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Bilateral Asymmetry and the Relationship Between Unilateral Isokinetic Strength and Balance Performance in Male Adolescent Football Players

Cíntia França[1,2,3], Francisco Martins[1,2], Diogo V. Martinho[4], Andreas Ihle[5,6,7], Adilson Marques[8,9], Hugo Sarmento[4], Filipe Manuel Clemente[10,11], Krzysztof Przednowek[12], Pedro Campos[2,13,14], Élvio Rúbio Gouveia[1,2,6*]

Affiliations: [1]Department of Physical Education and Sport, University of Madeira, Funchal, Portugal, [2]LARSYS, Interactive Technologies Institute, Funchal, Portugal, [3]Research Center in Sports Sciences, Health Sciences, and Human Development (CIDESD), Vila Real, Portugal, [4]University of Coimbra, Research Unit for Sport and Physical Education (CIDAF), Faculty of Sport Sciences and Physical Education, Coimbra, Portugal, [5]Department of Psychology, University of Geneva, Geneva, Switzerland, [6]Center for the Interdisciplinary Study of Gerontology and Vulnerability, University of Geneva, Geneva, Switzerland, [7]Swiss National Centre of Competence in Research LIVES—Overcoming Vulnerability: Life Course Perspectives, Lausanne, Switzerland, [8]CIPER, Faculty of Human Kinetics, University of Lisbon, Lisbon, Portugal, [9]ISAMB, Faculty of Medicine, University of Lisbon, Lisbon, Portugal, [10]Escola Superior Desporto e Lazer, Instituto Politécnico de Viana do Castelo, Rua Escola Industrial e Comercial de Nun'Álvares, Viana do Castelo, Portugal, [11]Instituto de Telecomunicações, Delegação da Covilhã, Lisboa, Portugal, [12]Institute of Physical Culture Sciences, Medical College, University of Rzeszów, Rzeszów, Poland, [13]Department of Informatics Engineering and Interactive Media Design, University of Madeira, Funchal, Portugal, [14]WoWSystems Informática Lda, Funchal, Portugal

Correspondence: Élvio Rúbio Gouveia. ORCID 0000-0003-0927-692X, address: Universidade da Madeira, Campus da Penteada, 9020-105 Funchal. Email: erubiog@staff.uma.pt

Abstract

Muscle strength and balance ability have been related to injury prevention and game actions performance in football. The aims of this study are twofold: (1) to examine bilateral asymmetries in isokinetic strength and balance assessments, and (2) to evaluate the relationship between muscle strength and balance measures. Eighty-eight male adolescent football players were assessed for body composition (InBody 770), isokinetic strength (Biodex System 4 Pro Dynamometer), and balance performance (Biodex Balance System). Paired samples t-tests were conducted to determine bilateral differences in strength and balance. Pearson correlations and multiple linear regression analyses evaluated the relationship between strength and balance. No significant bilateral strength differences were observed in knee flexors (KF) and knee extensors (KE) peak torque (PT) scores. No bilateral differences were found for balance measures, except in the lateromedial stability index, which was better while performing with the preferred leg ($p \leq 0.01$; $d = 0.29$). Significant correlations were found between KE PT and balance tasks ($p \leq 0.01$). KF and KE PT shared between 18 and 22% of the common variance in the overall stability index in the non-preferred and preferred leg, respectively. Monitoring strategies of bilateral asymmetries may be crucial to enhance performance in tasks underpinned by unilateral movements, such as changes of direction and sprints, and to identify players at risk of injury. Adopting these strategies during the early stages of football training might be crucial for players' long-term development.

Keywords: *soccer, peak torque, knee flexors, knee extensors, youth*

@MJSSMontenegro
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Introduction

In football, players often perform jumping, sprinting, and rapid change of direction actions (Wisloff et al., 2004). Since these movements are associated with force-time characteristics (Suchomel et al., 2016; Wisloff et al., 2004), muscle strength is recognized as one critical physical attribute of football players. Greater muscle strength has been associated with enhanced sport-specific skills performance and decreased injury rates (Suchomel et al., 2016).

