Saša Bubanj*[1]
Ratko Stanković[1]
Saša Joksimović[1]
Radoslav Bubanj1
Stanimir Joksimović[1]
Goran Kozomara[1]
Pavlos Efthimiadis[2]

KINEMATICS OF ACCURATE INSIDE OF FOOT KICK

KINEMATIKA NATANČNE BRCE Z NOTRANJO STRANJO STOPALA

Abstract

The aims of this research were to quantify the range in values of examined kinematic variables and the existence of statistically significant differences in values of the kinematic variables in accurate attempts of soccer kicks inside the foot, subsequent to approach abreast, within an angle of 0 degree and angled approaches, within angles of 30 and 60 degrees. The sample of subjects consisted of 20 professional soccer players of F.C. 'Radnički' from Niš, Serbia. A high-speed camera operating at 300 Hz was used to record the inside-foot kicking technique, in a horizontal plane. One-way ANOVA showed significant differences in the values of all examined variables, with the exception of the linear velocity of the ball after the kick and the duration of foot-ball contact. There are certain ranges in the values of the examined variables within which the accuracy was achieved. Also, although the angle of attack of the swing foot significantly differed compared to angle of approach of soccer player (0, 30 and 60 degrees), subjects automatically set their swing foot in almost a similar position before the kick, and hit the target.

Key words: biomechanics analysis, soccer, angle of approach, differences

[1]Faculty of sport and physical education, University of Niš, Serbia

[2]1st E.P.A.L. High School, Kozani, Greece

**** Corresponding author:***
Faculty of Sport and Physical Education, University of Niš
St. Čarnojevića 10a
18000 Niš, Serbia
Phone: +381 1 8510900
Fax: +381 1 842482
E-mail: bubanjsasa@yahoo.co.uk

Izvleček

Cilj raziskave je bil izmeriti vrednosti preučevanih kinematičnih spremenljivk in ugotoviti, ali obstajajo statistično pomembne razlike v vrednostih omenjenih kinematičnih spremenljivk pri natančnih nogometnih brcah z notranjo stranjo stopala po približanju žogi pri kotu 0 stopinj ter pod kotoma 30 in 60 stopinj. V vzorcu preizkušancev je bilo 20 poklicnih nogometašev iz nogometnega kluba 'Radnički' iz Niša, Srbija. Za snemanje tehnike brcanja z notranjo stranjo stopala v vodoravni ravnini smo uporabili hitro kamero, ki je delovala s frekvenco 300 Hz. Enosmerna analiza variance je pokazala pomembne razlike v vrednostih vseh preučevanih spremenljivk, z izjemo linearne hitrosti žoge po brci in trajanja stika stopalo-žoga. V nekaterih razponih vrednosti preučevanih spremenljivk so bile dosežene natančne vrednosti. Poleg tega so preizkušanci, kljub temu da se je kot udarca noge pomembno razlikoval od kota približevanja nogometaša (0, 30 in 60 stopinj), svojo nogo pred brco samodejno nastavili v skoraj enak položaj in nato streljali.

