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Original Article

Relationships Between Shot Velocity and Selected Performance and Anthropometric Characteristics in Football Players

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Abstract

This study examined the relationships between shot velocity and lower extremity volume, interlimb asymmetry, anaerobic power output, vertical jump performance, sprint speed, and basic anthropometric indicators in trained football players. Using a correlational research design, height and body mass of the voluntarily participating active players (n=24) were measured, body mass index was calculated, lower limb volumes were determined, and asymmetry ratios between the legs were obtained. Vertical jump performance was assessed using a digital jump measurement system, while sprint performance was evaluated through a 20-meter sprint test with photocell timing gates. Anaerobic performance was measured with the Running-Based Anaerobic Sprint Test, and shot velocity was recorded using a radar-based speed measurement device while participants performed maximal power shots with a standard football from a predetermined distance. All statistical analyses were conducted using GraphPad Prism software (Version 10.3.1). The findings demonstrated that there were no statistically significant relationships between shot velocity and any of the evaluated physical or performance variables. The low correlation coefficients indicated that these variables do not strongly or directly predict shooting performance. These results support the notion that shooting performance is multideterministic in nature. Shot velocity cannot be explained by a single physical or morphological parameter; rather, it appears to be influenced by the integrated interaction of technical skill, neuromuscular coordination, joint angular velocity of the lower limbs, kinematic movement quality, and the player's cognitive-motor strategy.

Keywords: Shot velocity, Lower limb volume, Anaerobic performance, Limb asymmetry.

Introduction

The Football is a multifaceted sport that integrates technical skills, tactical awareness, physical conditioning, and psychological preparedness (Ludvigsen, 2022; Mumford, 2019). Among the technical skills contributing to successful performance, shooting ability, particularly the speed and accuracy of the shot, is considered a critical factor influencing match outcomes (Milenković, 2011). Shot velocity is defined as the speed of the ball at the moment it leaves the player's foot and plays a key role in scoring ability, as higher shot speeds reduce the goalkeeper's reaction time and increase the likelihood of scoring a goal (Hunter et al., 2018; Sinclair et al., 2014). Therefore, understanding the factors that influence shot velocity has become an important area of research in sports science.

Existing literature indicates that shot performance can be influenced by both anthropometric characteristics (Medina et al., 2022) and physical performance qualities (Brahim et al., 2013; Sanpasitt et al., 2023). The lower extremities contribute substantially to kicking mechanics by generating the required momentum and transferring force through coordinated kinetic chain movements (Da Silva Carvalho et al., 2024). The morphology of the thigh and calf may influence force production by determining limb volume, muscle cross-sectional area, and biomechanical leverage (López et al., 2024). Additionally, bilateral asymmetry between the legs has been associated with reduced motor coordination efficiency, which may affect shot performance, although findings in this area have been inconsistent (Katis et al., 2017; McLean & Tumilty, 1993; Nunome et al., 2006).

Physical performance indicators such as vertical jump height, sprint speed, and anaerobic power output are commonly employed to assess neuromuscular strength and lower-limb explosiveness (İlbak & Acak, 2022; Karadenizli et al., 2026; Kurak et al., 2024). Given that kicking largely relies on rapid acceleration of the lower limbs, athletes with greater explosive power may be capable of producing higher shot velocities. However, empirical findings remain mixed: while some studies report positive associations between power-based metrics and shot velocity (Gadev & Peev, 2022; Hanuš et al., 2011), others have found weak or non-significant relationships (Sannicandro et al., 2014; Sousa et al., 2003). These discrepancies suggest that shot performance is not solely determined by physical attributes, but also by technical proficiency, intermuscular coordination, motor learning, and biomechanical execution.

Anthropometric variables such as body mass, height, and body mass index (BMI) may also be associated with shot velocity by influencing total momentum generation (Bekris et al., 2015; Jalilvand et al., 2019). Greater body or limb mass may facilitate greater force transfer to the ball, provided that neuromuscular control and movement speed are sufficient (Busse et al., 2023; Hart et al., 2016). However, excessive body mass not supported by strength and power development may impair technical execution (Ben Mansour et al., 2021). Thus, the interaction between morphological structure and functional performance must be examined carefully.

