Biomechanical Characteristics of Accurate Football Kicking: A Systematic Review

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ABSTRACT

Kicking a soccer ball involves coordination of the torso, pelvis, supporting leg, and kicking leg. However, several challenges complicate accuracy. For example, studies use different measurements and tasks, and some report ball velocity rather than accuracy. This review focuses on biomechanical and performance research on soccer ball kicking and attempts to separate accuracy studies from other biomechanical studies that support their hypotheses or methodological constraints. We searched Scopus for studies as of August 24, 2026, and initially identified 472 studies. After removing irrelevant studies, we selected 25 research papers for further analysis. We included 14 studies because they met the criteria of direct accuracy measurement, relevance to soccer-specific biomechanics, and reliable measurement. Ten studies provided direct measures of accuracy or placement, three included relevant biomechanical evidence, and one analysed reliability. The most common themes were segmental coordination, support-leg and approach mechanics, fatigue, neuromuscular control, and accuracy measurement. Velocity and accuracy did not always change together. The most useful way to consider accurate kicking is as a coordinated, full-body task in a biomechanical context, even if direct evidence is limited.

Keywords*: Biomechanics, Football, Kicking Accuracy, Kicking Performance, Kinematics, Soccer*

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INTRODUCTION

Kicking in football refers to a quick, goal-oriented technique that utilizes coordinated movements of the pelvis, trunk, support leg, as well as the kicking limb. Virtually, the process is referred to as a proximal-distal process, whereby all the movements travel from the pelvis to the leg, shank, as well as the foot, while the approach and support leg are able to create necessary conditions for ball contact (Lees et al., 2010; Ikegami, et al., 2006). Accuracy concerns whether the ball reaches the target and cannot be used interchangeably with ball velocity. Researchers have operationalised accuracy using radial error and target placement, as well as task-specific accuracy scores. Additionally note changes in leg mechanics during kick execution, while others link few studies linked ball kinematics to penalty kick accuracy, while kinematic and electromyographic studies examined the control requirements for accurate instep kicking (Katis et al., 2013; Scurr et al., 2011).

Kicking methods, support-leg use, biomechanics, and movement patterns influence kicking and hitting performance. Research indicates that the approach angle alters spine and leg mechanics. Some studies have noted changes in leg mechanics during kick execution, while others have linked the supporting leg's committed position to kicking accuracy (Augustus et al., 2017, 2024).

Another factor is related to coordination between human body segments. Competitive sportsmen possess different patterns of foot velocity in relation to hip-knee and knee-ankle coordination. Training

practice likely promotes foot velocity and kick accuracy during the game (L. Zhang et al., 2026; Zhou et al., 2025).

Previous reviews have documented the methodology behind soccer kicks, but the evidence varies across different tasks, populations, and outcomes. Direct and indirect accuracy findings often appear alongside studies reporting velocity and kinematics. Thus, this review makes this distinction considering a limited body of biomechanical and methodological evidence that can contextualise these findings (Aedo-Muñoz et al., 2020; Lees et al., 2010).

The goal, in this case, was to present the findings of both biomechanical and kinematic studies while separating the direct accuracy findings.

REVIEW OF LITERATURE

Biomechanical organisation of football kicking

Kicking in football can be expressed as a sequence of movements in which the pelvis, hip, knee, ankle and foot act. The movement consists of the preparation action that creates speed and determines body position. While the support leg keeps the body stable, the kicking limb strikes the ball. Stroke accuracy requires control of the point of contact and the angle of the ball, not only the speed of movement (Kapidžić et al., 2014; Lees et al., 2010).

Lower-limb kinematics and coordination

Three-dimensional studies analyze angles at various joints, angular speed, range of motion and inter-segmental coordination. Coordination patterns differ between elite and amateur players and also depend on foot speed. In addition, training studies suggest that training may improve coordination in starters (L. Zhang et al., 2026; Zhou et al., 2025). Other studies identify segment speed and knee extension angular speed as factors that influence ball speed, while developmental studies describe changes in kicking mechanics with age (De Witt & Hinrichs, 2012; Katis & Kellis, 2010; Bottoms, et al., 2014). These findings are valuable for biomechanics, but they cannot be treated as proof of accuracy unless accuracy was measured.

