



CORRELATIONS BETWEEN BALL VELOCITY AND ACCURACY FOR DOMINANT AND NON-DOMINANT LEG KICK IN U19 FOOTBALL PLAYERS

POVEZANOST BRZINE LOPTE I PRECIZNOSTI UDARCA KOD DOMINANTNE I NEDOMINANTNE NOGE U19 NOGOMETAŠA

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ABSTRACT

Kicking performance is an important determinant of a player's success during a soccer match. It is often divided into ball velocity and kicking accuracy and it is performed with either dominant or non-dominant leg. Although both components are crucial, little evidence has been provided regarding their mutual relationship, according to leg dominance. Thus, the main purpose of the present study was to examine the correlations between ball velocity and kicking accuracy as well as their differences in relation to the dominant and non-dominant leg in elite U19 soccer.

We recruited 37 soccer players competing in the 1st Croatian Football League for players under 19 years of age (U19). Ball velocity and kicking accuracy were objectively evaluated using the 356 Soccer Shooting Test (356-SST) for dominant and non-dominant leg.

Ball velocity did not significantly differ between dominant and non-dominant leg, while kicking accuracy exhibited better results when using dominant leg ($p < 0.001$). In the total sample, the correlation between ball velocity and shooting accuracy was trivial and positive ($r = 0.09$, $p = 0.438$). However, even smaller and negative correlations between ball velocity and shooting accuracy for dominant ($r = -0.05$, $p = 0.763$) and non-dominant leg ($r = -0.01$, $p = 0.977$) were observed.

In summary, null correlations between ball velocity and kicking accuracy occur, irrespective of leg dominance. This will suggest that faster ball velocity does not necessarily

SAŽETAK

Izvedba udarca je važan čimbenik uspjeha igrača tijekom nogometne utakmice. Često se dijeli na komponentu brzine lopte i točnosti udarca koja se izvodi dominantnom ili nedominantnom nogom. Iako su obje komponente ključne, postoji mali broj dokaza o njihovom međusobnom odnosu, s obzirom na pucačku nogu. Stoga je glavni cilj ovog istraživanja bio utvrditi korelacije između brzine lopte i točnosti udarca kod U19 nogometaša, na temelju dominantne nasuprot nedominantne noge.

U istraživanje je bilo uključeno 37 nogometaša koji se natječu u 1. Hrvatskoj nogometnoj ligi. Brzina lopte i točnost udarca objektivno su ocijenjeni za najboljih 7 od 10 pokušaja korištenjem 356 Nogometnog testa šuta (356-SST) za dominantnu i nedominantnu nogu.

Brzina lopte se nije značajno razlikovala između dominantne i nedominantne noge (7.4 %), dok je preciznost udarca pokazala bolje rezultate korištenjem dominantne noge (11.4 %). U ukupnom uzorku korelacija između brzine lopte i točnosti udarca bila je trivijalna i pozitivna ($r = 0.09$, $p = 0.438$). Međutim, uočene su još manje i negativne korelacije između brzine lopte i točnosti udarca za dominantnu ($r = -0.05$, $p = 0.763$) i nedominantnu nogu ($r = -0.01$, $p = 0.977$).

U zaključku, javlja se nulta korelacija između brzine lopte i točnosti udarca, bez obzira na dominaciju noge. To će sugerirati kako veća brzina lopte ne znači nužno točniji

mean a more accurate kick in soccer players. Thus, the velocity-accuracy tradeoff in soccer needs further investigation.

Keywords: kicking performance, speed-accuracy tradeoff, leg dominance, team sports, soccer

udarac kod nogometaša. Stoga, odnos brzine lopte i točnosti udarca u nogometu se treba dodatno istražiti.

Ključne riječi: pucačka izvedba, odnos brzine-preciznosti, dominantnost noge, timski sportovi, nogomet

INTRODUCTION

Kicking performance represents one of the key factors for success in soccer (24). It is used for multiple purposes during the attacking and defensive actions, including covering as much distance as possible with the ball, trying to pass the ball to another teammate, or having the possibility of shooting at goal (3, 23). Since the main aim is to score more goals against the opposing team (14, 15), a player's kicking skills towards the goal are considered a key factor in the successful completion of the action and the outcome of the match (23). It is therefore not surprising that at the 2018 World Cup, around 80% of all goals were scored with a kick (5, 12), and the same trend has continued at the 2022 World Cup (6).

