The Effect of Neuromuscular Control on Motor Performance and Physical Capacity in Professional Football Players

Profesyonel Futbolcularda Nöromüsküler Kontrolün Motor Performans ve Fiziksel Kapasite Üzerindeki Etkisi

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ABSTRACT

This study aims to investigate the effects of neuromuscular control on motor performance and physical capacity in professional football players.

Twenty-five male soccer players participated in the study, and the relationships between dynamic balance levels and the reactive strength index, sprint performance, and shooting speed were examined. Pearson correlation and linear regression analyses were conducted.

According to the analyses, dominant leg balance level explained 44% of the variance in the reactive strength index, 66% in sprint performance, and 89% in shooting speed ($p<0.05$), while non-dominant leg balance level accounted for 59% of the variance in the reactive strength index, 54% in sprint performance, and 84% in shooting speed ($p<0.05$).

In conclusion, improved dynamic balance was found to positively influence explosive strength, ball-striking efficiency, neuromuscular coordination, and sprint performance. These results highlight the importance of neuromuscular training in optimizing athletic performance in football players.

Keywords: Biomechanical Efficiency, Dynamic Balance, Reactive Strength Index, Shooting Speed, Sprint

ÖZ

Bu çalışma, profesyonel futbolcularda nöromüsküler kontrolün motor performans ve fiziksel kapasite üzerindeki etkilerini araştırmayı amaçlamıştır.

Çalışmaya yirmi beş erkek futbolcu katılmış; dinamik denge düzeyleri ile reaktif kuvvet indeksi, sprint performansı ve şut hızı arasındaki ilişkiler incelenmiştir. Pearson korelasyonu ve doğrusal regresyon analizleri uygulanmıştır.

Analizlere göre, baskın bacak denge düzeyi reaktif güç indeksinin %44'ünü, sprintin %66'sını ve şut hızının %89'unu açıklarken ($p<0.05$), baskın olmayan bacak denge düzeyi reaktif güç indeksinin %59'unu, sprintin %54'ünü ve şut hızının %84'ünü açıklamıştır ($p<0.05$).

Sonuç olarak, gelişmiş dinamik denge düzeylerinin patlayıcı kuvvet, topa vurma verimliliği, nöromüsküler koordinasyon ve sprint performansını olumlu yönde etkilediği bulunmuştur. Bu bulgular, futbolcularda atletik performansın artırılmasında nöromüsküler antrenmanlarının kritik bir rol oynadığını göstermektedir.

Anahtar Kelimeler: Biyomekanik Verimlilik, Dinamik Denge, Reaktif Kuvvet İndeksi, Sprint, Şut Hızı

Important Points

* Balance increases explosive power and shooting speed in soccer players!
* Dominant and non-dominant leg balance shortens sprint time!
* Balance training improves the motor skills of soccer players and increases their performance!

Ethics committee approval was received for this study from the ethics committee of Recep Tayyip Erdogan University Non-Interventional Clinical Research Ethics Committee (Date: February 29, 2024, Decision Number: 2024/48, Protocol No: E-40465587-050.01.04-979).
This study was supported by the Scientific and Technological Research Council of Turkiye (TUBİTAK) under the TUBİTAK 2209-A Undergraduate Students Research Projects Support Program with Grant Number 1919B012300162. The authors thank TUBITAK for their support.

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Geliş Tarihi / Received: 26.06.2025
Kabul Tarihi/Accepted: 09.09.2025

INTRODUCTION

The interrelationships among physical fitness components that influence general athletic performance have long been a focus of sports science research. Dynamic balance, in particular, is widely recognized as an important component of athletic performance across various sports. Previous studies have shown that dynamic balance ability can be influenced by factors such as muscular strength and joint mobility.[1] However, the strength and nature of these relationships may vary depending on variables such as age, gender, sport discipline, specialized training, and individual performance levels.[2]

Understanding these relationships is also crucial for injury prevention, as deficits in neuromuscular control components—including balance—are linked to a higher risk of injury and impaired postural stability.[3] Despite the recognized importance of this topic for both health and athletic performance, current literature on the subject remains limited.[3-6] Furthermore, the physical and physiological demands of each sport differ, which leads to variations in athletic performance characteristics—such as strength, endurance, power, speed, agility, and balance—based on the sport-specific context.[4] For instance, football players often transfer their body weight onto one leg while kicking, a movement that may enhance unilateral stability compared to athletes in other sports.[5, 6] As kicking is a core skill that directly affects game outcomes, the role of balance in improving this ability warrants focused investigation.