Mechanics of the Support Leg and the Approach

The support leg enables the kick. Research suggests that support-leg action is critical to maximising the effectiveness of an instep kick. Research shows that support-leg movements differ by play level and leg preference. Approach speed also affects how angular momentum is converted between the pelvis and kicking leg (Augustus et al., 2021). While these studies provide useful insight into how the body moves, most do not quantify errors affecting the target.

Fatigue and kicking ability

Fatigue can significantly affect kicking motion and kick efficiency. An intermittent exercise program can be potent enough to change kick biomechanics. A study (Kellis et al., 2006; Torreblanca-Martínez et al., 2020) involving female players shows that fatigue from repeated sprints can slow kicks. Recent studies have examined local muscular fatigue and recovery after high-intensity running in hot conditions (J. B. Carstensen et al., 2026; Palucci Vieira et al., 2023).

Accuracy measurement

Accuracy is defined and measured through different approaches. Studies have relied on methods such as radial errors, mean radial errors, height-to-width ratio, target placement, scoring in specific tasks, and free-kick shooting. Reliability testing addresses whether testing yields consistent scores each time (J. Carstensen & Andersen, 2026; Carling, et al., 2022; Palucci Vieira et al., 2023; Lastella, et al., 2022). There is no need to include these measurements with the report of the velocities of the ball.

Aim and objectives

Objective. This review collated research on kicking accuracy in association football, distinguishing between studies that directly examine kicking accuracy and those that provide supportive biomechanical or methodological insights.

Aim. This review set out to achieve the following goals:

1. To outline the motion and coordination features associated with football kicking
2. To gather direct evidence about kicking accuracy and ball placement.
3. To integrate supporting evidence on the influence of approach, support-leg mechanics, segmental coordination, fatigue and muscle factors, and player characteristics.
4. To describe the methods employed to measure kicking accuracy along with the measurement reliability evidence available.

METHODOLOGY

The review followed PRISMA 2020 principles for clear reporting of the identification, selection, and synthesis process (Page et al., 2021). There was no prospectively registered plan. The screening records do not indicate the number of reviewers or whether different individuals screened independently; therefore, the resolution process for disagreements cannot be described.

Database and Search Strategy

Scopus was the only database used. The search took place on 24 August 2026 and returned 472 total records. The following is the unedited search query obtained in Scopus. It does not have added parentheses that would change the meaning of the search.

(TITLE-ABS-KEY (football) OR TITLE-ABS-KEY (soccer) AND TITLE-ABS-KEY (biomechanics) OR TITLE-ABS-KEY (kinematics) AND TITLE-ABS-KEY (kick) OR TITLE-ABS-KEY (technique) OR TITLE-ABS-KEY (performance))

Since the search query used ORs and ANDs without being grouped, all three concept groups may not be present in the search. The search included no accuracy-related terms. The search record provides no additional information on filters used.

Eligibility Criteria

The studies were considered appropriate for the focused synthesis only if:

- They were about soccer players of different ages, genders, and competition levels.
- They examined the kicking movement (i.e. instep and inside-foot kick, penalty kick, free kick) using biomechanical, kinematic, neuromuscular or performance-related parameters.
- They provided either direct kicking-accuracy findings or biomechanical proof regarding the kicking movement under review. We considered measurement-reliability studies as methodological evidence only if they addressed kicking-accuracy and kicking-performance measurements.

We excluded studies from sports unrelated to kicking. The classification system separated direct-accuracy studies from supporting studies that provided relevant movement characteristics without measuring accuracy. We limited supporting evidence to studies of walking, support-leg mechanics, or interaction mechanics, and classified reliability evidence separately.