Evidence shows that the two most important outcomes of soccer kicking ability include ball velocity (9, 21) and kicking accuracy (1, 3, 17). By assuming the accurate kick, the ball velocity plays a significant role while kicking towards the goal, giving goalkeepers less time to react (7, 24). However, the inverse interplay between ball velocity and kicking accuracy has been a foundation in the area of motor control (8, 26). In general, such a tradeoff highlights that accuracy can be improved by a reduction in movement velocity, with limited evidence being observed in soccer (11, 22). For example, a study by Rakojević et al. (22) showed an inverse correlation between ball velocity and accuracy in a complex, multi-joint and discrete motor tasks, where a decrease in ball velocity resulted in an increase in kicking accuracy and consistency. Similar findings were observed in another study, where the correlation between ball velocity and kicking accuracy was trivial and inverse for the fastest kick ($r = -0.17$), while moderate and positive correlation between the lowest ball velocity and kicking accuracy was obtained ($r = 0.34$) (11). It has been suggested that the most accurate kicks are often achieved at ball velocities between 60% and 75% (1, 14, 15, 22, 29), and the error rapidly increases >85% of maximum ball velocity (28).

Research has shown that ball velocity (19, 20, 21, 27) and kicking accuracy (2, 21) are subject to different moving patterns when using dominant vs. non-dominant leg. As speculated, dominant legs often lead to faster ball velocity, due to the production of higher angular speed and swing during the kick, which exhibit the higher moment (7). Such motion differences between the dominant and non-dominant

legs are attributed to greater asymmetry and the frequency of usage in the soccer match (27). Although Carey et al. (4) reported that the dominant leg was used more frequently in the FIFA World Cup 1998, previous evidence suggests no differences in match-related outcomes among professional soccer players (16). However, Radman et al. (21) showed that kicking performance was significantly better for dominant, compared to non-dominant leg, especially for shooting accuracy and ball velocity in both amateur and semi-professional soccer players.

Despite the literature that faster movement causes greater inaccuracy (8), such findings are still being proven in soccer. Although a literature review indicates poorer kicking accuracy with greater ball velocity, only a few studies have examined the aforementioned correlations in soccer players (11, 22). Due to different methodology and sample size, the findings of these studies should be interpreted with caution. It is commonly expected that ball velocity and kicking accuracy are inversely related, yet trivial to small correlations between the two constructs have been reported (11, 22). However, the existing data have been predominantly collected from professional soccer players or older recreative people, while this topic is still unknown in soccer players who are under technical and tactical development. Moreover, it is still unknown to what extent the usage of dominant vs. non-dominant leg may differ the correlation between ball velocity and kicking accuracy. The necessity of investigating such correlations would help soccer players to determine which leg should be preferred during the kick, in order to adjust ball velocity and improve kicking accuracy. As the kicking patterns of the dominant leg are different from the non-dominant leg, we speculated that it would be reasonable to hypothesize that the ball velocity and accuracy of the kick would be also different between dominant and non-dominant leg.

Therefore, the main purpose of the study was to examine the correlations between ball velocity and kicking accuracy in U19 soccer players, specifically for dominant and non-dominant legs. Based on previous studies (11, 22), it was hypothesized that performing the kick with the dominant leg would lead to faster ball velocity, but impaired kicking accuracy, yielding an inverse correlation. On the other hand, the non-dominant leg would exhibit slower ball velocity with more accuracy, which might lead to positive correlation.

MATERIALS AND METHODS

Participants

The sample of subjects consisted of 37 healthy football players, of a football club competing in the 1st Croatian Football League for players under 19 years of age (U19). The sample size estimate was made using the G*Power program. With a statistical error value of 0.05; a statistical power value of 0.80; and an effect size of 0.06 (eta squared); the estimated required sample size was 36 respondents. The Ethics Committee of the University of Zagreb approved the study. All participants were informed about the potential risks of the study and written informed consent was obtained before entry into the study, in accordance with the Declaration of Helsinki.

Testing procedure

To assess the kicking performance of soccer players, we used the 356 - SST (21). The test has been designed to evaluate: i) ball velocity, ii) kicking accuracy, and iii) ball quality. More detailed information regarding the layout and description of the test can be found elsewhere (21). In brief, the test was performed in a way that the ball was stationary in the middle of the far side of a rectangle measuring 2x3 m. The near side, 3 m long, was 16.5 m away from the goal. The subject pushed the ball to the side with the first touch and from the rectangular space performed a shot with the inner part of the middle of the instep of the foot towards the opposite side of the goal (7.33x2.44 m), with their dominant foot. Each side of the goal net consisted of 30 squares measuring 48.8 x 48.8 cm. The distance of the square from the center of the goal was expressed in meters (m) and represented a measure of precision, with the farthest squares having the highest value (3.56 m).

The main task and instruction to the respondents was to hit the ball as quickly as possible while simultaneously achieving maximum precision (21). The same protocol was performed for non-dominant leg as well. A successful kick was defined by a minimal ball velocity of 64 km/h and kicking performance from a marked area (21).