In athletic training, neuromuscular programmes that include balance exercises are frequently employed to enhance performance, prevent injuries, and support rehabilitation. Several studies have demonstrated that such interventions improve functional capacity and reduce the risk of sports-related injuries.[7, 8, 9] Improved balance ability has been associated with enhanced reactive strength,[10] which contributes to the development of explosive power and agility—key elements in football performance.[11] Balance also supports movement efficiency by stabilizing the body during rapid acceleration and sudden direction changes, thereby improving sprinting performance and reducing reaction time.[12] In addition, balance plays a critical role in increasing shooting speed and accuracy by ensuring proper body alignment and effective force transmission.[13, 14]

Given this background, examining the impact of dynamic balance on specific motor performance parameters—such as reactive strength, sprint speed, and shooting accuracy—can provide valuable insight into how neuromuscular control mechanisms affect both stability and movement efficiency.[15] This perspective contributes not only to the understanding of performance components but also to the holistic development of athletes. Therefore, the current study aims to fill an important gap in the literature by investigating the role of balance in football-specific performance outcomes. This research is expected to offer practical implications for designing effective training protocols that enhance functional and athletic capabilities in football players.[16]

Based on this framework, the study tested the following hypotheses:

(i) Dynamic balance ability of the dominant leg positively influences the reactive strength index, sprint performance, and shooting speed in young football players.

(ii) Dynamic balance ability of the non-dominant leg positively influences the reactive strength index, sprint performance, and shooting speed in young football players.

MATERIALS AND METHOD

Procedure

In this study, a correlational design was used within the quantitative research framework. The main purpose of the study was to examine the relationships between the variables and the strength of these associations. In this direction, dynamic balance, reactive strength, sprint and shooting speed of the athletes were measured and the relationship between these parameters was analysed.

Participants

This study focus on male athletes participating in official competitions in professional football clubs operating in Rize province. Within the scope of the study, sample size to be included in the study was determined by G-Power (Universität Düsseldorf: Psychologie-HHU) analysis with reference to the research of Burhaein et al. and it was seen that at least 25 participants were reliable with a power of 0.80, a significance level of 0.05 and an effect size of 0.34.[17] Accordingly, a total of 25 male football players were included in the study. The mean age of the athletes was 21.33±1.34 years, mean height was 176.06±4.65 cm, and mean weight was 72.00±6.27 kg.

Inclusion criteria:

- No history of lower limb injury within the last 6 months prior to testing.
- Possession of a valid professional football license.
- A minimum of 5 years of continuous participation in football training and competition.
- Participation in a minimum of two training sessions per week.

Exclusion criteria:

- History of a recent sports injury.
- Presence of acute or chronic pain in the extremities.

Measures

Prior to testing, athletes were informed about the purpose, importance, and procedures of the tests. During the assessments, athletes were required to wear shorts and t-shirts to ensure consistency in measurement conditions.

To maintain standardized testing conditions, all measurements were conducted between 15:00 and 18:00 in a designated area within the sports hall. This time frame aligns with previous studies recommending afternoon testing to minimize diurnal variations in performance.[16] Additionally, athletes performed a standardized warm-up protocol and were allowed sufficient rest intervals between trials to prevent fatigue, as supported by established testing guidelines.[16] Each athlete completed two measurements within a maximum of 30 minutes, with results recorded on individualized data forms.

