# A Critical Review of the Technique Parameters and Sample Features of Maximal Kicking Velocity in Soccer

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# A Critical Review of the Technique Parameters and Sample Features of Maximal Kicking Velocity in Soccer

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## ABSTRACT

THE STUDY OF THE MAXIMAL KICK BALL VELOCITY (MKBV) IN SOCCER IS OF RELEVANCE FOR THE SCORE ACHIEVED IN A SOCCER MATCH. THIS REVIEW FOCUSES ON STUDIES THAT HAVE EXPLORED TECHNIQUE PARAMETERS AND INDIVIDUAL FEATURES THAT CAN CONTRIBUTE TO THE MKBV. THE EFFECTS OF AGE, GENDER, LIMB DOMINANCE, PRACTICE DURATION, COMPETITION LEVEL, PLAYING POSITION, AND VARIATIONS IN THE KICKING TECHNIQUE ARE DISCUSSED. WE PROVIDE METHODOLOGICAL SUGGESTIONS THAT MAY HELP IN THE COMPARISON OF RESULTS ACROSS DIFFERENT STUDIES AND THUS LEAD TO A BETTER UNDERSTANDING OF THE UNDERLYING FACTORS THAT CONTRIBUTE TO MAXIMAL KICKING VELOCITY. FOR A VIDEO ABSTRACT OF THIS ARTICLE, SEE SUPPLEMENTAL DIGITAL CONTENT 1 (http://links.lww.com/SCJ/A164).

## INTRODUCTION

Kicking is the most widely studied soccer skill (4,18,24,43,50) and is defined as the ability of a player to consciously hit the ball (16). Kicking is considered a fundamental skill for the soccer players' performance (7,35,47) because it is used in passes, crosses, and clearances. Moreover, kicking is a determining factor for scoring goals in a game (13,34,57). An analysis of the 2010 soccer world cup revealed that 80.69% of the goals were achieved by kicking (53).

From a biomechanical point of view, a kicking action can be described as a "throw-like" pattern in which the distal segments are allowed to lag behind the proximal segments as they move forward (19). In addition, kicking can also be described as a summation of forces (62), in which the foot is the last and fastest segment to intervene in the open kinetic chain (78). Therefore, the foot velocity at the initial instant of the impact correlates with the ball velocity (5,6,17,39,42).

The performance of soccer kicking depends on the kicked ball velocity and accuracy (40). Although accuracy is an important factor, the kicking performance in soccer has been evaluated predominantly by the maximum ball velocity (22,31,45). Therefore, assuming that the kick is accurate, the chance of scoring increases with an increased ball velocity as there is less time for the goalkeeper to react (45).

The role of the ball velocity in soccer has been investigated by several studies by identifying the factors that contribute to the maximal kicking velocity. These factors include the effect of age (7,44), gender (10,65), limb dominance (5,8–10,14,18,48,49,51,55,59,76), practice time (4,65), competition level (1,15), and playing position (27,37,67,72). Other studies have explored the relationship between the ball velocity and the different kicking techniques, such as the ability to strike a target (kicking accuracy) (7,29,30,38,41,71), the different contact surfaces of the foot with the ball (28,32,42,52,54,56), with or without

**KEY WORDS:**
kicking accuracy; maximal ball velocity; maximal kicking performance; protocols

a previous run-up (26,36,45,47,58,64), and after "faking" (cutting) a maneuver task (33).

The purpose of this review is to critically discuss the relevance of each of the factors mentioned above to the maximal kicking velocity in soccer, so that these could be interpreted by coaches and practitioners accordingly.

## METHODS

The following databases were used in this review: MEDLINE, Sport Discus, Dialnet, Google Scholar, and Scopus. The keywords used were combinations of "football," "soccer," "kick," "kicking," "speed," "maximal," "ball," "velocity," and "shot." Studies in English, Spanish, and Portuguese from 1979 to 2014 were included in this review with a focus on the maximal kicking velocity and one or more of the following factors: age, gender, limb dominances, practice time, competition level, playing position, and kicking technique. We analyzed more than 300 articles, of which 210 were studies about ball velocity, and 48 of which were included in this review.

## FACTORS RELATED WITH THE SAMPLE CHARACTERISTICS

*Age and gender.* Kicking ability, as a basic skill, has been shown to naturally develop from an early age (40). The ball velocity increases with age during the first stages of human development (7,12,44). Bloomfield et al. (12) suggest that the skill develops rapidly between the ages of 4 and 6 years and at the mean age of 11.2 years a mature kicking pattern is achieved by 80% of the children (12). The authors also suggest that this age is ideal for the evaluation of stable parameters for investigation. The ball velocity increments associated with age are likely not only due to skill development of the kicking pattern but also due to the increased body size and muscle strength associated with growth and maturation (60,62,74,75).