Study Selection

The Scopus search returned 472 documents; after title and abstract screening, we excluded 447, leaving 25 papers to screen for eligibility. Fourteen papers made it to the final synthesis (Figure 1): of those, ten addressed the accuracy of kicking or ball placement directly, while three provided biomechanical evidence (support-leg biomechanics, interlimb coordination, and approach-momentum transfer) without referring to accuracy, and one dealt with methodological issues of the reliability of the accuracy measure.

Of the excluded studies, 11 did not meet the criteria. Two were related to Australian Rules football, whereas the remaining nine did not directly assess kicking accuracy. The two identified developments in kicking mechanics were filmed using two motion-analysis techniques (markerless and inertial sensors), whereas the rest either examined overall running and technology performance or predicted kicking direction without gauging movement-related error.

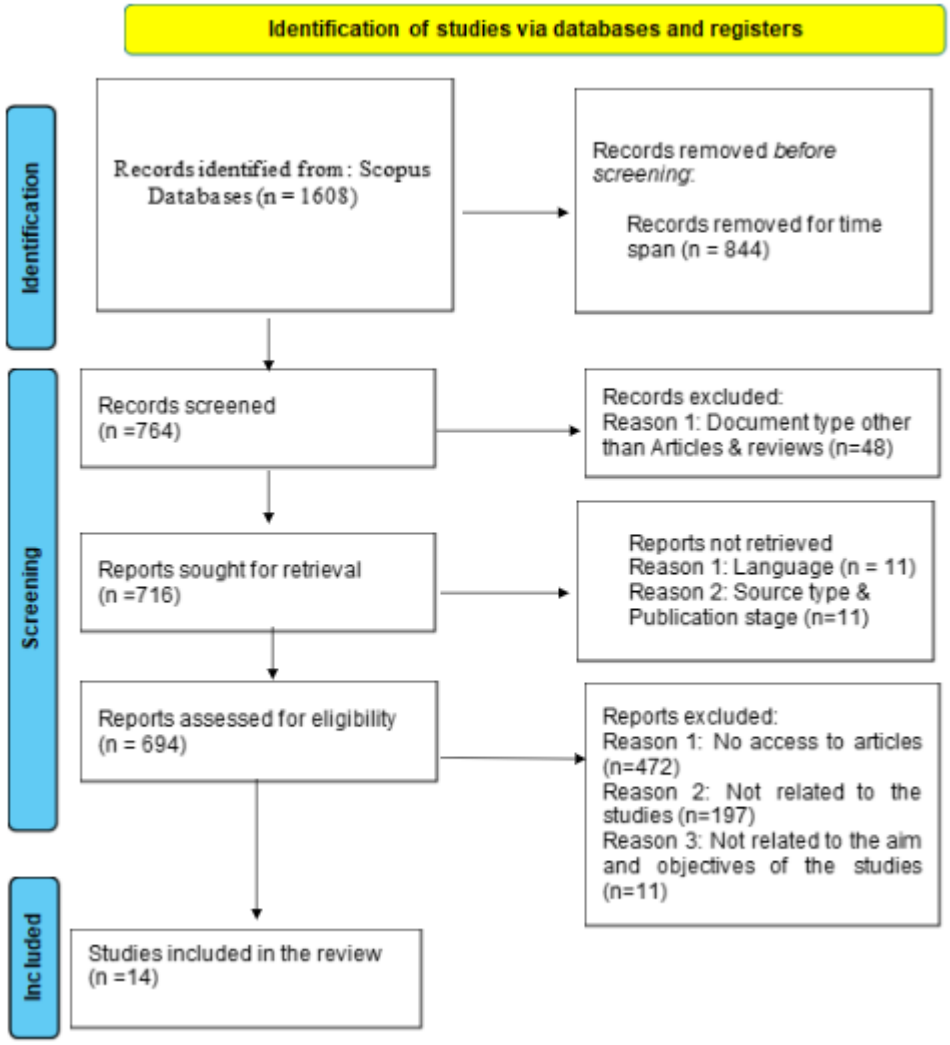


Figure 1. PRISMA 2020 flow diagram of the study selection process

Data Extraction

In the process of data extraction, the review authors employed a standardized table to gather information from all 14 included studies. The data captured included information on the authorship and year of the study, study participants and their competitive experience, the kicking method used in the study, biomechanical and neuromuscular variables included in the study, the method of assessment, outcomes concerning accuracy, and performance outcomes such as the velocity of the foot or the object. However, the authors reported no quantitative effect size.