Height and weight protocol: Both height and body weight were measured with the stadiometer used in the study. While the athlete was standing barefoot in the anatomical position during deep inspiration, the ruler part of the stadiometer was placed on the athlete's head and the measurement value was recorded. In the same posture, the body weight of the athlete was recorded in kg.[16-20]

After the athletes were measured for height and weight, 8 minutes of warm-up running and 8 minutes of stretching exercises were performed. After the warm-up, 1 minute resting time was given between the tests.[16]

Balance protocol: Y Balance Test Kit™ (Functional Movement Systems, Chatham, VA, USA) used to measure dynamic postural control. It has been validated in athletic populations[18] Leg length was measured bilaterally in the supine position, from the anterior superior iliac spine to the distal part of the medial malleolus, and recorded in centimeters.

All measurements were performed barefoot. Reach distances were assessed in three directions: anterior (from the participant's central toe), posteromedial, and posterolateral (both measured from the heel to the furthest point reached). Participants were instructed to keep their hands on their iliac crests and their stance heel flat on the floor, while lightly touching the furthest point with the toe of the reaching leg. Before testing, a brief demonstration was provided by the researcher. Participants completed at least six familiarization trials in each direction, followed by a 2-minute rest period. Afterward, three recorded trials were performed in each direction.

An attempt was considered invalid if the participant: (a) transferred weight onto the reaching leg, (b) lifted the heel of the stance foot, or (c) removed the hands from the hips.

In such cases, the trial was repeated after verbal feedback. All valid reach distances were recorded in centimeters.[18]

A composite reach score was calculated for each leg using the following formula:

Composite Score (%) = (Anterior + Posteromedial + Posterolateral reach distances) / (Leg Length × 3) × 100

This normalized score was used to compare overall dynamic balance performance between legs and across participants.

Reactive strength index protocol: Jump Mat Pro (FSL JumpMat, Tyrone, Ireland) used to assess reactive strength index (RSI). The reliability coefficient of the Jump Mat device was calculated as 0.99 for countermovement jump, 0.99 for squat jump and 0.64 for drop jump.[19] The athlete was asked to fall with one foot (right-left) on an electronic jumping mat with hands free over a 30 cm box and to land and jump vertically at the highest possible speed. Pulling the knee while in the air during the jump and not falling on the mat were considered as faulty movements. The test was repeated in case of faulty movements. The test was repeated twice with 30 s rest intervals and the highest RSI (m/s) was recorded.[19]

Sprint protocol: Sprint time was measured using a Telemetric Photocell System (Sinar, Telemetric Chronometer, Turkiye), which has been validated for its reliability in evaluating sprint performance.[14] The test was conducted on a 30-meter sprint track, where each athlete started from a position 1 meter behind the starting line. Upon the "ready" command, the athlete exited the starting gate and completed the test by crossing the finish gate at the end of the track. The sprint time was recorded in seconds. Each athlete completed three repetitions of the sprint test, with a 2-minute passive rest interval between each trial to minimize fatigue. For analysis purposes, the best performance (i.e., the shortest time) of each athlete was used.

Shooting speed protocol: Multi Sports Personal Speed Radar (Net Playz, Taiwan) used to measure ball shooting speed with reliability coefficient ≥0.89.[20] The measurement was conducted from a distance of 10 meters, where athletes aimed at two 1-meter square target points located in the upper left and right corners of the goalposts. During the test, athletes were allowed to approach the 10-meter line 1-2 meters behind to ensure a natural free shot motion. The athletes were free to use different shooting techniques, such as off-foot or in-foot, according to their preference. Each athlete made a total of 10 free shots, 5 shots to the right target and 5 shots to the left target. The speed (km) of each shot was recorded using radar.[20]