Ključne besede: biomehanska analiza, nogomet, kot približevanja, razlike

INTRODUCTION

Previous studies in biomechanics that focused on accurate soccer kick indicated the possible influence of certain kinematic variables on the accuracy of target hit. These studies showed a decrease in the approach velocity of the soccer player, as well as linear and angular joint velocities and ball speed, compared with powerful kicks (Godik, Fales, & Blashak, 1993; Lees and Nolan, 1998; Teixeira, 1999). In regard to curve kicks, Asai and colleagues (Asai, Carre, Akatsuka, & Haake, 2002) indicated that the determinant factor in spinning a ball was the angle between the direction of impact surface of the kicking foot and the swing direction. In contrast, the ball would follow a nearly straight trajectory and gain the maximum possible velocity with minimal spin, if it is hit at the center (Asai et al., 2002; Carre, Asai, Akatsuka, & Haake, 2002). Concerning the point of impact on the foot, the results of study conducted by Ozaki and Aoki (2008) showed that the impact point in the in-front curve kick, in which a player kicks a ball by rubbing it up with toe, was located nearer to the toe, compared to the in-front curve kick, in which a player utilizes the angle of attack to spin the ball and in the inside kick. According to results of the research conducted by Shinkai et al. (Shinkai, Nunome, Ikegami, & Isokawa, 2008), in side-foot kicking, the foot contacted the ball slightly longer than in the instep kicking. The mentioned variables that affect the accuracy are also influenced by various factors, such as training level, i.e. professional vs amateur soccer players (Asami and Nolte, 1983; Commetti et al., 2001; Davids, Lees, & Burwitz, 2000; Lees and Nolan, 1998), gender (Barfield, Kirkendall, Yu, 2002), preferred leg (Dorge, Andersen, Sorensen, & Simonsen, 2002; Nunome et al., 2006) and muscle strength (Masuda et al., 2005; Ostojić, 2003; Reilly, 1996). Opavsky (1988) examined maximal ball speed, subject to type of approach. Values of ball speed were higher after running, compared to the stationary approach. However, results concerning the ball speed obtained during competition differ from those obtained in laboratory conditions (values were higher during competition, compared with the values reported in the literature, Ekblom (1994).

The aims of the research were to quantify the range in values of examined kinematic variables and the existence of statistically significant differences in values of the variables, in accurate attempts of inside of foot soccer kick, subsequent to approach abreast, within an angle of 0 degree and angled approaches at 30 and 60 degrees.

METHOD

Participants

The sample of subjects consisted of 20 professional soccer players of F.C 'Radnički', 14 right-footed, 6 left-footed (age: M = 20.3 years, SD = 4.45 years; height: M = 180.16 cm, SD = 6.44 cm; weight: M = 76.4 kg, SD = 7.32 kg), competing in the 2nd Serbian division. The study was conducted at the Faculty of Sport and Physical education of Niš, and in accordance with the ethical principles of the Helsinki Declaration, whereby each of the subjects agreed with a written consent to any procedures related to research.

Instruments and procedure

For the purposes of study, a special designed steel platform was constructed, on which were placed a wooden board (P = 3m^2) and glass plate (P = 1m^2) in the form of square. The glass plate

consisted of three layers (thickness of each layer was 10mm) mutually connected by plastic film, in order to increase plate strength. Glass and wood substrates were located at a height of 1m from the ground. A mirror in the form of a square (P = 1m^2), was placed below the glass plate at an angle of 45 degrees to the ground surface, with purpose of reflect the kicking technique of the subjects. At a distance of 2m from the mirror, in the projection of mirror's centre and y axis, a Casio Exilim Pro F1 high speed camera was placed and adjusted to record 300 frames per second. At 10m distance from the centre of the glass plate and at a height of 2 m from the ground, i.e. in the projection of x axis, on a ripstol, a circular target (0.3m in diameter) was fixed (Figure 1).