Quality of each study

The absence of a formal bias risk or methodological quality evaluation arises because the included studies were of different types (experimental, longitudinal, reliability studies, etc.), so no single evaluation tool was applied to all. The results are therefore reported in written form without assessing study quality. This is an identified shortcoming that needs to be acknowledged (Section 9).

Evidence Synthesis and Classification

A narrative synthesis approach was chosen because the studies differed in participants, tasks, variables, and outcome definitions. Each study was categorized according to its primary contribution in terms of direct accuracy evidence, supportive biomechanical evidence (relevant kicking techniques and without direct accuracy measure), or methodological evidence (measurement reliability).

RESULTS

Study Characteristics

The comprehensive synthesis contained 14 studies published from 2020 to 2026, including six studies published in 2025 and 2026. The sample sizes ranged from 6 to 78 individuals and included youth, academy, college, experienced, semi-professional, elite, and professional players. Only one study purposefully recruited all female participants. Instep kicking was the main task in the studies, alongside target-directed kicking, penalty kicks, free kicks, and inside-foot kicks.

Table 1. Characteristics of the 14 studies in the refined evidence synthesis

Study	Participants	Technique	Biomechanical variables	Performance outcome	Main finding
Attaallah et al. (2021)	12 male soccer players	Penalty kick	Ball kinematics; HWR; radial error	HWR and radial error	Selected ball kinematic variables showed significant relationships with the accuracy measures.
Torrebl anca-Martínez et al. (2020)	18 U23 female players	Shooting/kicking	Fatigue-related performance variables	Kicking accuracy; velocity	Repeated-sprint fatigue significantly reduced maximal kicking velocity; the accuracy measure was not significantly reduced.
Carsten sen et al. (2026)	16 experienced players	Kicking	Kicking performance; fatigue	Kicking accuracy	Tested the effect of fatiguing knee-muscle contractions, relative to a control condition, on kicking performance.
Jihad et al. (2025)	6 elite football players	Free kick	Muscular mechanical properties; dynamic balance	Free-kick accuracy	Examined how muscular mechanical properties and dynamic balance relate to free-kick accuracy.
Vieira et al. (2022)	24 U17 players	Instep kick	EEG; movement kinematics	Mean radial error; ball velocity	EEG signals and movement kinematics were modelled in relation to kicking outcome.
Vieira et al. (2022)	28 U17 academy players	Target-directed kicking	Sleep quality; morningness-eveningness; ball placement; kicking velocity	Mean radial error; ball placement; ball velocity	Poorer sleep quality and chronotype scores were associated with impaired ball placement but not kicking velocity.
Nugroho & Doewes (2023)	12 professional players	Inside-foot and instep	Swing and impact kinematics	Shooting accuracy	Biomechanical differences were reported between inside-foot and instep shooting.
Augustus et al. (2024)	20 male soccer players	Instep kick	Lumbo-pelvic, hip and knee sequencing	Target-directed accurate kicking; ball/foot velocity	Different approach angles altered sequencing while performance and accuracy could be maintained.