Data Analysis Procedure

Statistical applications were performed in SPSS (Version 27 for Windows; IBM, Armonk, NY, USA) licensed package programme. Descriptive statistics were shown as mean, standard deviation, minimum and maximum values.[22] Before the analyses, normality distributions of the data were examined and kurtosis-skewness values (±1.5) showed that the data had a normal distribution.[21] Pearson correlation analysis was used to determine the relationship between variables.[23] The correlation coefficient was evaluated as very weak in the range of 0-0.20, weak in the range of 0.21-0.40, moderate in the range of 0.41-0.60, strong in the range of 0.61-0.80, and very strong in the range of 0.81-1.00.[24] According to the Shapiro-Wilk test, the residuals are normally distributed ($p>0.05$) and according to the Breusch-Pagan test, the variances are homogeneous ($p>0.05$). The Durbin-Watson value was in the range of 1.5-2.5, indicating that there was no autocorrelation. Linear relationship and normal distribution were observed in the scatter plot and Q-Q plot graphs, and Cook's Distance value <1 revealed that there was no outlier effect. In this context, the effect of balance on RSI, sprint and throwing speed was evaluated using Linear Regression analysis.[24] In all analyses, the statistical significance level for the rejection of the null hypothesis was determined as $p<0.05$.

Finally, GraphPad Prism 8 (GraphPad Software Inc.; San Diego, CA, USA) software was used to present the data visually. Graphs were presented with a resolution of 300 dpi to ensure high quality visuals.

Ethical Considerations

Ethics committee approval was received for this study from the ethics committee of XXXX University Non-Interventional Clinical Research Ethics Committee (Date: February 29, 2024, Decision Number: 2024/48, Protocol No: E-40465587-050.01.04-979). In addition this study was supported by Scientific and Technological Research Council of TUBITAK under the Grant Number XXXX. The authors thank TUBITAK for their supports. The study was conducted in accordance with the ethical principles of the 1964 Declaration of Helsinki.

RESULTS AND DISCUSSION

Table 1. Descriptive Characteristics of Football Players

Variable (n=25)	Mean	SD	Minimum	Maximum
Age (year)	21.33	1.34	19,00	23,00
Sports History (year)	11.27	2.78	8,00	17,00
Height (cm)	176.06	4.65	170.00	186.00
Weight (kg)	72.00	6.27	64.00	84.00

Note. N= sample size, SD= standard deviation, cm= centimeter, kg= kilogram.

Table 1 shows that the mean age of the football players was 21.33±1.34 years, the mean sports history was 11.27±2.78 years, the mean height was 176.06±4.65 cm, and the mean weight was 72.00±6.27 kg.

Table 2. Descriptive Statistical of Performance Variables

Variable	Mean	SD	Minimum	Maximum
DL Balance (cm)	100.35	11.50	74.93	115.77
NDL Balance (cm)	95.39	7.21	80.89	107.47
DL RSI (m/sec)	1.05	0.22	0.78	1.53
NDL RSI (m/sec)	0.93	0.13	0.64	1.12
30 m Sprint (sec)	2.93	0.14	2.74	3.19
Shooting Speed (km)	91.13	8.54	75.00	110.00

Note. SD= standard deviation, DL= dominant leg, NDL= non-dominant leg, RSI= reactive strength index, cm= centimeter, m= meter, sec= seconds, km= kilometer.

Table 2 presents the average balance score was 100.35 cm for the DL and 95.39 cm for the NDL. The RSI was measured at 1.05 m/s for the DL and 0.93 m/s for the NDL. The mean 30 m sprint time was 2.93 seconds, while the average shooting speed was recorded at 91.13 km.

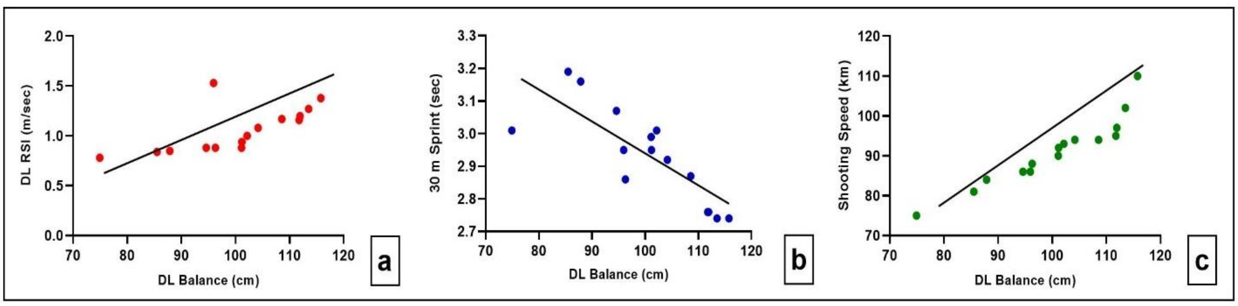

Figure 1. The Relationship Between DL Balance Level and RSI (a), Sprint (b) and Shooting Speed (c). *Note. DL: dominant leg, km: kilometer, m: meter, RSI: reactive strength index, sec: seconds.*