The youngest sample used in the study of the maximal kicking velocity in soccer included children from 10.3 ± 0.9 to 17.1 ± 2.3 years (44). In this study, the authors compared the maximal kicking velocity across ages and reported the highest maximal velocities for postadolescence and preadolescence. These results have been replicated by Bacvarevic et al. (7) for ages of 12.2 ± 0.3 to 15.3 ± 0.3 years. Bacvarevic et al. (7) also reported that the differences between children of 12 and 15 years old remain when the kick is performed with the nondominant limb and when subjects were instructed to kick with accuracy. The values of the above-mentioned studies are included in Table 1.

The studies comparing the maximal kicking soccer velocity between genders are scarce and have been conducted primarily in adults (10,23,65). These studies show that the maximal kicking velocity in females is significantly lower than males. These findings have been replicated in skilled and novice soccer players (65). However, the factors contributing to these gender differences remain inconclusive. Barfield et al. (10) have shown that females have the ability to kick with both the dominant and nondominant limbs with similar kinematic profiles of males. However, other studies attribute the lower maximal velocity in females to the use of different techniques in comparison with males (23,65). Thus, after a powerful kick, males follow through with a jump to dissipate residual leg momentum, whereas females avoid this airborne phase and, instead, counteract the momentum with an upper-body flexion (65). In addition, male players use absolute explosive muscle work patterns (higher maximum and faster increase rate of muscle tension) and effective deceleration of the more proximal joints (hip and knee) to a greater extent than skilled female players (23,65).

In the following review for the sake of fluency, the gender will be discussed explicitly only when the studies include female subjects.

*Practice time accumulation and competition level.* Table 2 summarizes the maximal kicking velocity values for players with different practice time accumulation, competition level, and playing position. Practice time accumulation is clearly a factor that affects maximal kicking velocity (4,65), likely because of the influence of experience. This experience provides the player with a greater capacity to adjust to different forms of neuromuscular coordination (65). Thus, it is supported by findings showing that expert players can kick further than inexperienced players (18). Additionally, expert male and female soccer players reached higher ball velocity values compared with novice players (65). Similar results have been obtained comparing trained and untrained players (4) and elite versus nonelite university soccer players (1) (Table 2). However, the ball velocity values did not show significant differences between different groups of professional elite players (15). Nevertheless, a comparison between these studies is difficult because there is no clear definition for the amount of training and experience of the elite and novice players.

*Different play positions in soccer: Goalkeepers, defenders, midfielders, and strikers.* Several studies (Table 2) have shown that the ball velocity values did not differ across various soccer player positions, nor between the dominant (27,67,72) and nondominant legs (27,67). However, 1 study demonstrated higher ball velocities by midfielders and strikers compared with defenders (37).

*Limb dominance.* Table 3 summarizes the maximal kicking velocity values for dominant and nondominant leg performance. There is an agreement across studies that ball velocity is significantly faster after a kick with the dominant leg compared with the nondominant one. This is true for expert soccer players (9,10,18), amateurs (48,49,51,55,59,76), young subjects (8), both genders (10,14), for kicks with or without accuracy demand (7), and for different techniques and kick conditions (46,48). The

**Table 1**
**Maximal kicking velocity values for different ages and gender**

| Research | Subject characteristics | | | | Kick | Approach steps/angle | RI | VB ($m \cdot s^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| | n | Age | Player level | Gender | | | | |
| Age | | | | | | | | |
| Luhtanen (44) | 29 | | Amateur | M | Instep | 2/free | 1C | [a] |
| | 8 | 10.3 ± 0.9 | | | | | | 14.9 ± 1.7 |
| | 8 | 14.4 ± 1.1 | | | | | | 18.4 ± 1.7 |
| | 13 | 17.1 ± 2.3 | | | | | | 22.2 ± 3.0 |
| Bacvarevic et al. (7) | 106 | 11.514.5 | High level | M | Instep | Free | R | |
| | 27 | 12.2 ± 0.3 | | | Maximum | | | 22.7 ± 2.5[b] |
| | 26 | 13.1 ± 0.2 | | | Maximum | | | 24.8 ± 2.1[b] |
| | 26 | 14.3 ± 0.3 | | | Maximum | | | 27.1 ± 2.8[b] |
| | 27 | 15.3 ± 0.3 | | | Maximum | | | 28.7 ± 2.3[b] |
| Gender | | | | | | | | |
| Barfield et al. (10) | 8 | 19–22 | Elite | | Instep | 2/30–45° | 2C | [a] |
| | 2 | | | M | | | | 25.3 ± 1.51 |
| | 6 | | | F | | | | 21.5 ± 2.44 |
| Shan (65) | 44 | 21.7 ± 2.2 | College students | | Instep | Free | 3D | [b] |
| | | | Skilled | M | | | | 24.2 ± 3.1 |
| | | | Skilled | F | | | | 19.6 ± 2.6 |
| | | | Novice | M | | | | 16.9 ± 2.7 |
| | | | Novice | F | | | | 13.2 ± 2.3 |

3D = motion capture system; C = video camera; F = female; M = male; n = sample size; R = radar; RI = register instrument; VB = kicking ball velocity.