Zhang et al. (2026)	32 male college students	Instep kick	Inter-segmental coordination; EMG	Kicking accuracy; ball speed	Coordination training improved kicking accuracy and altered inter-segmental coordination.
Vieira et al. (2023)	15 U17 academy players	Target-directed kicking	3D lower-limb kinematics; foot velocity; recovery/cooling	Mean radial error; placement; ball speed	Examined whether rapid local cooling aided recovery of kicking kinematics and placement after repeated high-intensity running in the heat.
Zhang et al. (2025)	78 soccer players	Maximal instep kick	Support-leg ROM; angular velocity	Ball velocity; spin	Support-leg mechanics varied across competitive levels and leg preference; accuracy was not directly measured.
Zhou et al. (2025)	30 male players (15 elite, 15 amateur)	Instep kick	Interlimb coordination; CRP; foot velocity	Foot velocity; performance	Elite players showed different hip-knee and knee-ankle coordination patterns associated with foot velocity.
Augustus & Hudson (2021)	11 semi-professional footballers	Instep kick	Approach velocity; support-leg GRF; pelvis/kick-leg angular momentum	Fast/accurate kicking condition	Approach velocity influenced pelvis and kick-leg angular momentum conversion strategies.
Carstensen & Andersen (2026)	53 elite youth players, 14–18 years	Penalty-style/target-directed kicks	Kicking-performance assessment; reliability	Accuracy reliability; maximum ball speed	Examined test-retest reliability of kicking-performance assessments over a 2-day interval.

Evidence Classification

Ten studies assessed actual accuracy or place; three presented supporting evidence on conversion biomechanics; and one examined measurement reliability (Table 2; Figure 2). These categories represent each study's main contribution.

Table 2. Classification of studies according to their principal contribution

Evidence category	**Studies**
Direct accuracy evidence (n = 10)	Attaallah et al. (2021); Torreblanca-Martínez et al. (2020); Carstensen et al. (2026); Jihad et al. (2025); Vieira et al. (2022); Vieira et al. (2022); Vieira et al. (2023); Nugroho & Doewes (2023); Augustus et al. (2024); Zhang et al. (2026)
Supporting biomechanical evidence (n = 3)	Zhang et al. (2025); Zhou et al. (2025); Augustus & Hudson (2021)
Methodological evidence (n = 1)	Carstensen & Andersen (2026)

Figure 2. Evidence categories in the refined 14-study synthesis.

Kicking Techniques and Outcome Domains

Seven studies reported the instep kick, three reported task-oriented skills, two reported penalty kicks, and one each reported free kicks and inside-foot kicks. Two studies did not specify technique. Eleven studies examined accuracy or placement, nine considered velocity or performance, and nine verified coordination or kinematic issues, while three examined fatigue/recovery and neuromuscular/physiological factors. The categories given in Figures 3 and 4 do not exclude each other.