In Figure 1, it was determined that there was a significant positive correlation between DL balance level and DL RSI (r= 0.663; Figure 1-a) and shooting speed (r= 0.943; Figure 1-c), and a significant negative correlation with sprint (r= -0.813; Figure 1-b).

Table 2. The Effect of DL Balance Levels on RSI, Sprint and Shooting Speed

Predictor Variable	Predicted Variable	B	Std. Error	R^2	F	p
	DL RSI	0.013	0.004	0.440	10.205	**0.007****
DL Balance	Sprint	-0.010	0.002	0.661	25.340	**0.000****
	Shooting Speed	0.701	0.068	0.890	105.218	**0.000****

*Note. **p<0.01; DL: dominant leg, RSI: reactive strength index, Std: standard.*

In Table 2, a linear regression model was created to predict the RSI, sprint and shooting speed depending on the DL balance level. The regression model calculated for DL balance level and DL RSI ($F_{(1-24)}$= 10.205; p=0.007), sprint ($F_{(1-24)}$= 25.340; p=0.000) and shooting speed ($F_{(1-24)}$= 105.218; p=0.000) was statistically significant. DL balance level explained 44% (R^2=0.440), 66% (R^2=0.661) and 89% (R^2=0.890) of DL RSI, sprint and shooting speed, respectively. It was determined that one unit increase in DL balance level resulted in 0.013 unit increase in RSI, 0.701 unit increase in shooting speed and -0.010 unit decrease in sprint.

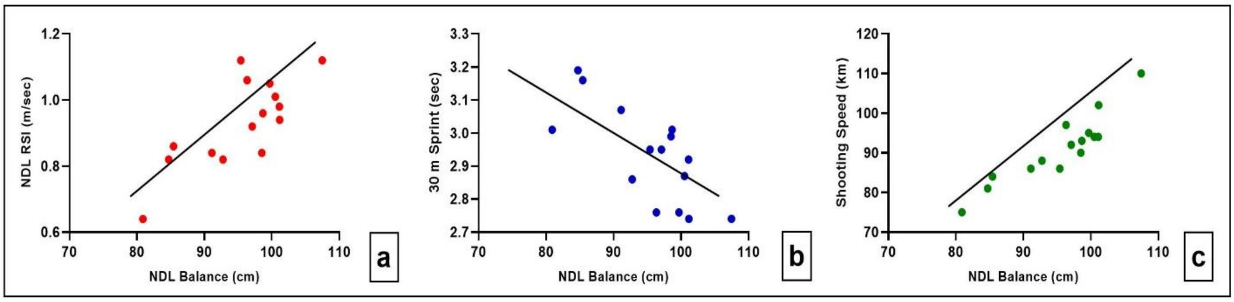

Figure 2. Relationship Between NDL Balance Level and RSI (a), Sprint (b) and Shooting Speed (c). *Note. NDL: non-dominant leg, km: kilometer, m: meter, RSI: reactive strength index, sec: seconds.*

In Figure 2, Pearson correlation test was applied to determine whether the NDL balance level of football players was related with RSI, sprint and shooting speed. In the test results, it was determined that there was a significant positive correlation between NDL balance level and NDL RSI (r= 0.770; Figure 1-a) and shooting speed (r= 0.913; Figure 1-c), and a significant negative correlation with sprint (r= -0.735; Figure 1-b).