[a] $P < 0.001$.

[b] $P < 0.05$.

consistent ball velocity differences between the 2 limbs are likely due to a more efficient intersegmental motion pattern and transfer of velocity from the foot to the ball when kicking with the preferred leg (18). Furthermore, faster leg swing observed for the preferred leg was most likely the result of a larger muscle momentum (55). In addition, these differences depend on the skill level of the players so that the higher the skill level, the better the coordination of both limbs (55). For a young soccer player, performance with the dominant leg is characterized by a faster and more accurate "powerful-kick" in comparison with the nondominant leg (48). However, during a "chip kick," the velocity and accuracy do not show this trend (48). The chip kick places more emphasis on skill and could thus account for the similar performance observed for both legs (48). Furthermore, the playing position did affect the performance of the dominant versus the nondominant leg (67).

The use of the dominant leg, compared with the nondominant one, during a soccer game occurs about 90% of the time in controls, passes, and crosses of the ball (57). However, this percentage decreases to 70%, for kicks aimed at the goal, probably due to time limitation, the proximity of rival players, and the stress that players are subjected to (57). This could explain why

**Table 2**
**Maximal kicking velocity values for players with different practice time accumulation, competition level, and playing position**

| Research | Subject characteristics | | | | Kick | Approach steps/angle | RI | VB $(m \cdot s^{-1})$ |
|---|---|---|---|---|---|---|---|---|
| | n | Age | Player level | Gender | | | | |
| Practice time accumulation | | | | | | | | |
| Anthrakidis et al. (4) | 24 | 21.4 ± 0.7 | Amateur | M | Instep | Free | R | [a] |
| | | | Trained | | | | | 29.45 ± 1.86 |
| | | | Untrained | | | | | 23.86 ± 1.81 |
| Shan (65) | 44 | 21.7 ± 2.2 | College students | | Instep | Free | 3D | [b] |
| | | | Skilled | M | | | | 24.2 ± 3.1 |
| | | | Skilled | F | | | | 19.6 ± 2.6 |
| | | | Novice | M | | | | 16.9 ± 2.7 |
| | | | Novice | F | | | | 13.2 ± 2.3 |
| Competition level | | | | | | | | |
| Cometti et al. (15) | 95 | | Elite/amateur | M | Free | Free | R | |
| | 29 | 26.1 ± 4.3 | 1° France division | | | | | 29.55 ± 3.58 |
| | 34 | 23.2 ± 5.6 | 2° France division | | | | | 29.54 ± 2.09 |
| | 32 | 25.8 ± 3.9 | Amateur (regional) | | | | | 29.94 ± 1.59 |
| Ali et al. (1) | 48 | 20.02 ± 1.5 | University | M | Free | | R | **** |
| | 24 | | 1–2 division | | | | | 22.22 ± 1.25 |
| | 24 | | 3–4 division | | | | | 20.55 ± 1.67 |
| Playing position | | | | | | | | |
| Taïana et al. (72) | 15 | 18.1 ± 0.3 | Experts | M | Instep | Free | P | [c] |
| | | | Defenders | | | | | 27.95 ± 1.15 |
| | | | Midfielders | | | | | 27.14 ± 1.80 |
| | | | Strikers | | | | | 28.19 ± 1.46 |
| Sousa et al. (67) | 31 | 16.5 ± 0.6 | Young elite | M | Free | 90° | R | 27.3 ± 1.4 |
| | 4 | | Goalkeepers | | | | | 27.1 ± 1.3 |
| | 9 | | Defenders | | | | | 26.9 ± 1.8 |
| | 13 | | Midfielders | | | | | 27.4 ± 1.4 |
| | 5 | | Strikers | | | | | 27.5 ± 1.0 |
| Khorasani et al. (37) | 15 | 20.8 ± 0.77 | Elite | M | Free | 3 meters/90° | 4C | [b] |
| | | | Defenders | | | | | 22.19 ± 2.8 |
| | | | Midfielders | | | | | 30.14 ± 5.4 |
| | | | Strikers | | | | | 29.29 ± 1.6 |

(continued)

| Table 2 (continued) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Izquierdo et al. (27) | 40 | 18.02 ± 0.54 | Young elite | M | Instep | 2/free | R | [c] |
| | 4 | | Goalkeepers | | | | | 28 ± 1.40 |
| | 12 | | Defenders | | | | | 27.86 ± 1.35 |
| | 12 | | Midfielders | | | | | 28.11 ± 1.54 |
| | 12 | | Strikers | | | | | 28.14 ± 0.33 |
| 3D = motion capture system; C = video camera; F = female; M = male; n = sample size; P = photocell; R = radar; RI = register instrument; VB = kicking ball velocity. | | | | | | | | |
| [a]$P < 0.001$. | | | | | | | | |
| [b]$P < 0.05$. | | | | | | | | |
| [c]Nonsignificant. | | | | | | | | |

the nondominant leg is most frequently used when the player kicks the ball toward the goal in comparison with other situations (57).

