 15)	CM (n = 23)
Body mass [kg]	$89.80^{a} \pm 6.14$	73.73 ± 6.69	$77.91^{c} \pm 5.92$	72.67 ± 5.54	$82.00^{b} \pm 5.53$	$76.98^{d} \pm 6.04$
Body height [cm]	$191.20^{\#} \pm 4.42$	179.73 ± 4.51	$183.44^{\#\#\#} \pm 4.98$	177.27 ± 4.73	$187.00^{\#\#} \pm 5.39$	$181.13^{\#\#\#\#} \pm 5.17$
Age [years]	24.37 ± 4.53	24.39 ± 4.74	25.50 ± 5.92	23.63 ± 4.39	23.94 ± 4.71	25.77 ± 5.24

Note: $^{\#}$G > CD^{a}, F^{c}, CM^{c}, ED^{c}, EM^{c}; $^{\#\#}$CD > F^{a}, CM^{a,b}, ED^{b}, EM^{c}; $^{\#\#\#}$F > ED^{a}, EM^{a,c}; $^{\#\#\#\#}$CM > EM^{a} (if statistically significant values are at the same level, the first letter refers to the body height and the second to the body mass)Significantly higher value of the body height and mass across playing position: $P < 0.05^{a}$, $P < 0.001^{b}$, $P < 0.0001^{c}$.

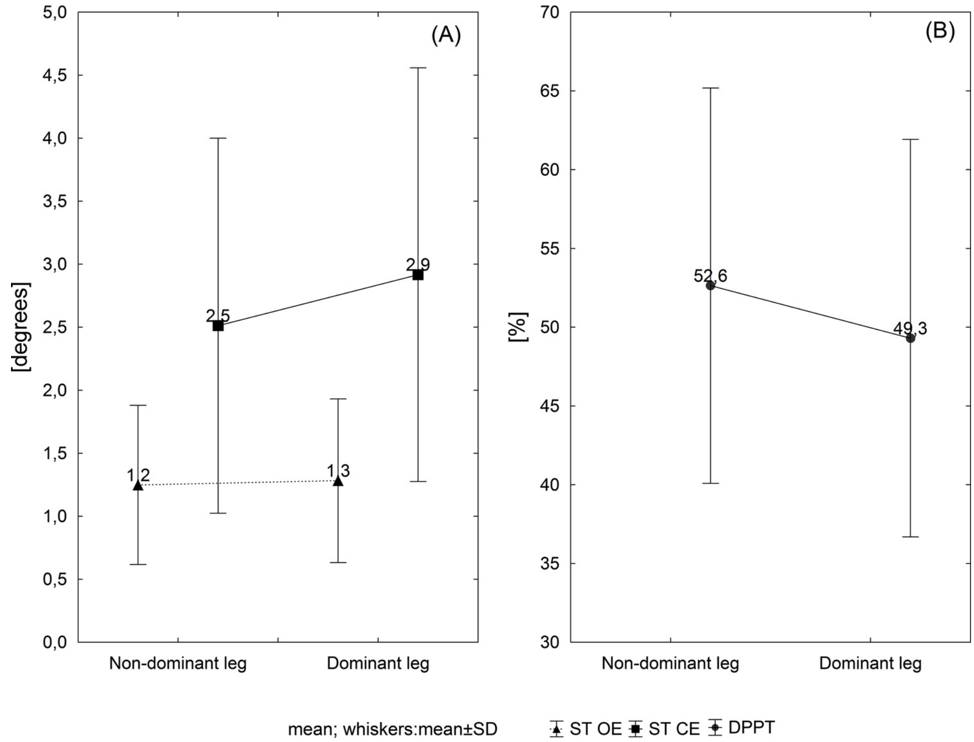

Fig. 1. Mean values for: (A) ST with OE and CE by legs (dominant, non-dominant); (B) DPPT by legs (dominant, non-dominant).

level show differences in static balance performance and represent different dynamic postural priority depending on their playing position. Midfielders need to be able to change direction more appropriately and accelerate with changes in direction. The specific characteristics in response to these specific demands of the midfielder position appear to be present in the physical profile of these players [6]. Due to the unique character of actions in the field, players in the CM positions cover the longest distance on average and thus are characterized by the highest physical fitness. Whereas, the results of studies performed by Bangsbo et al. [1] and Mohr et al. [3] indicate that players with better aerobic