Meanwhile, lower-body strength assessments (i.e., squat or the half-squat) tend to be bilateral and fail to examine strength asymmetries in the lower limbs. The existence of bilateral strength differences between the preferred leg (PL) and the non-preferred leg (NPL) remains controversial, with acceptable deficits ranging between 10 and 15% (Teixeira et al., 2014). Pending the player's characteristics, the asymmetries between limbs can be functional at different magnitudes (Sannicandro et al., 2012). Previous research has reported that morphological adaptations between the kicking and support limbs of football players might occur in response to repetitious asymmetrical loading patterns resulting from their functional differences within the context of their sport (Hart et al., 2016). As an example, relationships between levels of training exposure and asymmetrical loading exposure (kicking limb vs support limb) were observed, with distinct morphological adaptation noted between limbs (Hart et al., 2016).

Although some literature suggests that significant imbalances can be associated with increased musculoskeletal injury occurrences (Croisier et al., 2008; Van Dyk et al., 2016), a recent systematic review reported that relationship as low to moderate, and there is inconsistency in the findings (Helme et al., 2021). Despite these inconsistencies, knowing the asymmetry level between limbs is helpful to address the detrimental effects of possible inter-limb asymmetry. A recent study described that inter-limb asymmetries seem to present a negative impact on tasks underpinned by unilateral movements, such as changes of direction and sprints (Fox et al., 2023). Therefore, monitoring strategies should be adopted to identify and address inter-limb asymmetries according to individual needs.

Frequently, muscle strength has been defined as the ability to produce a force on an external object or resistance (Suchomel et al., 2016). Thus, isokinetic strength assessments have become popular, safe, and reliable in the sports literature. Several investigations have examined bilateral strength imbalances through isokinetic strength tests in professional football (Croisier et al., 2008; Menzel et al., 2013; Van Dyk et al., 2016). Among 46 male professional footballers aged 24.8±3.2 years, the authors reported a mean of bilateral strength asymmetry of 9.14% at peak torque (PT) for concentric knee flexion (KF) while performing at 60º/s (Menzel et al., 2013). In the same testing conditions, another study showed a mean difference of 7% at KF and 6.5% at KE between the PL and the NPL in footballers aged 23.8±2.12 years (Teixeira et al., 2014). Although these strength asymmetries have been identified, the scores reported are within the respective average values. Besides strength comparison between limbs, research has also analyzed the hamstrings to quadriceps ratio (H:Q ratio) due to its relationship with injury. For isokinetic strength testing at 60º/s, lower values than 0.60 for the H:Q ratio has been associated with injuries, such as anterior cruciate ligament injuries and hamstring strains (Croisier et al., 2002). However, most data on lower-limb strength asymmetries are available at the professional football level, and a detailed analysis still lacks among youth.

Meantime, football players frequently perform actions using unilateral stances, such as kicking, passing, and dribbling, which demands balance control. Better balance ability, both in stable and dynamic conditions, was observed in elite players compared to their non-elite counterparts (França et al., 2022). Besides, a significant relationship between balance and injury prevention was previously found (Al Attar et al., 2022). In contrast, different reports have emerged concerning bilateral asymmetries in balance measures (Gkrilias et al., 2018; González-Fernández et al., 2022; McCurdy & Langford, 2006; Thorpe & Ebersole, 2008). While no differences were observed among healthy adults (McCurdy & Langford, 2006) and female collegiate football players (Thorpe & Ebersole, 2008), substantial bilateral asymmetries were found in youth footballers (Gkrilias et al., 2018; González-Fernández et al., 2022). Additionally, in youth football, inter-limb asymmetry in dynamic balance performance was reported (Gkrilias et al., 2018; González-Fernández et al., 2022), but no data concerning stability is available.

Of note, muscle strength levels may be beneficial to balance control (Booysen et al., 2015; Śliwowski et al., 2021).

The ability to generate eccentric strength and power presented moderate correlations with the Y-Balance scores on the NPL in male footballers (Booysen et al., 2015). Among volleyball players, both the KF and KE PT were significantly correlated with the overall stability index (OSI) in both legs' performance (Soylu et al., 2020). However, most of the previous research designed to examine the relationship between muscle strength and balance performance in sports has favored elite players or non-athlete populations, and importantly, detailed knowledge regarding youth is still lacking.