Despite the existing research, the contributions of anthropometric and performance factors to shot velocity in football players are not yet fully clarified. Variations in measurement techniques, participant training levels, and physical performance assessment methods may account for inconsistencies in the literature. Therefore, further investigation among trained football players is warranted.

The aim of this study was to examine the correlations between shot velocity and selected anthropometric and performance variables in football players. Investigating the relationships between shot velocity and leg volume, bilateral leg asymmetry, vertical jump height, sprint performance, anaerobic power, body mass, height, and BMI may provide valuable insights into the physical determinants of shooting performance. Understanding these relationships may assist coaches and sports scientists in designing targeted training strategies to enhance shooting ability and overall technical performance.

Material and Methods

Experimental Design

This study employed a correlational research design to investigate the relationships between shot velocity and selected anthropometric and performance variables in football players. A total of 24 active football players voluntarily participated in the study. Body height and body mass were measured, and body mass index (BMI) was subsequently calculated. Leg volume was assessed, and the bilateral asymmetry ratio between the legs was determined. Vertical jump performance was measured using a digital jump assessment system, while sprint performance was evaluated during a 20-meter sprint using a photocell timing system. For shot velocity measurements, a standard football was used, and participants were instructed to perform maximal-effort shots from a predetermined distance. Shot velocities were recorded using a radar-based speed measurement device. Each participant completed three attempts, and the highest recorded value was used for statistical analysis.

Participants

The minimum required sample size for inclusion in the study was determined using the G*Power 3.1.9.7 software. An a priori power analysis was conducted for a Pearson correlation analysis. The analysis was performed two-tailed, with an effect size of r = 0.55 (moderate-to-large), a significance level of $\alpha = 0.05$, and a statistical power of $1-\beta = 0.80$. The power analysis indicated a minimum sample size requirement of n = 23. Considering potential measurement losses, the sample size was set at 24 participants. Accordingly, 24 male licensed football players volunteered to participate in the study. The participants' mean height was 175.2 ± 6.06 cm, mean body mass was 65.45 ± 5.5 kg, and mean age was 17.87 ± 0.68 years. The mean training experience (years of sport participation) of the players was determined as 6.6 ± 1.6 years.

The inclusion criteria required participants to be healthy, licensed male football players who were actively training within a football club and who voluntarily agreed to take part in the study. In line with the exclusion criteria, individuals who were not male, those who were not actively competing as licensed players, and those who had experienced any injury, musculoskeletal complaint, or lower-limb–related health problem within the previous six months were not included in the study.

Anthropometric Measurements

Anthropometric assessments were conducted between 09:00 and 11:00 a.m., with participants standing barefoot while wearing sports shorts and t-shirts. Body height was measured using a SECA 213 stadiometer (SECA GmbH, Hamburg, Germany) with a precision of 0.1 cm, and body mass was assessed using a calibrated Tanita BC-545N digital body composition scale (Tanita Corp., Tokyo, Japan) with a precision of 0.1 kg. Body mass index (BMI) was subsequently calculated using the kg/m^2 formula based on these measurements.

Prior to the leg volume assessment, the reference point of the gluteal fold was identified. After the participant changed into a slip swimsuit, the most prominent point of the gluteal fold on the leg to be measured was located and marked using a waterproof dermatographic skin marker (HBW, Germany). A 50 cm stainless-steel ruler equipped with a spirit level (Bürkle GmbH, Germany) was placed on the marked point to ensure horizontal alignment, after which the reference line was drawn. The same procedure was applied to the contralateral leg.

Leg volume was defined as the volume of the segment extending from the gluteal fold to the plantar surface, with thigh and calf volumes determined separately. The distance between the tibial tuberosity and the inguinal fold was used for thigh volume calculations, whereas the distance between the tibial tuberosity and the medial malleolus was used for calf volume. Each segment length was divided into 10% intervals, and circumference measurements were obtained at each interval using a ±1 mm precision measuring tape (Lufkin W606PM, Apex Tool Group, USA).