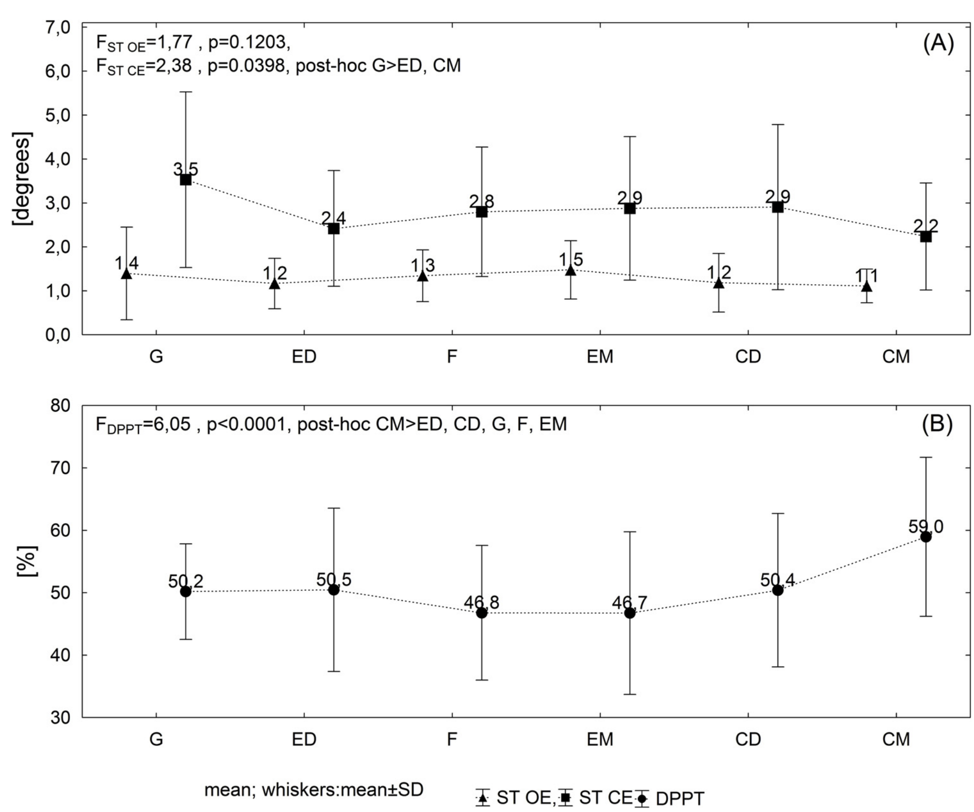

Fig. 2. Mean values for: (A) ST with OE and CE by playing positions; (B) DPPT by playing positions (G, CD, ED, CM, EM, F).

Table 2
Characteristics of the static test with opened and closed eyes and dynamic postural priority test on dominant and non-dominant leg across playing position (mean ± SD).

Variables	Leg	G[a](n = 10)	ED(n = 15)	F(n = 23)	EM(n = 15)	CD(n = 15)	CM[b](n = 23)
ST OE [degrees]	Dominant	1.14 ± 0.62	1.23 ± 0.75	1.42 ± 0.71	1.51 ± 0.74	1.17 ± 0.67	1.16 ± 0.43
	Non-dominant	1.65 ± 1.35	1.10 ± 0.34	1.27 ± 0.44	1.45 ± 0.60	1.19 ± 0.69	1.06 ± 0.34
ST CE [degrees]	Dominant[c]	4.04 ± 2.18	2.43 ± 1.21	2.92 ± 1.25	3.13 ± 1.97	3.41 ± 2.04	2.28 ± 1.15
	Non-dominant	3.02 ± 1.76	2.41 ± 1.46	2.67 ± 1.68	2.62 ± 1.23	2.41 ± 1.62	2.20 ± 1.31
DPPT [%]	Dominant	48.79 ± 7.51	48.97 ± 12.44	45.94 ± 10.84	43.83 ± 12.90	47.75 ± 12.78	57.70 ± 12.92
	Non-dominant[d]	51.58 ± 7.95	51.97 ± 13.98	47.64 ± 10.90	49.65 ± 12.92	53.04 ± 11.60	60.21 ± 12.70

[a] is significantly lower than CM ($p = 0.0226$) for variable ST CE.
[b] is significantly higher than ED ($p = 0.0302$), CD ($p = 0.0279$), EM ($p = 0.0002$) and F ($p \leq 0.0001$) for variable DPPT.
[c] there is a trend to statistical significance higher than Non-dominant leg.
[d] is significantly higher than Dominant leg ($p = 0.0479$).

capacity have a better tolerance and resistance to increasing fatigue and recover faster during and after the game. Moreover, a player reaches the psychomotor fatigue threshold at higher effort intensities, which allows them to play for longer in the psychomotor comfort zone [28]. As static balance performance is closely related to the fatigue threshold [29], these data may explain to a large extent the differences in CM compared to players in other positions.