Therefore, the aims of this study are twofold: (1) to examine bilateral asymmetries according to the PL and NPL in strength and balance, and (2) to evaluate the relationship between strength and balance measures. First, it was hypothesized that superior levels of strength and balance would be observed in the performance of the PL, and secondly, it was expected a significant and positive relationship between strength and balance.

Methods

Study design

The study followed a descriptive cross-sectional design. The study protocol was approved by the Faculty of Human Kinetics Ethics Committee (CEIFMH N°34/2021) and followed the Declaration of Helsinki. All the assessments were conducted in a physical performance laboratory by trained staff from the research team. All participants were volunteers, and informed consent was obtained from their respective legal guardians.

The study was conducted during the sports season 2021/2022, after two months of training sessions. Each participant was assessed on two consecutive days, with a rest interval of at least 12h regarding the latest training session.

Participants

Eighty-eight male adolescent football players aged 15.9±1.6 years participated in this study. The optimal sample size calculation was performed using G*Power 3.1. A priori paired-sample t-test (two-tails) indicated a sample size of 54 participants to achieve 80% power to detect an interaction effect size of 0.5 at 0.05 level of significance. In the second anal-

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ysis, a priori Pearson product-moment correlation showed a total sample of 84 participants to achieve 80% power to detect an interaction effect size of 0.3 at 0.05 level of significance. Then, a priori multiple regression analysis indicated a sample size of 55 participants to achieve 80% power considering an effect size of 0.15 at 0.05 level of significance.

Twenty players had the left leg as the preferred limb. Limb preference was defined as the leg that is preferred when kicking a ball. Participants had at least three years of football training experience and competed at the regional level in Portugal. Training frequency was four times per week plus one match during the weekend.

Body composition

Body composition was evaluated during the early morning while participants were fasting. Stature was assessed to the nearest 0.01 cm using a stadiometer (SECA 213, Hamburg, Germany). A hand-to-foot bioelectrical impedance analysis (InBody 770, CA, USA) was used for measurement (McLester et al., 2020), with participants only wearing their underwear. Among the body composition variables, body mass, body fat percentage (BF%), total fat-free mass (FFM), and segmental FFM of the PL and the NPL were retained for analysis.

Isokinetic testing

Isokinetic measurements were performed on the hamstrings and quadriceps muscles using the Biodex System 4 Pro Dynamometer (Shirley, NY, USA) (Van Tittelboom et al., 2022). Before data collection, a 5-minute warm-up in a reclining bicycle (Technogym Xt Pro 600 Recline, Cesena, Italy) was performed. Then, participants were seated in the dynamometer following the manufacturer's guidelines. The lever arm of the dynamometer was aligned with the lateral epicondyle of the knee, while the trunk, the evaluated thigh, and the leg were stabilized with belts. The range of motion was defined as participants carrying the knee extension to its maximum range. Then, participants were asked to flex the kneed until 90º of flexion. As recommended, individual calibration for gravity correction was performed at 30º of knee flexion. During testing, participants were asked to keep their arms crossed with the hand on the opposite shoulder holding the belts, and verbal support was given throughout the tests. Three repetition trials were given before testing to ensure the correct execution. After, five repetitions of concentric contraction efforts of knee flexion and knee extension were performed at 60º/s, with a 60 s interval. This testing speed has been recommended to assess strength. For analysis, the peak torque (PT), the relative peak torque/body weight (PT/BW), and the conventional hamstring-to-quadriceps (H:Q) strength ratio for KF and KE in the PL and NPL were calculated. The H:Q conventional ratio was used since it was generally measured during concentric contraction (Aagaard et al., 1998) and was calculated by dividing the mean concentric KF PT by the mean KE concentric PT over the five repetitions. Finally, the limb symmetry index (LSI) was calculated using the equation (1):