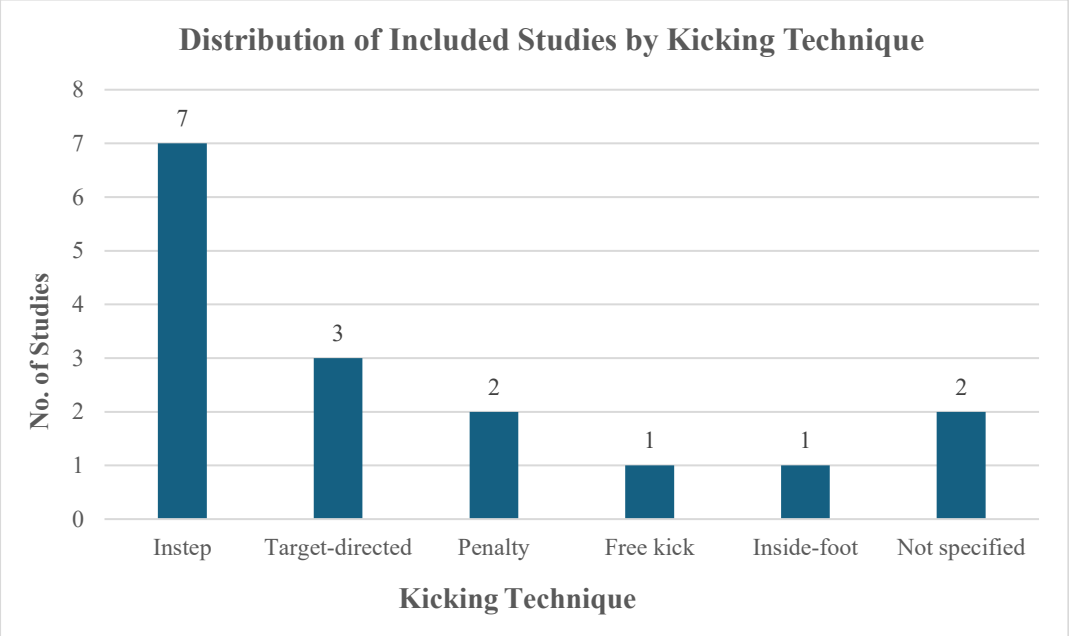


Figure 3. Kicking techniques represented in the refined evidence.

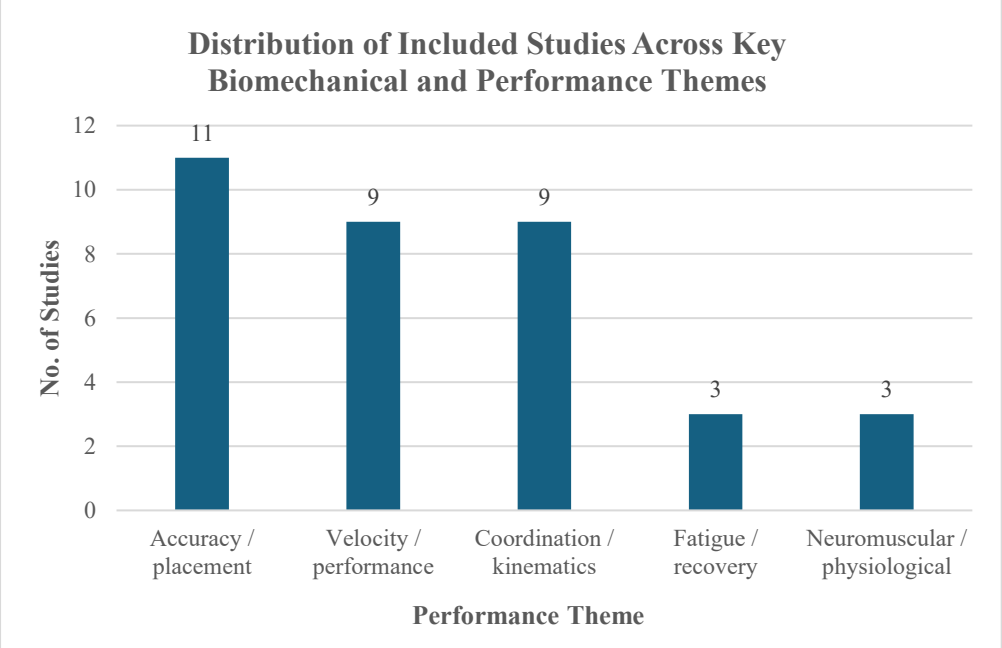


Figure 4. Major outcome domains represented in the refined evidence.

Lower-Limb Kinematics and Coordination

Two studies specifically examined coordination. Zhou et al., (2025) showed elite vs amateur differences in interlimb coordination related to foot speed, while L. Zhang et al., (2026) demonstrated increased accuracy and changes in coordination after training in novice college players. Other studies in the review have correlated

approach angle with lumbo-pelvic and lower-limb sequencing and compared swing and impact kinematics for shots made with the inside foot versus the instep (Augustus et al., 2024; Nugroho et al., 2023). These results present different types of evidence and should not be treated as the same proof of a mechanism related to accuracy.

Support-Leg Mechanics, Approach and Segmental Sequencing

Three studies addressed either action mechanics or support-leg mechanics. Support-leg kinematics differed across competition levels and leg preference, while approach speed affected the conversion of angular momentum between the pelvis and kicking leg (Augustus et al., 2021; Y. Zhang et al., 2025). Augustus et al., (2024) showed that changing the approach angle affects fragment sequencing but leaves accuracy and ball/foot action performance unchanged. Evidence linking support-leg parameters to accuracy remains insufficient.