The best 7 out of 10 shots according to the criterion of the distance from the center of the goal were considered and kicking accuracy was expressed as an average in meters

(m). The ball velocity was measured by a radar located behind the goal at a height of 1.1 m and it was expressed in kilometers per hour (km/h). The subjects' shots were recorded with 4 high-resolution and high-frequency cameras (GoPro Black Edition, USA) at a horizontal angle of 90 degrees to each other. The speed of the ball was measured with radar (Stalker, Applied Concept, USA). Of note, the radar has excellent reliability and validity properties and has been extensively used in soccer players to examine ball velocity (9, 21).

Data analysis

The data were analyzed using SPSS ver. 26 (Chicago, Illinois, USA). The Kolmogorov-Smirnov (K-S) test was used to examine the normality of the distribution. Since both ball velocity and kicking accuracy exhibited normal distribution, Pearson correlation of coefficients was then applied to examine the relationship between ball velocity and kicking accuracy, according to dominant and non-dominant leg. The size of a correlation coefficient was determined by the rule of thumb as follows: i) negligible (0.0 - 0.3), ii) low (0.3 - 0.5), iii) moderate (0.5 - 0.7), iv) high (0.7 - 0.9), and v) very high (0.9 - 1.0) (10). Leg-related differences in the aforementioned variables were examined using Student t-test for independent samples. The results were reported as means and standard deviations (SD) and the significance was set at $p < 0.05$ (two-sided).

RESULTS

Characteristics of kicking performance, i.e. ball velocity and kicking accuracy and leg-related differences are presented in table 1. Kicking with dominant leg yielded faster, but non-significant ball velocity, opposed to non-dominant leg (mean diff. = 6.8 km/h, 95% CI = 4.6 - 9.1 km/h, t - value = 6.06). However, kicking accuracy was significantly improved when using dominant vs. non-dominant leg (mean diff. = 0.23 m, 95% CI = -0.04 - 0.5 m, t - value = 1.74).

Table 2 shows the correlation coefficients between ball velocity and kicking accuracy for the total sample (74 legs) and according to dominant vs. non-dominant leg. In total sample, a trivial and positive correlation between ball velocity and kicking accuracy was shown. Similar patterns

Table 1. Characteristics of ball velocity and kicking accuracy, according to dominant and non-dominant leg
 Tablica 1. Karakteristike brzine lopte i preciznosti udarca, s obzirom na dominantnu i nedominantnu nogu

Study variables	Total sample	Dominant leg	Non-dominant leg	P - value
	Mean (SD)	Mean (SD)	Mean (SD)	
Ball velocity (km/h)	88.4 (6.4)	91.8 (4.9)	85.0 (5.8)	0.091
Kicking accuracy (m)	1.7 (0.6)	1.8 (0.5)	1.6 (0.6)	< 0.001

$P < 0.05$

Table 2. Coefficients of correlation between ball velocity and kicking accuracy, according to dominant and non-dominant leg
 Tablica 2. Koeficijenti korelacije između brzine lopte i preciznosti udarca, s obzirom na dominantnu i nedominantnu nogu

Leg dominance	Ball velocity (km/h)	
	<i>r</i> (95% CI)	<i>P</i> - value
Total sample		
Kicking accuracy (m)	0.09 (-0.12 - 0.32)	0.438
Dominant leg		
Kicking accuracy (m)	-0.05 (-0.31 - 0.22)	0.763
Non-dominant leg		
Kicking accuracy (m)	-0.01 (-0.28 - 0.26)	0.977

P < 0.05

were observed for dominant and non-dominant leg, where the correlations between ball velocity and kicking accuracy were trivial and negative.

DISCUSSION

The main purpose of the study was to examine the correlations between ball velocity and kicking accuracy for dominant and non-dominant leg in U19 elite soccer players. The findings show that only kicking accuracy is significantly better when using dominant vs. non-dominant leg, and the coefficients exhibit trivial and negative to positive correlation between ball velocity and kicking accuracy.

The data obtained of this study are somewhat comparable to previous findings conducted among soccer players (11, 22, 27). A study by Rakojević et al. (22) conducted among 13 soccer players with a mean age of 15 years old showed an inverse correlation between ball velocity and kicking accuracy in a complex, multi-joint motor task, such as kicking performance in soccer. Moreover, it was determined that the ball velocity between 61% and 74% of maximal ball velocity yielded the most accurate kicks, while a faster ball velocity decreased kicking accuracy (22). Similar findings were observed in a study by Izovska et al. (11), where the fastest ball velocity was only explained by 2.7% of kicking accuracy. On the other hand, when the soccer players were instructed to kick the ball with lower speed and greater accuracy, the correlation between them was significantly improved (*r* = 0.34), indicating that slower ball velocity led to better accuracy (11). A most recent study indicated moderate and negative correlation between ball velocity and kicking position in the short axis direction (*r* = -0.42) (27).