Balance testing

Balance assessment was performed using the Biodex Balance System SD (Biodex, Shirley, NY, USA). For testing, participants were barefoot in an upright position, arms placed laterally to the body, and feet set shoulder-width apart. Before testing, the equipment was adjusted to the height of the participants. A single training session was allowed before data collection to ensure correct execution and minimize learning effects during the testing phase. The rest interval between testing conditions was set at 60 s. Bilateral comparison consisted of a protocol performed in a unilateral stance. Level 4 was the most stable, and level 1 was the most unstable. The testing scores reflect the level of deviation from the horizontal position. Therefore, lower scores indicate better balance performance (Yamada et al., 2012). For analysis, the Overall Stability Index (OSI), Anteroposterior Stability Index (APSI), and Lateromedial Stability Index (LMSI) were used.

Statistics

Descriptive statistics are presented as means ± standard deviation. All data were checked for normality using the Kolmogorov-Smirnov test. Paired samples t-tests were conducted to identify bilateral differences in isokinetic strength and balance assessments. Effect size (d) was interpreted using d-Cohen as follows (Cohen, 1988): $d < 0.2$ (small), $0.2 > d < 0.6$ (moderate), $0.6 > d < 1.2$ (large), and $d > 1.2$ (very large). The Pearson product-moment correlation was used to explore the relationships between isokinetic strength and balance tests according to each leg. Correlations values were interpreted according to their size (Cohen, 1988): $0.10 > r < 0.29$ (small), $0.30 > r < 0.49$ (medium), $0.50 > r < 1.0$ (large). Finally, multiple linear regression analyses were performed to determine the association between isokinetic strength and balance performance. To avoid heteroscedasticity, the dependent variable was transformed using the log. All analyses were performed using IBM SPSS Statistics software 28.0 (SPSS Inc., Chicago, IL, USA). The significance level was set at 0.05.

Results

Table 1 resumes descriptive statistics concerning age and body composition.

Table 1. Descriptive statistics for body composition of adolescent male football players (n = 88)

Variable	Mean (95% CI)	SD
CA (years)	15.9 (15.5 - 16.2)	1.6
Stature (cm)	172.3 (170.5 - 174.1)	8.3
Body mass (kg)	63.5 (61.5 - 65.5)	9.3
FFM (kg)	55.7 (54.0 - 57.5)	8.3
BF (%)	11.7 (10.6 – 12.9)	5.3

95% CI (95% confidence interval), SD (standard deviation), CA (chronological age), FFM (fat-free mass), BF (body fat)

Table 2 presents the descriptive statistics and bilateral comparison in strength and balance assessments. No significant differences between the PL and NPL were observed for KF PT/BW, KE PT/BW, and H:Q strength ratio in isokinetic strength parameters. LSI analysis showed a difference of 1.7% for KF PT and 1.2% for KE PT values when the PL was compared to the NPL.

Concerning body composition, FFM was significantly higher in the PL than in NPL (p≤0.01, trivial effect size). No overall differences were seen in balance performance, except in the LMSI testing, which was substantially better in the PL (p≤0.01, moderate effect size). Although the results are not statistically significant, better overall balance scores were achieved while performing with the PL compared to the NPL.

Table 2. Descriptive statistics and comparison of preferred and non-preferred leg performance in isokinetic dynamometer and unilateral balance assessment (n = 88)