Taking into account all the findings from the above-mentioned studies, it seems that the expertise of the soccer player and the difficulty of the task are the main factors that affect the symmetric or asymmetric performance of the legs.

### FACTORS RELATED WITH THE TECHNIQUE CHARACTERISTICS

*Accuracy.* Table 4 summarizes the maximal kicking velocity values for kicks under accuracy demands. Kicking accuracy is an important factor of success in soccer, and it can be defined as the ability to kick the ball at a specified area (20,61). However, this factor has been relatively understudied compared with maximal kicking in soccer (34). Nevertheless, several studies have evaluated the relationship between different kinematic parameters and the accuracy of a soccer kick (29,30,41,73), using both lower limbs (48), and across different kicking techniques (38,48,71).

There is no standard procedure for the evaluation of accuracy of a soccer kick. Thus, accuracy can be defined as the number of goals scored per game, the number of shots toward a goal per game, the ability to strike a target (number of points and the time needed for execution), the ability to kick the ball between 2 markers, or the subjective assessment of independent referees (7). In addition, there have been several attempts to validate kick test protocols to obtain a reliable kicking accuracy measurement (1,7,20,45,63,77). However, to date, none of these protocols has been used extensively. The validation of a protocol to measure kicking accuracy is relevant, especially when the variability of accurate soccer kicks is higher than those of powerful kicks (71), probably because of different muscle activation patterns (31). It is likely that the complex requirements involved in the performance of an accurate kick complicate the development of a feasible, reliable, and operative test to measure the kick accuracy. For instance, although the assessment of the kicking velocity of a stationary ball requires few trials (1,2), the simultaneous evaluation of both the accuracy and kicking may require a significantly higher number (7,11–41). Thus, the accuracy test loses its validity because it does not replicate a real game situation in which there is a dynamic change of the context.

Nevertheless, maximal ball velocities for kicks under accuracy demands are significantly lower in comparison with kicks that are performed without accuracy requirements (2,30,41,73). Furthermore, other studies suggest that the soccer players with highest maximal kicking velocity are also the fastest under accuracy demands (29,30).

*Contact surfaces at the moment of impact.* Table 5 summarizes the kicking velocity values for different kicking surfaces. There are several kicking techniques that can be used to cope with the demands of specific game situations (69). Bisanz and Gerisch (11) distinguished between the side-foot kick and 3 variations of the instep kick: the inner instep kick, the outer instep kick, and the full instep kick (68). Whereas the side-foot kick is predominantly used for highly accurate and relatively slow passes or for goal shots over short distances, the instep kicking techniques are mainly used for faster passes and for goal shots from longer distances (69). Furthermore, the inner and outer instep kicks aim to rotate the ball to tradeoff velocity (52).

Findings show that the instep and inner instep kicks are faster compared with the side-foot kicks (32,42,54,71). However, these differences were absent in female soccer players (28). Among the 3 types of instep kicks, the

**Table 3**
**Maximal kicking velocity values for dominant and nondominant legs**

| Research | Subject characteristics | | | | Kick | Approach steps/angle | RI | VB ($m \cdot s^{-1}$), dominant | VB ($m \cdot s^{-1}$), nondominant |
|---|---|---|---|---|---|---|---|---|---|
| | n | Age | Player level | Gender | | | | | |
| Narici et al. (51) | 11 | 25.1 ± 5.0 | Amateur | M | | | ARS | 20.0 ± 3.6[a] | 17.7 ± 2.2[a] |
| McLean and Tumilty (48) | 20 | 16.8 ± 0.7 | Elite junior | M | Drive kick | | R | 21.95 ± 1.67[b] | 18.34 ± 1.39[b] |
| | | | | | Chip kick | | | 18.34 ± 2.22 | 17.78 ± 1.39 |
| Mognoni et al. (49) | 24 | NA | Junior | M | | | | 23.6 ± 2.5 | 21.4 ± 2.6 |
| Barfield (9) | 18 | NA | Expert | M | | | R | 26.4 ± 2.1 | 24.3 ± 2.0 |
| Patritti et al. (59) | 10 | 25.2 | Amateur | M | | 2/free | R | 23.05 ± 1.23 | 21.10 ± 1.30 |
| Dörge et al. (19) | 30 | | Skilled | M | | 3 meters/90° | R | 24.7 ± 2.5[b] | 21.5 ± 2.0[b] |
| Barfield et al. (10) | 8 | 19–22 | Elite | | Instep | 2/45–30° | 2C | [a] | [a] |
| | 2 | | | M | | | | 25.3 ± 1.51[a] | 23.6 ± 1.57[a] |
| | 6 | | | F | | | | 21.5 ± 2.44[a] | 18.9 ± 2.05[a] |
| Vaverka et al. (76) | 12 | 15.7 ± 0.4 | Skilled | M | | | 3D | 27.68 ± 1.32 | 23.49 ± 2.05 |
| Nunome (55) | 5 | 16.8 ± 0.4 | Skilled | M | Instep | Free | 3C | 32.1 ± 1.7[b] | 27.1 ± 1.2[b] |
| Barbieri et al. (8) | 19 | 13.6 ± 0.5 | Indoor players | M | Instep | Free | 4C | 18.2 ± 1.8[a] | 14.7 ± 2.8[a] |
| Sedano et al. (14) | 10 | 22.8 ± 2.1 | Elite female | F | Pretrained | 2/free | R | 19.45 ± 0.7[b] | 16.25 ± 0.45[b] |
| | | | | | Posttrained | | | 21.75 ± 0.58[b] | 18.39 ± 0.64[b] |
| Bacvarevic et al. (7) | 106 | 11.514.5 | Elite young | M | Instep | Free | R | | |
| | 27 | 12.2 ± 0.3 | | | Maximal | | | 22.7 ± 2.5[b] | 19.7 ± 2.3[b] |
| | 26 | 13.1 ± 0.2 | | | Maximal | | | 24.8 ± 2.1[b] | 20.3 ± 2.7[b] |
| | 26 | 14.3 ± 0.3 | | | Maximal | | | 27.1 ± 2.8[b] | 23.1 ± 2.9[b] |
| | 27 | 15.3 ± 0.3 | | | Maximal | | | 28.7 ± 2.3[b] | 24.5 ± 3.1[b] |
| | 27 | 12.2 ± 0.3 | | | Accuracy | | | 16.3 ± 1.7[b] | 15.2 ± 1.4[b] |
| | 26 | 13.1 ± 0.2 | | | Accuracy | | | 16.8 ± 1.5[b] | 15.8 ± 1.2[b] |
| | 26 | 14.3 ± 0.3 | | | Accuracy | | | 18.0 ± 2.7[b] | 16.5 ± 1.7[b] |
| | 27 | 15.3 ± 0.3 | | | Accuracy | | | 18.4 ± 2.5[b] | 16.9 ± 1.6[b] |