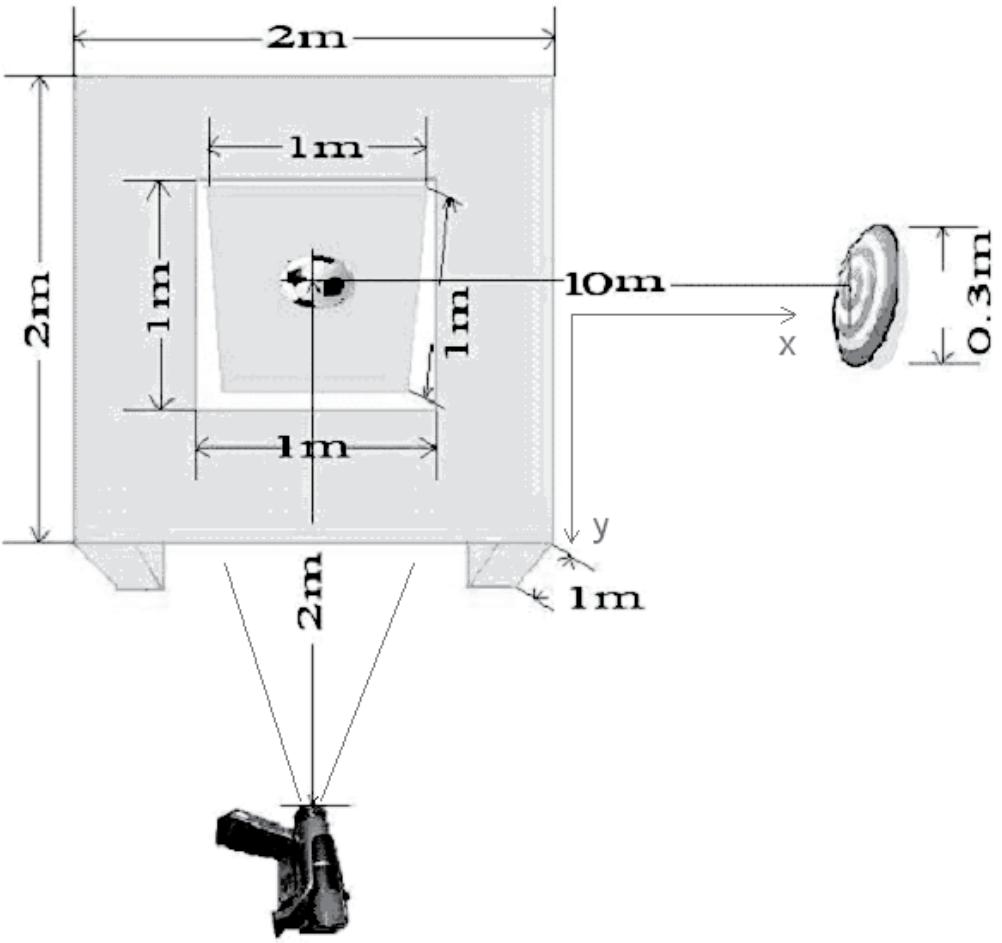

Figure 1. The view (from above) of polygon.

A mirror set at an angle of 45 degrees to the surface enabled the recording of kicking technique in the horizontal plane. The point of intersection of x and y axis, i.e. the centre of the glass plate, was condense, the initial position of the ball, prior to ball kick. The rubber soles of subjects' shoes were marked with coloured tape, which showed the extreme proximal and distal points of foot (Figure 2).

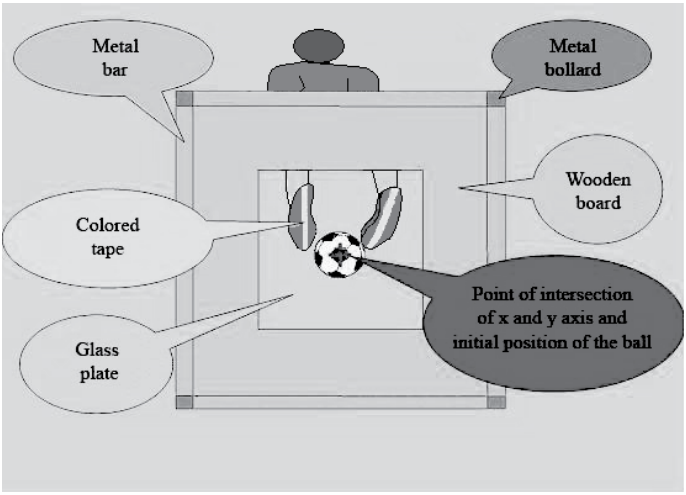

Figure 2. The view (from below) of platform and subject.

For the purpose of measurement, we used a FIFA-approved Nike ball, size five, with a diameter R = 220 mm, with markers drawn on it, in order to determine the number of ball rotations. Subjects were instructed to kick a stationary ball, aiming at a circular target placed in front of the ball, by using inside-foot kicking and stationary onestep approaches (0 degree, 30 and 60 degree, Fig. 3). Subjects were asked, in the case of approach at an angle of 0 degrees, to hit the ball centrically, in order to avoid rotation of the ball in the horizontal plane while, in the case of approach at angles of 30 and 60 degrees, to hit the ball excentrically, in order to cause the rotation of the ball in the horizontal plane. The task was to hit the target 5 times with each of the three approaches, i.e. a total of 15 hits. In this experiment, only successful attempts of kicking the ball were considered (300 target hits).