Parameter	Preferred leg		Non-preferred leg		Paired comparisons			
	Mean (95% CI)	SD	Mean (95% CI)	SD	t	p	d	LSI (%)
Isokinetic strength								
KF PT (Nm)	90.0 (85.7 – 94.4)	20.7	88.5 (84.1 – 93.0)	21.2	1.184	0.24	0.07	98.3
KF PT/BW (Nm/kg)	1.36 (1.28 – 1.45)	0.38	1.35 (1.27 – 1.44)	0.37	0.499	0.62	0.03	
KE PT (Nm)	151.0 (141.7 – 160.3)	43.8	152.8 (144.2 – 161.3)	40.2	1.000	0.32	0.04	98.8
KF PT/BW (Nm/kg)	2.32 (2.15 – 2.49)	0.78	2.35 (2.18 – 2.52)	0.76	0.960	0.34	0.04	
H:Q strength ratio (%)	0.62 (0.59 – 0.65)	0.15	0.60 (0.57 – 0.63)	0.15	1.762	0.08	0.13	
Body composition								
FFM (kg)	8.93 (8.60 – 9.25)	1.46	8.86 (8.54 – 9.18)	1.43	4.947	≤ 0.01**	0.05	
Balance								
OSI (º)	2.14 (1.70 – 2.58)	2.06	2.37 (1.93 – 2.81)	2.07	1.775	0.08	0.11	
APSI (º)	1.64 (1.22 – 2.06)	1.97	1.73 (1.32 – 2.15)	1.95	0.739	0.46	0.05	
LMSI (º)	1.02 (0.85 – 1.20)	0.84	1.27 (1.08 – 1.46)	0.92	2.567	≤ 0.01**	0.29	

95% CI (95% confidence interval), SD (standard deviation), KF (knee flexors), KE (knee extensors), PT (peak torque), BW (bodyweight), H:Q (hamstrings/quadriceps), FFM (fat-free mass), OSI (overall stability index), APSI (anteroposterior stability index), LMSI (lateromedial stability index), LSI (limb symmetry index), ** p ≤ 0.01

Tables 3 and 4 show the significant correlation coefficients between isokinetic strength and balance parameters for the PL and NPL, respectively. Significant correlations were found between KF and KE PT/BW, both for the PL (r = 0.80, p≤0.01) and the NPL (r = 0.74, p≤0.01). The KE PT/BW presented strong and negative correlations with balance indicators both for the PL (p≤0.01) and the NPL (p≤0.01). In contrast, KF/PT only showed significant correlations with balance indicators in the PL analysis. Among balance parameters, the OSI correlated significantly and positively with the APSI and LMSI in both evaluations. Overall, the PL analysis observed the highest number of relationships between isokinetic strength and balance tasks.

Table 3. Correlation coefficients between isokinetic strength and balance in the preferred leg assessments

Parameter	1.	2.	3.	4.	5.
1. KF PT/BW	-	0.80**	-0.27*	-0.27*	-0.20
2. KE PT/BW		-	-0.48**	-0.44**	-0.40**
3. OSI			-	0.97**	0.63**
4. APSI				-	0.44**
5. LMSI					-

KF (knee flexion); KE (knee extension); PT/BW (Peak Torque/Bodyweight); OSI (overall stability index); APSI (anteroposterior stability index); LMSI (lateromedial stability index); * p ≤ 0.05; ** p ≤ 0.01

Table 4. Correlation coefficients between isokinetic strength and balance in the non-preferred leg assessments

Parameter	1.	2.	3.	4.	5.
1. KF PT/BW	-	0.74**	-0.16	-0.16	-0.11
2. KE PT/BW		-	-0.40**	-0.40**	-0.34**
3. OSI			-	0.97**	0.79**
4. APSI				-	0.63**
5. LMSI					-

KF (knee flexion); KE (knee extension); PT/BW (Peak Torque/Bodyweight); OSI (overall stability index); APSI (anteroposterior stability index); LMSI (lateromedial stability index); * p ≤ 0.05; ** p ≤ 0.01

Finally, the results of linear regression analyses with isokinetic strength (PT/BW) predicting balance performance are summarized in Figures 1 and 2. The model explained between 18 and 23% of the variance observed in the OSI performance for the NPL and PL, respectively. In both cases, KF PT/BW and KE PT/BW were significant predictors of the model. However, the strongest unique contribution for OSI scores was seen in KE PT/BW (PL: β = -0.712, p≤0.01, and NPL: β = -0.595, p≤0.01).