3D = motion capture system; ARS = audio recording system; C = video camera; F = female; M = male; n = sample size; NA = no available data; R = radar; RI = register instrument; VB = kicking ball velocity.

[a] $P < 0.001$.

[b] $P < 0.05$.

full instep kick resulted in significantly higher ball velocities followed by the inner and outer instep kicks (52,69,71). In contrast, the side-foot kick was the most accurate technique compared with the inner instep and the full instep kick (71). Furthermore, inner swerve instep kicks were faster compared with outstep swerve kicks

**Table 4**
**Maximal kicking velocity values for kicks under accuracy demands**

| Research | Subject characteristics | | | | Kick | Approach steps/trials | RI | VB ($m \cdot s^{-1}$), maximal kick | VB ($m \cdot s^{-1}$), accuracy kick |
|---|---|---|---|---|---|---|---|---|---|
| | n | Age | Player level | Gender | | | | | |
| Lees and Nolan (41) | 2 | — | Professional | M | Instep | 5–5 | 2C | | |
| | | | Subject 1 | | | | | 26.6 ± 1.51[a] | 20.4 ± 0.77[a] |
| | | | Subject 2 | | | | | 24.3 ± 1.52[a] | 18.1 ± 0.77[a] |
| Kristensen et al. (38) | 11 | 18–28 | Subelite | M | Instep | 3–10 | P | 23.38 ± 1.45[a] | 21.11 ± 1.69[a] |
| | | | | | Punt | 3–10 | | 22.99 ± 1.16[a] | 21.13 ± 1.20[a] |
| Juárez and Navarro (29) | 10 | 24.7 ± 3.0 | Elite indoor | M | Free | 3–3 | ARS | 27.24 ± 1.60[a] | 25.78 ± 1.42[a] |
| Sterzing et al. (71) | 19 | 23.7 ± 3.4 | Amateur | M | Full instep | 6–6 | R | 28.65 ± 1.80[a] | 24.38 ± 3.10[a] |
| | | | | | Inner instep | | | 27.99 ± 1.92[a] | 23.05 ± 4.02[a] |
| | | | | | Side foot | | | 21.50 ± 3.13[a] | 24.94 ± 1.57[a] |
| Juárez and Navarro (30) | 108 | 22.17 ± 3.6 | Amateur | M | Free | 3 | P | 28.35 ± 1.79[a] | 27.00 ± 1.96[a] |
| Bacvarevic et al. (7) | 106 | 11.514.5 | Elite young | M | Instep | Free | R | | |
| | 27 | 12.2 ± 0.3 | | | Maximal | | | 22.7 ± 2.5[b] | 16.3 ± 1.7[b] |
| | 26 | 13.1 ± 0.2 | | | Maximal | | | 24.8 ± 2.1[b] | 16.8 ± 1.5[b] |
| | 26 | 14.3 ± 0.3 | | | Maximal | | | 27.1 ± 2.8[b] | 18.0 ± 2.7[b] |
| | 27 | 15.3 ± 0.3 | | | Maximal | | | 28.7 ± 2.3[b] | 18.4 ± 2.5[b] |
| | 27 | 12.2 ± 0.3 | | | Accuracy | | | 19.7 ± 2.3[b] | 15.2 ± 1.4[b] |
| | 26 | 13.1 ± 0.2 | | | Accuracy | | | 20.3 ± 2.7[b] | 15.8 ± 1.2[b] |
| | 26 | 14.3 ± 0.3 | | | Accuracy | | | 23.1 ± 2.9[b] | 16.5 ± 1.7[b] |
| | 27 | 15.3 ± 0.3 | | | Accuracy | | | 24.5 ± 3.1[b] | 16.9 ± 1.6[b] |