The volume of each segment was calculated using the frustum (truncated cone) model, and the sum of the segment volumes represented the total thigh and calf volumes. Total leg volume (LV) was computed using the formula:
Leg Volume = Thigh Volume + Calf Volume
Bilateral leg asymmetry was calculated as the percentage difference between the volumes of the right and left legs.

Performance Tests

Performance testing procedures were conducted following standardized protocols commonly used in sports science literature. A general warm-up lasting 10 minutes was administered before all performance assessments. This warm-up consisted of 5 minutes of light running and 5 minutes of dynamic stretching and lower-extremity activation exercises, consistent with the recommendations for enhancing neuromuscular readiness prior to explosive performance tests (Behm & Chaouachi, 2011; Silva et al., 2018).

Vertical jump performance was assessed using a digital jump mat/optical timing system according to the countermovement jump (CMJ) protocol. The CMJ has been widely utilized to evaluate lower-limb power and demonstrates high validity and reliability in athletic populations (Markovic et al., 2004). Participants were instructed to perform an explosive upward jump following a controlled countermovement while keeping their arms fixed to the trunk, as arm swing can artificially inflate jump height. Incorrect trials were repeated. Each participant performed three valid attempts with at least 60 seconds of passive rest, and the highest jump height was used for analysis.

Sprint performance was measured on a synthetic field over a 20-meter distance using a photocell timing system. Short-distance sprint tests (10–30 m) are well established for assessing acceleration ability in football players (Little & Williams, 2005; Haugen et al., 2012). The starting line was positioned 20 cm behind the photocell gates to prevent premature triggering. Participants began from a standing start at their own readiness. Two trials were completed with a minimum of 3 minutes of passive rest, and the fastest time was retained for analysis.

Anaerobic performance was evaluated using the Running-based Anaerobic Sprint Test (RAST), introduced by Saville (2025) as a field-based method for estimating anaerobic power. The test consisted of six maximal 35-meter sprints, each separated by 10 seconds of passive recovery. RAST has been used extensively in team-sport research and has demonstrated acceptable reliability and practical applicability (Zagatto et al., 2009). Sprint times were recorded via photocells, and to minimize deceleration, a point 5 meters beyond the finish line was marked. Any trial affected by slipping or mechanical error was repeated. Power output was calculated using the formula:
Power (W) = (Body Mass × Distance^2) / Time^3,
and the highest value among the six sprints was used for analysis.

Shot velocity was assessed using the Pocket Radar Ball Coach Speed Gun (USA), a device shown to provide accurate and reliable measurements of ball speed in sport settings. Participants were provided three familiarization shots before testing. The assessment took place on a flat synthetic turf surface, with shots taken from 20 meters toward a FIFA-regulated goal (2.44 m × 7.32 m). Standard size 5 footballs were used, and ball pressure was checked before each attempt. Participants wore their regular training apparel, including cleats, and were instructed to strike the ball with maximal effort using their natural technique. Shots did not need to hit the target to be considered valid. The radar device was positioned directly behind the player in alignment with the ball's trajectory.

Each participant performed three maximal shots, with at least 90 seconds of rest between attempts. The highest ball velocity was used in the analyses.

Statistical Analysis

All statistical analyses were conducted using GraphPad Prism software (Version 10.3.1; GraphPad Software, LLC, San Diego, CA, USA). The normality of the data distribution was assessed using the Shapiro–Wilk test. As all variables satisfied the assumptions for parametric analysis, Pearson's product–moment correlation coefficient (r) was calculated to examine the relationships between shot speed and selected performance and anthropometric variables, including right and left leg measures, leg asymmetry, RAST maximum power, vertical jump height, 20 m sprint time, average leg volume, height, body mass, and body mass index (BMI). For each correlation, the coefficient of determination (R^2) and 95% confidence intervals (CI) were reported to indicate the magnitude and precision of the associations. Statistical significance was evaluated using two-tailed p-values, with the level of significance set at $\alpha = 0.05$. Correlation strength was interpreted based on conventional criteria: trivial ($|r| < 0.10$), small (0.10–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89), and nearly perfect ($|r| \geq 0.90$).