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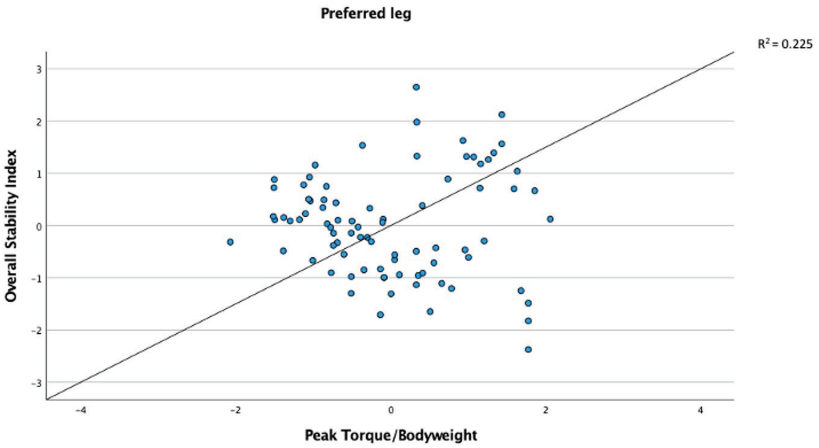

Figure 1. Multiple regression analyses with KF and KE PT/BW as predictors of the OSI scores in the preferred leg analysis.

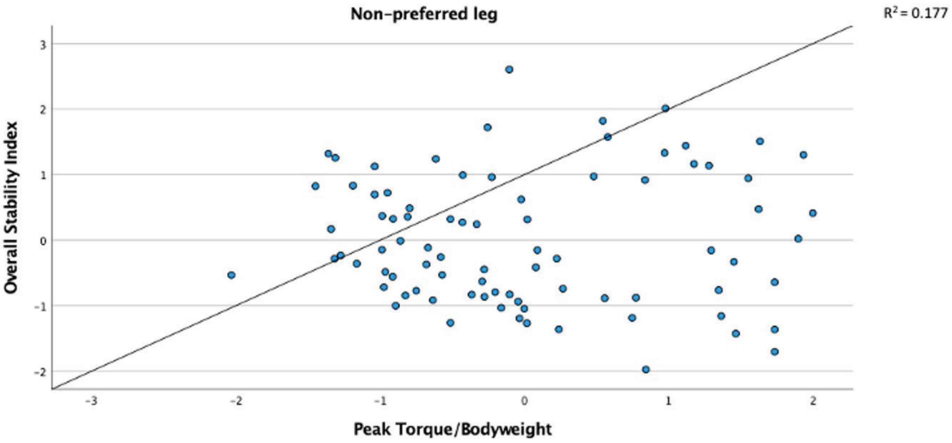

Figure 2. Multiple regression analyses with KF and KE PT/BW as predictors of the OSI scores in the non-preferred leg analysis.

Discussion

This study examined bilateral asymmetries according to the PL and NPL leg in muscle strength and balance tasks in youth football. Also, the relationship between strength and balance measures was assessed. First, it was hypothesized that superior levels of strength and balance parameters would be observed in the performance of the PL. However, no significant bilateral strength differences were observed in the isokinetic strength assessment or balance testing, except in the LMSI. Secondly, it was expected a substantial and positive relationship between strength and balance, which was underlined in the present study results. Overall, muscle strength was positively related to balance performance.

Bilateral asymmetry in youth football

Bilateral asymmetries have been observed in sports with predominant unilateral movements, such as football. Indeed, while playing, using the PL is often favored for football-specific skills performance (Zakas, 2006). In professional players, previous research reported a bilateral strength asymmetry ranging from 7% to 9% when muscle strength was assessed at an angular velocity of 60º/s (Croisier et al., 2003; Menzel et al., 2013). However, note that 10-15% bilateral strength differences have been suggested as relevant for injury occurrence (Croisier et al., 2003). In this study, significant statistical differences were seen in FFM between the PL and the NPL. However, LSI ranged between 98.3% and 98.8%, indicating the existence of small bilateral asymmetries. Previous research reported an average LSI of 103.8% among players between the U11 and U19 age categories when the jump performance was evaluated (Scinicarelli et al., 2022). Still, only one study examining bilateral asymmetry using isokinetic strength was found in youth football, with mean differences of nearly 8% being described at an angular velocity of 60º/s (Rutkowska-Kucharska, 2020). Indeed, performing an isokinetic strength assessment requires specialized measuring equipment that is not frequently available, particularly in youth samples.