ARS = audio recording system; C = video camera; M = male; n = sample size; P = photocell; R = radar; RI = register instrument; VB = kicking ball velocity.

[a] $P < 0.01$.

[b] $P < 0.05$.

(52,71), and barefoot kicks were faster compared with footwear kicks (70).

Finally, one study compared the kicking velocity and accuracy of the instep to the punt kick (the less frequently used toe kick), showing that the toe kick is less precise compared with the instep kick at 90% of maximum kicking velocity (38). However, the toe kick is faster than the instep kick when a player is restricted to a short execution time (3,66).

*Effects of the approach angle, and other variations.* Table 6 summarizes the ball velocity values for different approach angles and kicking techniques. The maximal kicking velocity for a stationary ball in comparison with a ball that is approaching the player at a speed of 2.2 m/s tends to be lower for the former condition (74). However, the maximal velocity of a drop kick (kicking the ball in a descending vertical movement) is higher than that of a stationary ball (45). The reason for this discrepancy is unlikely to be related to the speed of the ball because a ball that drops from approximately 1 meter could reach a velocity of 0.5 m/s,

**Table 5**
**Maximal kicking velocity values for kicks with different kicking surfaces**

| Research | Subject characteristics: n | Age | Player level | Gender | Kick | Approach steps/angle | RI | VB ($m \cdot s^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Levanon and Dapena (42) | 6 | Intercollegiate | Experts | M | Side foot | | 2C | 22.5 ± 1.8[a] |
| | | | | | Full instep | | | 28.6 ± 2.2[a] |
| Jónsdóttir and Finch (28) | 11 | | Amateur | F | | 2 steps | 1C | [b] |
| | | | | | Inner instep | | | 14.6 ± 2.4 |
| | | | | | Side instep | | | 14.4 ± 2.8 |
| Nunome et al. (54) | 5 | High school | Experts | M | Side | | 2C | 24.3 ± 1.7[c] |
| | | | | | Full instep | | | 28.0 ± 2.1[c] |
| Kristensen et al. (38) | 11 | 18–28 | Subelite | M | Punt | | P | 22.99 ± 1.16[c] |
| | | | | | Instep | | | 23.38 ± 1.45[c] |
| Neilson and Jones (51) | 25 | 19.68 ± 2.17 | Professionals | M | Instep | Free | 1C | 27.05 ± 2.23[a] |
| | | | | | Inner instep swerve | | | 23.52 ± 2.31[a] |
| | | | | | Side instep swerve | | | 20.85 ± 3.08[a] |
| Sterzing et al. (71) | 19 | 23.7 ± 3.4 | Amateur | M | Full instep | Free | R | 28.65 ± 1.80[c] |
| | | | | | Inner instep | | | 27.99 ± 1.92[c] |
| | | | | | Side foot | | | 21.50 ± 3.13[c] |
| Katis and Kellis (32) | 10 | 13.6 ± 0.7 | Amateur | M | Full instep | 2 steps/45° | 6C | 19.62 ± 1.89[a] |
| | | | | | Side instep | 2 steps/45° | | 18.10 ± 1.49[a] |

C = video camera; F = female; M = male; n = sample size; P = photocell; R = radar; RI = register instrument; VB = kicking ball velocity.

[a] $P < 0.05$.

[b] Nonsignificant.

[c] $P < 0.01$.

which is far from the 2.2 m/s used in the study by Tol et al. (74). Therefore, it is plausible that the vertical drop of the ball allows the player to use a more efficient foot contact with the surface of the ball and thus to achieve a higher maximal kicking velocity.

Kicking a ball during running also results in higher ball velocity values compared with a nonrunning approach (45,58) (Table 6). Soccer players often prefer 2 or 3 steps before the main kicking action (34). The difference in velocity between the one-step and multistep approach remains unclear (34), possibly because of higher coordinative demands associated with the long distance approach. Finally, one study indicated that performing instep kicks after a double-cutting maneuver reduces the ball velocity (33).

The analysis of the approach angles in the kicking velocity demonstrated that soccer players tend to choose a kicking angle between 30 and 60° and that the maximum ball velocity is achieved with an angle of 45° (26). Similar results have been reported for maximal and accurate kicks (36,47). However, when the player is asked to perform a "faking" (cutting) maneuver before the kick, there is a reduction in the maximal kicking velocity.