Results

The findings of the study are presented below through tables and figures.

Table 1. Correlations Between Shot Velocity and Selected Anthropometric and Performance Variables

Variable Comparison	r	95% Confidence Interval	R^2	p (two-tailed)
Shot speed vs. Right leg Volume	-0.03054	-0.4206 → 0.3690	0.0009328	0.8848
Shot speed vs. Left leg Volume	0.07218	-0.3324 → 0.4544	0.005210	0.7317
Shot speed vs. Asymmetry	-0.2997	-0.6213 → 0.1082	0.08984	0.1455
Shot speed vs. RAST Maximum Power	0.1805	-0.2311 → 0.5373	0.03259	0.3878
Shot speed vs. Vertical Jump	-0.1221	-0.4934 → 0.2869	0.01490	0.5610
Shot speed vs. 20 m Sprint	0.2253	-0.1865 → 0.5697	0.05075	0.2790
Shot speed vs. Average Leg Volume	0.02282	-0.3757 → 0.4142	0.0005208	0.9138
Shot speed vs. Height	-0.09165	-0.4698 → 0.3149	0.008399	0.6631
Shot speed vs. Weight	-0.03926	-0.4278 → 0.3615	0.001541	0.8522
Shot speed vs. BMI	0.001539	-0.3938 → 0.3964	0.00000236	0.9942

Examination of Table 1 indicates that, according to the Pearson correlation analysis, no statistically significant relationships were found between shot velocity and any of the assessed variables ($p > .05$ for all). This suggests that the measured performance and anthropometric characteristics may have limited direct influence on shot velocity.

The correlation coefficients calculated between shot velocity and right leg, left leg, and total leg volume were notably low ($r \approx -0.03$ to 0.07), indicating that leg circumference and volume do not appear to substantially contribute to shot performance. Similarly, the correlations between shot velocity and RAST peak power, vertical jump height, and 20 m sprint performance were also weak ($r \approx -0.12$ to 0.22). Although sprint time and RAST peak power demonstrated slightly positive but very weak associations with shot velocity ($r \approx$ 0.18–0.22), these relationships were not statistically significant ($p > .05$). These findings suggest that lower-limb explosive power and speed alone are insufficient predictors of shot velocity.

Additionally, the anthropometric variables of height, body mass, and body mass index (BMI) also exhibited low correlations with shot velocity (r ≈ -0.09 to 0.001), indicating that overall body size does not have a meaningful effect on shot speed.