Meanwhile, the H:Q strength ratio analysis did not show a significant muscle imbalance between KE and KF. The results indicate an acceptable H:Q score following the literature recommendations for the 60º/s testing speed (>0.60). In contrast, values below 0.60 indicate a substantial strength imbalance between the KE and KF, which could predispose the individual to a non-contact injury (Croisier et al., 2002). According to the literature, football training appears to increase the strength of the knee joint muscles. However, it seems that greater development of the quadriceps muscles is favored compared with the hamstrings muscles (Iga et al., 2009). Moreover, players with imbalances appeared five times more likely to sustain a hamstring strain (Croisier et al., 2003), underlining the importance of testing and monitoring muscle strength levels as a preventive measure.

Association between strength and balance

In this study, a significant correlation between muscle strength levels and balance performance was found. PT scores were significantly and negatively correlated to balance variables, indicating that a higher strength output contributes to a lower deviation from the horizontal position during balance tasks. This relationship is supported by the multiple regression analyses, which showed that PT values could explain between 18% and 22% of the variance observed in the OSI scores for the NPL and the PL, respectively. The results are in line with previous literature focused on the relationship between muscle strength and balance, although using different methods and protocols than the ones applied in this study. For example, among 26 football players aged 16.2±1.6 years, the values of maximal isometric strength were able to explain between 22% and 49% of the variance observed in the Y-balance performance (Chtara et al., 2018). In other studies, the KF PT was described as a significant predictor of the Star Excursion and Y-Balance Tests in athletes from several contexts (Ruiz-Pérez et al., 2019).

When analyzing the model, KF PT/BW and KE PT/BW were significant predictors of OSI in both legs' performance. However, the strongest unique contribution was made by KE PT/BW, emphasizing the role of quadriceps muscle strength in balance performance. Indeed, there is evidence in sports literature that the quadriceps muscle strength is the greater supporter of the knee joint during balance tasks (Śliwowski et al., 2021; Soylu et al., 2020). Reports in previous research described a strong correlation between KE strength and balance performance in male footballers (Śliwowski et al., 2021) and female volleyballers (Soylu et al., 2020), which is in line with the results of the present study.

Concerning balance, overall superior performance was observed with the PL compared to the NPL, although not significantly, except for the LMSI. Past research on this topic has reported controversial results. In football players, some authors reported no substantial asymmetry in balance performance between the lower limbs (Muehlbauer et al., 2019), while others said the opposite (Barone et al., 2011). However, note, that multiple factors could influence the postural balance differences between the lower limbs. Besides, the influence of leg dominance on unilateral balance should probably be context-dependent (Sannicandro et al., 2012).

Limitations and Strengths

This study presents some limitations, such as using cross-sectional data and the lack of assessment of participants' maturity status. Since strength gains are larger during and after the peak height velocity, the maturity status may play an important role in the present study results. Deploying a longitudinal analysis and controlling maturity status would be far more informative. However, few studies are available on isokinetic strength and balance assessment in such a representative sample of youth football players, which should be underlined. This study provides new insights into strength and balance performance in youth football and emphasizes the positive contribution of strength to balance performance. Finally, monitoring strategies of bilateral asymmetries may be crucial to enhance performance in tasks underpinned by unilateral movements, such as changes of direction and sprints, and to identify players at risk of injury. Adopting these strategies during the early stages of football training might be crucial for players' long-term development.

Conclusion

The results of the present study show no significant bilateral asymmetries in strength and balance performance among youth football players. However, a tendency for superior performance levels was seen for the PL. Moreover, strength (PT KE and PT KF) was able to explain between 18% and 22% of the variance observed in the OSI, which is believed to be the best indicator of the overall ability of the individual to balance the platform. Sports agents and coaches are advised to adopt monitoring strategies of strength and balance capabilities to detect inter-limb asymmetries that may compromise tasks supported by unilateral movements and/or enhance the risk of injury. These strategies might be decisive for youth players' long-term development. Future research should include a longitudinal assessment of strength and balance measures and control for the maturity status as a possible confounder of physical performance at this age gap.

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