Table 3. The Effect of NDL Balance Levels on RSI, Sprint and Shooting Speed

Predictor Variable	Predicted Variable	B	Std. Error	R^2	F	p
	NDL RSI	0.014	0.003	0.592	18.889	**0.001****
NDL Balance	Sprint	-0.015	0.004	0.541	15.309	**0.002****
	Shooting Speed	1.084	0.131	0.840	68.025	**0.000****

*Note. **p<0.01; NDL: non-dominant leg, RSI: reactive strength index, Std: standard.*

In Table 3, a linear regression model was created to predict the RSI, sprint and shooting speed depending on the NDL balance level. The regression model calculated for NDL balance level and NDL RSI ($F_{(1-24)}$= 18.889; p=0.001), sprint ($F_{(1-24)}$= 15.309; p=0.002) and shooting speed ($F_{(1-24)}$= 68.025; p=0.000) was statistically significant. NDL balance level explained 59% (R^2=0.592), 54% (R^2=0.541) and 84% (R^2=0.840) of NDL RSI, sprint and shooting speed, respectively. It was determined that one unit increase in NDL balance level resulted in 0.014 unit increase in RSI, 1.084 unit increase in shooting speed and -0.015 unit decrease in sprint.

In this study, it was initially hypothesised that dominant leg dynamic balance would positively influence the reactive strength index, sprint performance, and shooting speed in football players. The results support this hypothesis, showing that dominant leg balance significantly affects multiple physical performance parameters.

Specifically, the positive correlation between dominant leg balance and both the reactive strength index and shooting speed suggests that balance plays a crucial role in explosive power output and kicking precision. This finding aligns with prior literature indicating that improved postural control enhances energy transfer efficiency and movement effectiveness during dynamic tasks.[25] Such efficiency likely contributes to generating powerful and accurate shots, particularly under high-speed conditions.

On the other hand, the negative correlation observed between balance level and sprint time implies that enhanced balance is associated with faster sprinting. This does not confirm a causal relationship but suggests a strong link between neuromuscular control improvements through balance training and the economy of motion.[26] Regression analyses further showed that dominant leg balance can explain a substantial portion of the variance in performance outcomes, with notably high R^2 values. While these values underscore the strength of the model within this sample, they may reflect overfitting or sample-specific dynamics and should be interpreted with caution regarding generalizability.

The second hypothesis proposed that non-dominant leg dynamic balance would also positively influence the same performance metrics. Results confirmed this, indicating that non-dominant leg balance is significantly associated with improved reactive strength index, sprint time, and shooting speed. This finding highlights the role of bilateral balance in football, a sport requiring continuous transitions between legs during movement and skill execution.[27]

Similar to the dominant side, increased non-dominant leg balance was linked to improved reactive strength and shooting ability, suggesting a supporting role in power generation and accuracy. Furthermore, its negative correlation with sprint time again suggests that better balance is associated with enhanced movement efficiency.[17] Regression analyses reinforced this interpretation, showing high explanatory power, particularly for shooting speed—a result that accentuates the importance of incorporating non-dominant leg training in athletic conditioning.

These results are in line with prior studies indicating that dynamic balance can distinguish performance levels in football. For instance, Paillard et al. reported that national-level players outperformed regional players in both static and dynamic balance tasks.[28] Moreover, balance training has been shown to improve performance variables such as vertical jump height.[29,30] Such adaptations are believed to stem from enhanced proprioceptive awareness and motor coordination through repetitive training.[26]

When interpreting the relationship between balance and sprint, several studies have reported significant associations. Dolan[31] and Kartal[32] found that improved balance correlated with better sprint performance, a relationship also supported by Bressel et al.[26] and Myer et al. who showed post-training sprint improvements following balance interventions.[33] These results are typically explained through the biomechanical demands of sprinting, which involves repeated unilateral movements and trunk-pelvis stabilization.[34,35] For example, Behm et al. demonstrated the high level of trunk muscle activation required to stabilize the pelvis during sprinting.[36] These factors contribute to the theory that balance training may indirectly enhance sprint performance by improving control during acceleration phases.