Based on the theory of velocity-accuracy tradeoff (8, 26), the mechanism of motor control includes a linear inverse interplay, which can be applicable to soccer. Slower ball velocity makes kicking accuracy more stable and consistent across multiple attempts, irrespective of leg dominance (27). This was supported by our findings, where we found no significant differences between the dominant and non-dominant leg when examining ball velocity. However, kicking accuracy seemed to be significantly

better for dominant, opposed to non-dominant leg. Such phenomenon is closely related to several aspects of motor control during kicking. First, kicking in soccer represents a complex decision-making process composed of various components (25). Leg preference is often attributed to genetic factors and higher senso-motoric functions that control lower extremity manipulation (with the ball in soccer), and stability (25). It has been observed that the center of pressure during the kick exhibits greater displacement and unstable pattern for non-dominant leg, which directly affects foot position on the ball and inaccuracy in hitting the target (27). Second, the nature of kicking performance is in its fast movement, which is not suitable for getting adequate biofeedback for limb regulation (13). It has been postulated that longer movement duration may be able to give enough time to gain motor control and to restore appropriate movement patterns during the performance (27). Since the duration of the kick from back- to forward swing can be as rapid as 400 ms (13), the players often rely on their individual motor control processes during kicking (27). However, similar correlations between dominant and non-dominant legs in terms of ball velocity and kicking accuracy may be attributed to equal movement patterns for both sides of the body. For the dominant side, the level of neuro-motor control is on a higher level, enabling a soccer player to kick the ball with greater velocity, but with poorer kicking accuracy, according to Fitt's law (8, 26). On the other hand, the non-dominant side of the body exhibits slower ball velocity, due to lower neuro-motor control, but possibly better kicking accuracy. These patterns of faster ball velocity and poorer shooting accuracy align to previous evidence of inverse correlation between these two constructs (8, 26). It seemed that the side of the body did not play a significant role in the direction and the effect of the correlation, since both sides yielded almost equal correlation coefficients. However, the outcomes of both ball velocity and kicking accuracy were better for dominant, opposed to non-dominant leg.

Previous evidence suggests that group level plays an important role in examining ball velocity and shooting accuracy in soccer (18, 21, 27). Both components were greater for semi-professional (21) and elite (18), compared to

amateur soccer players (27), irrespective of leg dominance. Specifically, more experienced soccer players tend to perform the kick with >60% and >10% of greater accuracy and ball velocity (21). This is particularly observed in this study, where the ball velocity performed by soccer players U19 was slightly lower (around 89 km/h). The discrepancy between the ball velocity in this study, opposed to previous evidence, may be explained by the group level (experienced vs. less experienced soccer players), the level of motivation, and data collection. For example, the nature of collecting the data was to choose 7 from the top 10 kicks, which might have led to a greater kicking variability. Within each group, the same group of authors showed that kicking accuracy and ball velocity were higher for dominant, opposed to non-dominant leg (21). Although this was not the topic of this study, we conducted an experiment among elite U19 soccer players, who generally exhibit no differences between kicking performance success rate between dominant and non-dominant leg (4, 16). This is in line with our findings, where ball velocity did not differ between the legs, yet the difference in kicking accuracy was significant, but the effect size was small ($r = 0.18$). This would imply that attaining a high level of ambidexterity and minimal asymmetry between the legs could be observed as a potential indicator of players' skill level (27). Also, the coefficients of correlation between ball velocity and kicking accuracy produced similar effects for dominant and non-dominant leg ($r = -0.05$ and -0.01), indicating that motor control for kicking performance was not influenced by leg dominance.

This study has a few limitations. By using a cross-sectional design, we cannot establish the causality of the correlation between ball velocity and kicking accuracy. However, the interplay between these two constructs is bidirectional, and according to Fitts's law (8, 26), slower movements lead to greater motor control and accuracy and *vice versa*. Although the 356 - SST has been a reliable and valid method to assess the level of ball velocity and kicking accuracy (21), measuring the instep kicking from the stationary position might have led to lower ecological validity. Nevertheless, kicking performance is a complex, multi-tasking process that needs to be evaluated, and thus be implemented within the soccer training. Finally, the players in our study were only men and free of fatigue when performing the test, which could have affected practical reliability of the 356 - SST (21). Thus, future research should focus on investigating ball velocity and kicking accuracy properties under different fatigue conditions, soccer skill levels (amateur, semi-professional, elite), and populations (men vs. women).

CONCLUSION

In summary, null correlation between ball velocity and kicking accuracy occurs, indicating that faster ball velocity results in poorer kicking accuracy in a velocity-accuracy tradeoff. Similar correlations are observed for both dominant and non-dominant leg. In addition, only trivial to small differences between dominant and non-dominant leg in ball velocity and kicking accuracy were obtained, showing that elite U19 soccer players perform equally well in kicking performance, irrespective of leg dominance.

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