## DISCUSSION

The main goal of the current review is to explore several issues related with maximal kicking velocity in soccer. Specifically, this review focuses on

**Table 6**
**Ball velocity as reported in the literature by research that used different kicking techniques**

| Research | Subject characteristics | | | | Kick | Approach steps/angle | RI | VB ($m \cdot s^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| | n | Age | Player level | Gender | | | | |
| Kick a stationary ball vs a dynamic ball | | | | | | | | |
| Tol et al. (74) | 15 | 27.4 ± 8.4 | Elite | M | Instep | Stationary | C | 24.3 ± 4.5[d] |
| | | | | | | Rolling | | 24.9 ± 4.9 |
| Markovic.et al. (45) | 77 | 20.1 ± 1.1 | Universities | M | Instep | 0 step/0° | | 19.5 ± 1.9[a] |
| | | | | | Drop kick | 1 step | | 25 ± 2.2 |
| With and without previous run-up | | | | | | | | |
| Opavsky (58) | 6 | — | — | M | Instep | 0 step | C | 23.48[a] |
| | | | | | | 6-8 steps | | 30.78 |
| Markovic et al. (45) | 77 | 20.1 ± 1.1 | Universities | M | Instep | Free | R | 26.5 ± 2.5[a] |
| | | | | | Instep | 0 step/0° | | 19.5 ± 1.9 |
| | | | | | Drop kick | 1 step | | 25 ± 2.2 |
| Different previous run-up approach angles | | | | | | | | |
| Isokawa and Lees (26) | 6 | 20–36 | Amateur | M | Instep | 1 step/0° | C | 18.73 ± 0.95[d] |
| | | | | | | 1 step/15° | | 19.12 ± 1.23 |
| | | | | | | 1 step/30° | | 19.87 ± 1.14 |
| | | | | | | 1 step/45° | | 20.14 ± 1.58 |
| | | | | | | 1 step/60° | | 19.46 ± 1.59 |
| | | | | | | 1 step/90° | | 19.13 ± 1.64 |
| Kellis (36) | 10 | 21.3 ± 1.4 | Trained | M | Instep | 1 paso/0° | 2C | 19.79 ± 1.49[d] |
| | | | | | | 1 paso/45° | | 20.41 ± 2.44 |
| | | | | | | 1 paso/90° | | 18.51 ± 3.09 |
| Masuda et al. (47) | 14 | 20.6 ± 1.0 | Amateur | M | Instep | Free | R | 27.7 |
| | | | | | | 90° | | 25.0 |
| | | 0 | | | | 135.2° | | 22.2 |
| Scurr and Hall (64) | 19 | 26 ± 3 | Amateur | M | Instep | Free/free | 2C | 25.15 ± 07[d] |
| | | | | | | Free/30° | | 24.23 ± 2.30 |
| | | | | | | Free/45° | | 24.47 ± 2.12 |
| After a "faking" (cutting) maneuver task | | | | | | | | |
| Katis and Kellis (33) | 10 | 13.6 ± 0.7 | Amateur | M | Instep | | 6C | |
| | | | | | | 2 steps/0° | | 19.44 ± 1.78[a] |
| | | | | | | 3 steps | | 17.06 ± 1.46[a] |

**Table 6**
**(continued)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Different techniques | | | | | | | | |
| Asami and Nolte (6) | 4 | | Professional | | Instep | | C | 29.90 ± 2.9 |
| Rodano and Tavana (62) | 10 | 17.5 ± 0.5 | Professional | | Instep | 2 pasos | 2C | 22.3–30 |
| Asai et al. (5) | 66 | — | Universities | | Swerve | — | | 25.44 ± 0.76 |
| Lees and Nolan (41) | 8 | 20.63 | Expert | | | Free | R | 24.5 ± 1.39 |
| Nunome et al. (56) | 9 | 27.6 ± 5.6 | Expert | | Instep | — | | 26.3 ± 3.4 |

C = video camera; F = female; M = male; n = Sample size; R = radar; RI = register instrument; VB = kicking ball velocity.

[a] $P < 0.05$.

[b] $P < 0.01$.

[c] $P < 0.001$.

[d] Nonsignificant.

studies that explore how the sample characteristics and kicking techniques affect the maximal kicking velocity. The methodological limitations of these studies are discussed and also how these may be addressed in future studies.

## FACTORS RELATED WITH THE SAMPLE CHARACTERISTICS

The studies exploring the contribution of age clearly indicate a positive relation between age and maximal kicking velocity (7,44). However, most of these studies are cross-sectional (i.e., 7,44) and do not specify the eligibility criteria or levels of physical activity in the studied children (i.e., 44). Thus, the factors contributing to the association between growing and the maximal kicking velocity are difficult to ascertain. This becomes even more complicated when the studies include children who play soccer because practice and growing effects may interact. Comparing children players with nonplayers of the same age may help to clarify the effect growing has on the increased kicking ball velocity, in addition to determining the role of systematic practice.