Direct Accuracy Evidence

Ten studies examined the relationship between accuracy and some variable or placement variable. Five of these studies looked at physiological or biomechanical variables that relate to accuracy: Attaallah et al. (2021) looked at selected kinematic variables with respect to penalty accuracy; Nugroho et al. (2023) looked at the differences between instep and inside-foot shooting; Palucci Vieira, Carling, et al. (2022) built models that correlate EEG and kinematic variables of the kick with kick outcome. The other five studies focused on contextual and/or physiological variables: they studied fatigue (J. B. Carstensen et al., 2026; Torreblanca-Martínez et al., 2020) the effect of sleep and chronotype on accuracy (Lastella, et al., 2022) a player's recovery after high-intensity running in the heat. Vieira et al. (2023) studied the effect of muscle properties and balance on free-kick accuracy.

Fatigue, Neuromuscular Activity and Player Characteristics

Findings on fatigue varied depending on the outcome measured in each study. Repeated sprint fatigue reduced kicking speed without significantly affecting kicking accuracy in research on female players. Other studies dealt with local muscular fatigue and recovery after hard running (J. B. Carstensen et al., 2026; Palucci Vieira et al., 2023; Torreblanca-Martínez et al., 2020).

Studies on neuromuscular approaches suggest limited evidence. EEG and kinematics in Carling, et al. (2022) EMG with coordination training in L. Zhang et al. (2026) and muscle mechanical properties paired with dynamic balance in Jihad et al. (2025) addressed these factors; however, neither study identified a specific neural or muscular determinant of accuracy. Y. Zhang et al. (2025) and Zhou et al. (2025) considered competition level and leg preference. Many studies involved youth or academy players, and Torreblanca-Martínez et al. (2020) studied only female players. Lastella, et al. (2022) found that poor sleep quality and chronotype scores were negatively correlated with ball-placement outcomes. Nevertheless, information on player characteristics remains limited.

Methods Used to Measure Kicking Accuracy

The concept of accuracy was defined through radial or mean radial error, placement of the targeted object, specific accuracy measurements, free-kick executions, and how often such measurements are repeated (Table 3). Accurate definitions varied across references. Some definitions analyzed both velocity and accuracy, and still others only considered velocity without regard to accuracy.

Table 3. Accuracy and performance measurement approaches

Measure	Operational meaning	Examples

Radial error / mean radial error	Spatial distance from intended target	Attaallah et al. (2021); Vieira et al. (2022, 2022, 2023)
Height-to-width ratio (HWR)	Ratio of ball-placement height to width within the goal	Attaallah et al. (2021)
Target placement	Location of ball relative to intended target	Vieira et al. (2022, 2023)
Shooting/kicking accuracy test	Task-specific successful or accurate kick outcome	Torreblanca-Martínez et al. (2020); Nugroho & Doewes (2023)
Free-kick accuracy	Accuracy under free-kick task	Jihad et al. (2025)
Reliability of accuracy assessment	Consistency of repeated measurement	Carstensen & Andersen (2026)

DISCUSSION

The findings from 14 studies suggest that a multifactorial model better explains football kicking than a general model of accuracy. The synthesis includes 10 accuracy studies, including three biomechanical studies and one validity study. Of these studies, five discussed the relationship between biomechanical or neuromuscular variables and accuracy, so analysis of movement reasons should be cautious.

Coordination can be another important element of a skill. Foot velocity differed between professional and amateur groups. The interventions showed that coordination training improves accuracy.

The mechanics of the support leg and approach provide the foundation for the kicking process. The literature notes differences by sport and preference in support-leg properties and speed-dependent angular-momentum approaches, but knowledge of how these factors relate to accuracy remains limited (Augustus et al., 2021; Y. Zhang et al., 2025). It is therefore necessary to analyze these mechanics in conjunction with target error to predict accuracy.