Similarly, evidence linking balance with explosive strength continues to grow. Bressel et al.[26] and Erkmen et al.[11] found correlations between dynamic balance and vertical jump performance. Kean et al. observed a 9% increase in jump height after a 5-week balance program, attributing this to reduced postural sway and improved direction of propulsive force.[29] These observations are consistent with reviews by Behm and Colado, who emphasized the impact of postural stability on vertical jumping capacity.[37] Additionally, Pant et al. reported a link between ankle joint strength and overall balance,[38] highlighting the interconnectedness of neuromuscular strength and performance measures such as sprinting and jumping.[39]

In relation to shooting performance, several studies have demonstrated that balance contributes significantly to shot accuracy and power. Tracey et al.[27] showed a relationship between contralateral leg stability and kicking accuracy. Henni et al.[13] found that the knee angle of the supporting leg affects accuracy, which may be tied to balance control at ball contact. During shooting, particularly under dynamic conditions, the entire body weight is supported on one leg, making balance a prerequisite for control.[17,40] Furthermore, Guebli et al. emphasized that accurate ball-kicking requires the integration of balance and coordination.[41] Hammami et al. added that maintaining both static and dynamic balance contributes to high-speed maneuvers by facilitating neuromuscular adaptations that counteract shifts in the center of gravity.[25]

CONCLUSION AND RECOMMENDATIONS

The results of this study demonstrate that dynamic balance is significantly associated with key performance parameters in youth football players, including the RSI, sprint time, and ball shooting speed. Specifically, as dynamic balance scores increased—particularly in both dominant and non-dominant legs—players tended to show improved explosive force production, shorter sprint times, and higher shooting velocities. Among these variables, the strongest association was observed between dynamic balance and shooting speed, suggesting that balance may play a notable role in supporting lower limb force application during ball striking. Regression analyses revealed that dynamic balance accounted for a considerable portion of the variance in these performance metrics; however, due to the cross-sectional nature of the study, these results should be interpreted as associations rather than causal effects. These results also imply that improved balance may contribute to enhanced neuromuscular coordination and postural control, which in turn could support greater movement efficiency and sport-specific skill execution. From a practical standpoint, incorporating balance-focused exercises into football training programs may benefit players' physical development, especially when combined with strength and speed components. This study adds to the existing literature by highlighting the performance-related relevance of dynamic balance, not just in injury prevention, but also in its potential influence on explosive athletic actions. It addresses a specific gap by examining this relationship in elite youth football players and encourages further longitudinal or experimental studies to explore underlying mechanisms.

In practical terms, these results suggest that incorporating balance exercises into strength and sprint training may enhance overall neuromuscular efficiency. Targeting both dominant and non-dominant limbs can improve bilateral coordination and help prevent performance asymmetries. Implementing football-specific balance tasks—such as shooting under pressure or rapid directional changes—may facilitate the transfer of balance skills to match situations. Furthermore, as balance is closely linked to postural control, its improvement may contribute to reducing injury risk during high-intensity movements.

Limitations

This research has certain methodological and sampling limitations. Firstly, the study was conducted only with young male footballers who are licensed competitors in football clubs, limiting the generalisability of the results for different age groups, genders or athletes at different levels of football. Secondly, the study assessed physical and motor skill parameters such as dynamic balance, reactive strength index, sprint and shooting speed, but not other performance components. This situation indicates that more comprehensive analyses are needed to fully reveal the effect of balance on football performance. Finally, the accuracy and reliability levels of the measurement methods and devices used in the study are another factor that may affect the results of the study. The use of more advanced technological measurement tools in future studies may contribute to a more precise evaluation of the effect of balance on sportive performance.

Funding

This study was supported by the Scientific and Technological Research Council of Turkiye (TÜBİTAK) under the TÜBİTAK 2209-A Undergraduate Students Research Projects Support Program with Grant Number 1919B012300162.

Conflict of interest statement

The authors have no conflicts of interest to declare.

Authors' contributions

Concept: AK, EF, ET; Design: AK; Supervision: AK, EF, ET; Resources: AK, EF, ET; Data collection: EF, ET; Analysis: AK, ET; Literature search: EF, ET; Writing manuscript: ET; Critical review: AK. All authors have read and accepted the published version of the manuscript.

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