Soccer requires a unipedal posture to perform different technical movements (e.g., shooting and passing), and this ability is more important than in other sports [19]. Brito et al. [30] indicate that athletes presented better unilateral stance in the non-dominant lower limb than in the contralateral limb. The study of Ricotti [11] shows an asymmetry depending on the sports level represented. Other researchers have found no significant difference between balance ability in opposing legs [20]. Our study clearly shows an asymmetry in favor of the NL compared to the DL in all positions, but only in DPPT. This is most probably due to the fact that soccer activity is characterized by intense, explosive movements, many of which are executed from a single leg on a slippery surface- which is grass- suggesting that the stability of the stance foot (NL) in the execution of successful football related movement is crucial [12,31].

The greatest value of our study for coaches is information about the effect of soccer training on the paramaters of quality of balance in static conditions and adequacy of postural priority. The knowledge of symmetries between the dominant and non-dominant leg is equally important. This makes it possible to implement individualized and optimal training programs for each player.

Declaration of Competing Interest

Authors have no conflict of interest and any financial or personal relationships with other people or organisations that could inappropriately influence their work.

Acknowledgments

The authors would like to thank Mrs. Magdalena Lewandowska for her assistance in statistical analysis.

References

[1] J. Bangsbo, M. Mohr, A. Poulsen, J. Perez-Gomez, P. Krustrup, Training and testing the elite athletes, J. Exerc. Sci. Fit. 4 (2006) 1–14.
[2] D.A. Padua, L.J. DiStefano, A.I. Beutler, S.J. Motte, M.J. DiStefano, S.W. Marshall, The landing error scoring system as a screening tool for an anterior cruciate ligament injury– prevention program in elite-youth soccer athletes, J. Athl. Train. 50 (2015) 589–595.
[3] M. Mohr, P. Krustrup, J. Bangsbo, Match performance of high standard soccer players with special reference to development of fatigue, J. Sports Sci. 2 (2003) 519–528.
[4] L.C. Lamond, J.B. Caccese, T.A. Buckley, J. Glutting, T.W. Kaminski, Linear acceleration in direct head contact across impact type, player position, and playing scenario in collegiate women's soccer players, J. Athl. Train. 53 (2018) 115–121.
[5] C.V. Ruas, F. Minozzo, M.D. Pinto, L.E. Brown, R.S. Pinto, Lower-extremity strength ratios of professional soccer players according to field position, J. Strength Cond. Res. 29 (2015) 1220–1226.
[6] J. Boone, R. Vaeyens, A. Steyaert, L. Vanden Bossche, J. Bourgois, Physical fitness of elite Belgian soccer players by player position, J. Strength Cond. Res. 26 (2012) 2051–2057.
[7] C. Lago-Penas, L. Casais, A. Dellal, E. Rey, E. Domınguez, Anthropometric and physiological characteristics of young soccer players according to their playing positions: relevance for competition success, J. Strength Cond. Res. 25 (2011) 3358–3367.
[8] P.S. Bradley, W. Sheldon, B. Wooster, P. Olsen, P. Boanas, P. Krustrup, High-intensity running in English FA Premier League soccer matches, J. Sports Sci. 27 (2009) 159–168.
[9] R. Śliwowski, M. Grygorowicz, R. Hojszyk, Ł. Jadczak, The isokinetic strength profile of elite soccer players according to playing position, PLoS One 12 (2017) 1–13.
[10] R.J. Butler, C. Southers, P.P. Gorman, K.B. Kiesel, P.J. Plisky, Differences in soccer players' dynamic balance across levels of competition, J. Athl. Train. 47 (2012) 616–620.
[11] L. Ricotti, J. Rigosa, A. Niosi, A. Menciassi, Analysis of balance, rapidity, force and reaction times of soccer players at different levels of competition, PLoS One 8 (2013) 1–22.