Speed and precision are different aspects. A kick can be fast but still fail to reach its target. The earlier mentioned studies utilised different objective measures of space. Mentioning speed alone is not enough evidence to speak to accuracy. Instead, it would be better to use common criteria of space, such as radial error or target deviation (Attaallah et al., 2021; Carling, et al., 2022; Palucci Vieira et al., 2023; Lastella, et al., 2022)

Fatigue research reinforces the importance of distinguishing outcomes: repeated sprint fatigue decreased maximum speed without reducing accuracy (Torreblanca-Martínez et al., 2020). Differences in fatigue protocols and participant groups limit comparisons between studies (Carstensen et al., 2026; Kellis et al., 2006; Palucci Vieira et al., 2023).

Neurophysiological and muscular parameters are extensive but under-discussed in the literature. EEG, EMG, and muscle parameters appear in only a few studies, so no single parameter can be considered a precise marker in current research. Thus, combining these parameters with kinematics seems like a sound approach (Jihad et al., 2025; Carling, et al., 2022; L. Zhang et al., 2026).

The results align with earlier reviews that describe football kicks as an interaction of coordination, strength, and task constraints, not as the outcome of a single physical variable (Aedo-Muñoz et al., 2020; Lees et al., 2010). In theory, it is significant to analyze football contact, but only one review included comparisons of this type (Nugroho et al., 2023; Lake, et al., 2006).

Integrated Biomechanical Framework

The contained literature supports a conceptual, not a causal, sequence:

Approach→ body preparation→ support leg positioning→ trunk/pelvic organisation→ hip movement→ knee acceleration→ ankle/foot control→ foot-ball contact→ ball trajectory→ target accuracy.

The sequence combines these proximal-distal descriptions of kicking and also the movement components evidenced in the included works (Lees et al., 2010). Some of this evidence is rather shaky; some is supported by studies that did not directly measure accuracy (Table 4). Rather than assuming that the putative precedents of such movements are somehow verifiable, experimenters should test the hypothesised links or correlates.

Framework component	Included studies	Type of evidence
Approach	Augustus & Hudson (2021); Augustus et al. (2024)	Supporting; accuracy outcome in one study only
Support-leg positioning	Zhang et al. (2025)	Supporting only; accuracy not measured
Trunk/pelvic organisation	Augustus & Hudson (2021); Augustus et al. (2024)	Supporting; accuracy maintained across approach angles in one study
Hip-knee-ankle coordination and foot velocity	Zhou et al. (2025); Zhang et al. (2026)	Supporting (Zhou et al.); direct, training-based (Zhang et al.)
Football contact	Nugroho & Doewes (2023)	Limited; one study compared swing and impact kinematics between techniques
Ball trajectory and target accuracy	Attaallah et al. (2021); Vieira et al. (2022, 2022, 2023)	Direct accuracy measures (radial error, placement)

Table 4. Evidence supporting each component of the conceptual framework

CONCLUSION

This examination establishes that association-football kick accuracy is a complex, whole-body action. Among the 14 studies examined in this targeted systematic review, most (10) focused on measuring precision and placement; three others provided supporting biomechanical evidence for accuracy. The direct studies highlighted factors that influence accuracy, such as ball velocity, coordination, fatigue, sleep state, recovery, muscle characteristics, and balance.

Velocity must not be confused with accuracy: a change in the speed of the ball does not mean a change in accuracy. Biomechanical studies can provide context but not concrete evidence for any accuracy mechanism. Interpretation is further limited by small, heterogeneous samples; vague accuracy definitions; a one-database search; the absence of any quality assessment; and an incomplete description of the screening process. Thus, the suggested order should be used as a testing framework rather than a causal model.

For practice and future studies, biomechanics should be combined with direct measures of spatial accuracy to produce more meaningful data related to task conditions and player traits. Further studies should use larger samples and aim to establish which movement characteristics can be considered predictors or enhancers of accurate kicking.

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