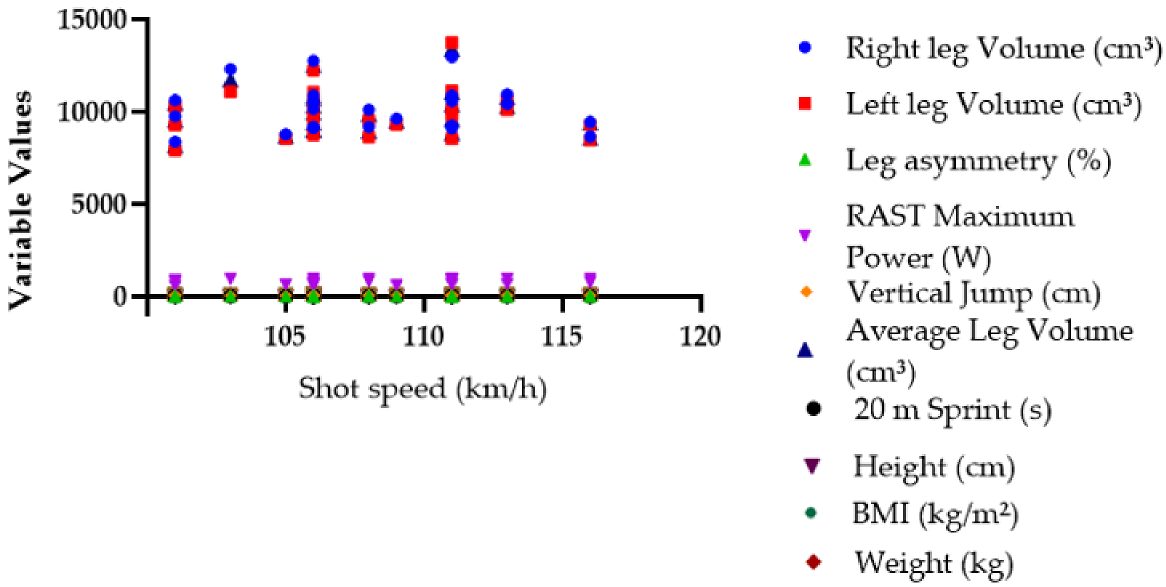

Figure 1. Performance and Anthropometric Measures in Relation to Shot Speed

Figure 1. Scatter plots illustrating the relationships between shot speed (km/h) and selected performance and anthropometric variables, including right leg volume, left leg volume, leg asymmetry, RAST peak power, vertical jump height, 20 m sprint time, average leg volume, height, body mass, and BMI. No statistically significant correlations were observed (p>.05 for all comparisons).

Discussion

This study examined the relationships between shot velocity and lower-limb volume, inter-limb asymmetry, anaerobic power output, vertical jump performance, sprint speed, and basic anthropometric characteristics in trained football players. The findings revealed no statistically significant associations between shot velocity and any of the evaluated variables. The generally low correlation coefficients suggest that the examined physical and morphological indicators do not strongly or directly predict shot performance. This indicates that physical attributes may contribute to performance potential but do not necessarily translate into shooting output without sufficient technical mediation.

These results contradict a considerable portion of the existing literature. Numerous studies have reported meaningful associations between lower-limb muscle mass, explosive strength, and anaerobic capacity with shot velocity. Bekris et al. (2015), for instance, demonstrated a significant relationship between lower-limb explosive power and shot velocity, indicating its potential relevance for differentiating performance levels among players. Similarly, Campo et al. (2009) showed that 12 weeks of plyometric training led to improvements in both explosive power and shot velocity in female footballers. Aydin et al. (2023) also reported that anaerobic power and muscular strength significantly influence shot velocity at different shooting distances, with muscle strength playing a more prominent role in short-distance shots and anaerobic performance being more influential in longer-distance attempts. However, the absence of such associations in the present study suggests that shot performance cannot be solely reduced to physiological capacity indicators. This discrepancy highlights that improvements in physical qualities may not transfer uniformly to skill-dependent tasks such as shooting.

Several factors may account for these outcomes. First, shot performance is inherently technique-dependent and relies heavily on motor control. The instep kick relies on a proximal-to-distal sequencing mechanism within the kinetic chain, wherein the efficiency of the sequence is determined not only by muscular force but also by coordination, segmental timing, and neuromuscular regulation (Chen et al., 2024; Egan et al., 2007; Zhou et al., 2025). Consequently, even adequately developed physical capacities may not translate into increased shot velocity in the absence of refined technical skill. This reinforces the notion that technical mastery may overshadow physical determinants when evaluating shooting performance.

Second, volume-based anthropometric measures do not fully reflect muscle cross-sectional area or neuromuscular activation potential. Previous research has demonstrated inconsistent or weak associations between muscle size and functional power outputs in youth footballers (Bahenskỳ et al., 2020). Ortega et al. (2020) further reported that similar increases in muscle volume across different resistance training modalities do not necessarily correspond to equivalent improvements in neuromuscular performance. Likewise, Lesinski et al. (2021) observed that comparable changes in body composition across training programs may yield divergent outcomes in strength and shot performance. Thus, morphological characteristics alone are insufficient to predict functional output, which may explain the absence of a relationship between lower-limb volume and shot velocity in the present study. Additionally, the volume measurement method used in this study-while systematic may not perfectly capture the distribution of contractile tissue, thereby introducing inherent limitations in its predictive capability.