Figure 3. The view (from below) of the performed kicking technique.

A sample of variables consisted of the approach velocity of swing foot-AVSF (in $m \cdot s^{-1}$), the attack angle of swing foot (AASF, in deg), the angle of direction of the ball after the kick-ADBAK (in deg), the linear velocity of the ball after the kick-LVBAK (in $m \cdot s^{-1}$), the angular velocity of the ball after the kick (AVBAK (in deg $\cdot s^{-1}$), the number of rotations of the ball after the kick-NRBAK (1 rotation=360 deg), the point of impact on foot-PCF (in %) and duration of foot-ball contact-DFBC (in s) (Figure 4). Concerning the variable PCF, in order to indicate the point of impact, the length of the foot was expressed in percentages. In this way, the proximal end of foot (heel) was 0% of total foot length while distal end of foot (toe) was 100%. PCF represented the projection of the point of impact between the foot and the ball (on coloured tape placed on sole of subjects and within an angle of 90 degrees).

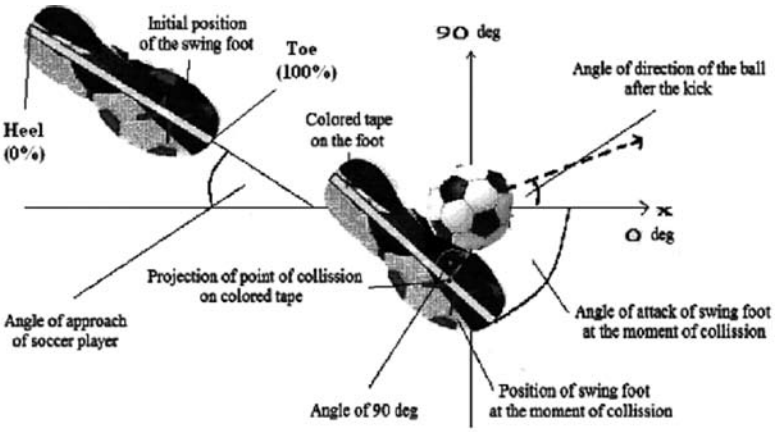

Figure 4. Closer explanation of certain variables.

In order to examine kicking technique and determine values of the analysed variables HU-M-AN™ software for kinematics movement analysis was used. For statistical analysis and interpretation of results, SPSS version 13 software was used. The results were expressed through descriptive statistics; for establishing statistically significant differences between variables in ball inside of foot kick, analysis of variance (one-way ANOVA) was used.

RESULTS

All results of descriptive statistics and one-way ANOVA, are presented in Table 1.

The highest mean value of the attack angle of the swing foot (AASF) was achieved by hitting the ball after approach of subjects at an angle of 0 degrees (74.77 deg), then after approaching at an angle of 30 degrees (72.45 deg) and finally, after approaching at an angle of 60 degrees (66.94 deg). Concerning the mean values of the approach velocity of swing foot (AVSF), descriptive statistics showed that the highest mean value was achieved by hitting the ball after the approach of subjects at an angle of 60 degrees (14.03 $m \cdot s^{-1}$), then after approach at an angle of 30 degrees (13.12 $m \cdot s^{-1}$) and finally, after approach at an angle of 0 degrees (12.59 $m \cdot s^{-1}$). The highest mean value of linear velocity of the ball after kick (LVBAK), was achieved by hitting the ball after approach of subjects at an angle of 0 degrees (16.37 $m \cdot s^{-1}$), then after approach at an angle of 60 degrees (16.09 $m \cdot s^{-1}$) and finally, after approach at an angle of 30 degrees (15.79 $m \cdot s^{-1}$). In regard to

Table 1. Descriptive Statistics and One Way ANOVA of kicking technique after different angles of approach of soccer player (0, 30 and 60 deg).