[12] T. Paillard, F. Noe, T. Riviere, V. Marion, R. Montoya, P. Dupui, Postural performance and strategy in the unipedal stance of soccer players at different levels of competition, J. Athl. Train. 41 (2006) 172–176.
[13] J. Han, G. Waddington, J. Anson, R. Adams, Level of competitive success achieved by elite athletes and multi-joint proprioceptive ability, J. Sci. Med. Sport 18 (2015) 77–81.
[14] D. Riva, R. Bianchi, F. Rocca, C. Mamo, Proprioceptive training and injury prevention in a professional men's basketball team: a six-year prospective study, J. Strength Cond. Res. 30 (2016) 461–475.
[15] B. Evangelos, K. Georgios, A. Konstantinos, I. Gissis, C. Papadopoulos, S. Aristomenis, Proprioception and balance training can improve amateur soccer players' technical skills, J. Physic. Educ. Sport. 12 (2012) 81–89.
[16] R. Śliwowski, M. Grygorowicz, A. Wieczorek, Ł. Jadczak, The relationship between jumping performance, isokinetic strength and dynamic postural control in elite youth soccer players, J. Sports Med. Phys. Fit. 58 (2018) 1226–1233.
[17] C. Hrysomalis, Balance ability and athletic performance, Sports Med. 41 (2011) 221–232.
[18] C.O. Kean, D.G. Behm, W.B. Young, Fixed foot balance training increases rectus femoris activation during landing and jump height in recreationally active women, J. Sports Sci. Med. 5 (2006) 138–148.
[19] S. Matsuda, S. Demura, M. Uchiyama, Centre of pressure sway characteristics during static one-legged stance of athletes from different sports, J. Sports Sci. 26 (2008) 775–779.
[20] S. Matsuda, S. Demura, Y. Nagasawa, Static one-legged balance in soccer players during use of a lifted leg, Percept. Mot. Skills 111 (2010) 167–177.
[21] R. Hammami, D.G. Behm, M. Chtara, A.B. Othman, A. Chaouachi, Comparison of static balance and the role of vision in elite athletes, J. Hum. Kinet. 40 (2014) 33–41.
[22] N. Romero-Franco, E. Martinez-Lopez, R. Lomas-Vega, F. Hita-Conteras, A. Martinez- Amat, Effects of proprioceptive training program on core stability and center of gravity control in sprinters, J. Strength Cond. Res. 26 (2012) 2071–2077.
[23] S. Vando, D. Filingeri, L. Maurino, H. Chaabène, A. Bianco, G. Salernitano, C. Foti, J. Padulo, Postural adaptations in preadolescent karate athletes due to a one week karate training camp, J. Hum. Kinet. 38 (2013) 45–52.
[24] Ł. Jadczak, M. Grygorowicz, W. Dudziński, R. Śliwowski, Comparison of static and dynamic balance at different levels of sport competition in professional and junior elite soccer players, J. Strength Cond. Res. IV (2018), https://doi.org/10.1519/JSC.0000000000002476.
[25] J. Cohen, Statistical Power Analysis for a Behavioral Sciences, Lawrence Erlbaum Associates, Hillsdale, NJ, 1988.
[26] T. Reilly, J. Bangsbo, A. Franks, Anthropometric and physiological predispositions for elite soccer, J. Sports Sci. 18 (2000) 669–683.
[27] J. Bloomfield, R. Polman, R. Butterly, P. O'donoghue, Analysis of age, stature, body mass, BMI and quality of elite soccer players from 4 European Leagues, J. Sports

Med. Phys. Fit. 45 (2005) 58–67.
[28] J. Chmura, K. Nazar, Parallel changes in the onset of blood lactate accumulation (OBLA) and threshold of psychomotor performance deterioration during incremental exercise after training in athletes, Int. J. Psychophysiol. 75 (2010) 287–290.
[29] M. Pau, G. Ibba, G. Attene, Fatigue-induced balance impairment in young soccer players, J. Athl. Train. 49 (2014) 454–461.
[30] J. Brito, I. Fontes, F. Ribeiro, A. Raposo, P. Krustrup, A. Rebelo, Postural stability decreases in elite young soccer players after a competitive soccer match, Phys. Ther. Sport 13 (2012) 175–179.
[31] D.W. Chapman, K.J. Needham, G.T. Allison, B. Lay, D.J. Edwards, Effects of experience within a dynamic environment on postural control, Br. J. Sports Med. 42 (2008) 16–21.