Third, while sprint and jump tests reflect general lower-limb power and speed capacities, shooting is a highly task-specific, skill-based action. A systematic review by Gheller et al. (2022) emphasized that although sprint and jump training can enhance power-related performance, the transfer of these improvements to sport-specific skills is limited. Similarly, Marques et al. (2013) reported that despite gains in explosive strength, improvements in shooting performance remained modest and were contingent upon technical proficiency. Smith et al. (2008) highlighted that segmental energy transfer in the instep kick is governed by passive dynamics and precise timing, underscoring the decisive role of technique. Therefore, explosive power represents performance potential, whereas its manifestation in shooting depends on skill acquisition, coordination, and sport-specific experience.

Lastly, variability in sample characteristics may explain discrepancies among studies. League level, positional demands, training history, motor learning background, and technical exposure can meaningfully influence shot performance. Rebelo et al. (2012) demonstrated significant differences in anthropometric, fitness, and technical characteristics between elite and non-elite U19 players, even within the same playing positions. Forcher et al. (2022) and Izquierdo et al. (2020) similarly reported positional and individual differences in technical match performance and shot velocity, shaped by tactical roles and personal playing style. The relatively small sample size of the present study likely increased inter-individual variability, thereby reducing the strength of statistical associations. Future studies may benefit from larger and more homogeneous samples to better isolate the contribution of specific performance components to shooting ability.

This study has several limitations that should be acknowledged. The small sample size may have limited statistical power and increased between-subject variability. Additionally, the use of volume-based anthropometric measures may not fully capture muscle architecture or contractile capacity. The cross-sectional design also prevents causal interpretation. Environmental factors such as testing surface and contextual familiarity may have influenced performance outcomes. Future research should incorporate larger samples, direct measures of muscle morphology, and longitudinal designs to better understand determinants of shot velocity.

Collectively, these findings support the multideterministic nature of shot performance. Shot velocity cannot be explained by a single physical or morphological parameter; instead, it emerges from the integrated interaction of technical skill, coordinative control, joint angular velocity patterns, kinematic sequencing, and cognitive-motor strategies. Accordingly, training programs aimed at improving shot performance should not rely solely on strength or hypertrophy-oriented interventions, but should incorporate high-repetition technical practice, kinetic chain awareness, proprioceptive control, and timing-based skill refinement exercises. In addition, integrating sport-specific motor learning strategies may further enhance the translation of physical capacities into improved shooting performance.

Conclusions

This study examined whether lower-limb volume, inter-limb asymmetry, vertical jump performance, sprint speed, anaerobic power, and basic anthropometric characteristics could predict shot velocity in trained football players. The findings demonstrated that none of these commonly assessed physical variables were significantly associated with shot velocity. This outcome clearly indicates that physical or morphological attributes alone are insufficient to explain variations in ball speed. These findings emphasize that shooting performance is driven primarily by the neuromechanical complexity of the kicking action rather than isolated measures of strength, speed, or body structure. Technical proficiency, coordination, and timing of force application therefore appear to play a more decisive role in generating shot velocity than physical qualities alone. Accordingly, training approaches aimed at improving shooting performance should place greater emphasis on technical repetition, motor learning, and movement execution quality, supported-rather than dictated by strength and power development. Integrating technical refinement with targeted physical preparation may offer a more effective pathway for enhancing shooting outcomes.

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Ethical Approval Statement: The Süleyman Demirel University Health Sciences Ethics Committee approved this study on 03 November 2025, with decision number 23.

Informed Consent Statement: Informed consent was obtained from all participants involved in the study.

Conflict of Interest: The authors declare no conflicts of interest regarding this study.

Data Availability Statement: Data supporting this study is available from the authors upon reasonable request.

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