Another important issue related with age is the definition of the age itself. All the studies included in this review used the chronological age to categorize the children (7,44). Although, from a practical point of view, this is the easiest and most direct way to evaluate age, the role of the biological age may also be of importance. For example, small differences in the biological age could account for greater differences in the maximal kicking velocity. This point is even more relevant when comparing the maximal kicking velocity between children of different gender. So far, there are no studies that have described the maximal kicking velocity in girls. The studies comparing the maximal kicking velocity between genders have only been conducted in adults (10,65) and are motivated by an increase in the number of female soccer players in several countries (e.g., USA).

Therefore, longitudinal studies, studies with a better description of the sample, and studies comparing between genders should be conducted to understand the effect of age on maximal kicking velocity. In addition, a better understanding of the characteristics of the practices used for female soccer athletes may improve training and teaching, prevent injuries, and assist with rehabilitation techniques (10).

Practice time has also been a recurrent topic in the study of maximal kicking velocity. However, it is difficult to interpret the results because of the inaccuracy in the definition of terms such as "experts," "novices," "amateurs," "trained," "untrained," and "skilled" subjects (4,65). Reaching a consensus regarding the definition of these terms is of importance so that results from different research groups may be compared more reliably. When players are categorized according to the competition level (i.e., League One France), the features of the players are easier to define (15).

The studies that focus on the differences between the dominant and nondominant legs generally do not report information about the characteristics of the subjects (i.e., 48), such as hand-dominance, trunk turn dominance, or ocular-dominance. These measures can be easily evaluated using validated scales and may contribute to determining the effects of dominance across different corporal segments on the maximal kicking performance.

The playing position in soccer does not seem to play a role in the maximal kicking velocity because most of the studies did not report differences between the player's positions (67,72). However, these studied did not evaluate the performance of accurate kicks, and thus, it is possible that such differences exist between player's positions when accuracy is required.

## FACTORS RELATED WITH TECHNIQUE CHARACTERISTICS

Velocity and accuracy of a soccer kick are the main factors that contribute to a successful outcome. However, few studies explored the relationship between velocity and accuracy (34). According to the Fitts law (21), an inverse relationship exists between speed and accuracy, which can be determined by a logarithmic equation. Recently, the notion of speed-accuracy tradeoff has received renewed interest in several fields such as cognitive neuroscience (25). It could be of interest to apply this approach to soccer to reach a better understanding of the relationship between speed and accuracy of a soccer kick. For instance, the players can be instructed to perform several kicks toward a target at different percentages of their maximal speed and record in each speed and accuracy (i.e., distance to the target). This will provide information regarding the change in the relationship between speed and accuracy rather than the change in speed and accuracy separately. In turn, this may help to develop a more rational learning skill process in the soccer-training field.

Kicking with running approach showed faster ball velocities compared with static kicks (45,58). Furthermore, approach angles did not have an effect either on the ball velocity or on the kicking accuracy (26,36,64). However, protocols measuring soccer kick performance vary across studies with regard to the different variables that are evaluated such as the angle, distance, and/or the number of steps in the previous run-up (26,36). Most studies include a stationary-ball kicking procedure, and few studies also used a rolling ball procedure, either on the ground (46,74) or after a drop (45). The run-up in kicking testing procedures has, in some cases, been left to the free choice of the players (64), whereas in other studies, players were given instructions regarding the number of previous steps, the distance, and/or the approach angles. This disparity in protocols does not allow for reliable comparisons across different studies, and thus, a validated specific test to explore the effect of the approach to the ball is strongly recommended.

In summary, in this review, we have discussed studies that have evaluated the technical factors that affect maximal kicking velocity in soccer, and also effects of age and gender. Although the studies provide important information regarding the role of each parameter, several methodological issues must be addressed so that findings across studies may be compared reliably. A consensus between experts of this field should be established to standardize the protocols or tests that are used to measure the maximal kicking velocity. In addition, there are no unified criteria (often these are absent) to categorize the participants in the studies (i.e., "expert" versus "elite"). In summary, there are a wide range of technical aspects that are related to ball kicking in soccer and maximal kicking velocities. These aspects seem to interact with the participants' features (experience, age, and gender) and affect their ability to achieve the maximal kicking performance. Nevertheless, more studies are needed to clarify the nature of these interactions.

## PRACTICAL APPLICATIONS

The outcomes from the current review are of interest because these may help coaches to formulate better recommendations for the assessment and selection of soccer players and also monitoring the training of a player for a competition. This review provides useful information to help interpret maximal kicking velocity values and to determine which factors should be taken into account when comparing these values across players. Several practical applications of the current review are (a) to avoid evaluation of the maximal kicking velocity in players younger than 11 years because this measurement is not reliable and (b) comparing maximal kicking velocities with and without a running approach may be useful to determine the potential existence of coordination deficits. Thus, the maximal kicking velocity must be evaluated in such a way that minimizes external variables, to allow for an objective measurement of the skill of a soccer player and to identify the most talented players.


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