Variables	N	0 deg		30 deg		60 deg		Sig. (ANOVA)
		Mean	SD	Mean	SD	Mean	SD	
AASF (deg)	100	74.77	11.34	72.45	8.11	66.94	16.46	.00*
AVSF ($m \cdot s^{-1}$)	100	12.59	1.66	13.12	1.76	14.03	1.78	.00*
LVBAK ($m \cdot s^{-1}$)	100	16.37	2.51	15.79	2.25	16.09	2.23	.22
AVBAK (deg $\cdot s^{-1}$)	100	1511.55	772.81	1569.90	828.17	1865.19	872.48	.01*
ADBAK (deg)	100	19.31	11.64	24.77	11.53	27.66	8.35	.00*
NRBAK (rotation)	100	4.20	2.15	4.36	2.30	5.18	2.42	.01*
PCF (%)	100	.50	.07	.52	.08	.54	.08	.00*
DFBC (s)	100	.0174	.00	.0173	.00	.0175	.00	.77

* Indicates a statistically significant difference ($P \leq 0.05$)

angular velocity of the ball after kick (AVBAK), the highest mean value was achieved by hitting the ball after approach of subjects at an angle of 60 degrees (1865.19 deg $\cdot s^{-1}$), then after approach at an angle of 30 degrees (1569.90 deg $\cdot s^{-1}$) and finally, after approach at an angle of 0 degrees (1511.55 deg $\cdot s^{-1}$). The increase in value of the variable AVBAK, directly affected the increase in value of the variable NRBAK. The highest mean value of angle of direction of the ball after kick (ADBAK), was achieved by hitting the ball after approach of subjects at an angle of 60 degrees (27.66 deg), then after approach at an angle of 30 degrees (24.77 deg) and finally, after approach at an angle of 0 degrees (19.31deg). The highest mean value of number of ball rotations after the kick (NRBAK) was achieved by hitting the ball after approach of subjects at an angle of 60 degrees (5.18), then after approach at an angle of 30 degrees (4.36) and finally, after approach at an angle of 0 degrees (4.20). Concerning the mean values of number of point of impact on foot (PCF), the point of impact on foot, effectuated by hitting the ball after approach of subjects at an angle of 0 degrees, was the closest to distal part of foot i.e., to the heel and that is situated on 50% of the total distance from the heel, in regard to approaches at angles of 30 degrees, (where the point of impact was situated on 52% of the total distance from the heel), and 60 degrees, (where the point of impact was situated on 54% of the total distance from the heel), respectively.

Concerning the mean values of duration of foot-ball contact (DFBC), the mean values achieved by hitting the ball after approach of subjects at angles of 0, 30 and 60 degrees, were almost equal (0.0174, 0.0173 and 0.0175 s, respectively). Based on results of one-way ANOVA, it can be concluded, that in all analyzed variables, except in LVBAK (p=0.22) and DFBC (p=0.77), there was a statistically significant difference between the arithmetic mean values achieved after different angles of approach.

DISCUSSION

The obtained results of the variable AASF, i.e the ratio between mean values in different angles of approach, was expected, but the small range of mean values of the AASF (7.83 deg) indicates that the subjects almost automatically set their swing foot in a nearly identical position before the kick, regardless to the different angles of approach. The ratio between mean values of the

variable LVBAK, in the different angles of approach, is in accordance with the ratio in the results of research, conducted by Kellis and colleagues (Kellis, Katis, & Gissis, 2004), Isokawa and Lees (1988), Opavsky (1988), and Roberts et al. (1974). This research was conducted in conditions in which the ball was stationary before impact. It usually is not the case in terms of a soccer game: the ball is usually moving towards the player just before the shot. Nevertheless, the results of research conducted by Tol et al. (2002) do not indicate statistically significant differences in the velocity of the ball after the kick, i.e., the ball that was stationary before impact, compared to the ball that was moving at a velocity of 2.2 $m \cdot s^{-1}$ before impact. By observing the mean values column, it is obvious that, as the approach angle of subjects increased in such a manner, the AVBAK and NRBAK variables increased, while on the contrast the attack angle of the swing foot AASF decreased. This is in accordance with the ratio between the mean values of research conducted by Ozaki and Aoki (2008). The ratio between mean values of the variable NRBAK in different angles of approach is in accordance with the ratio in the results of research conducted by Asai et al. (2002), Carre et al. (2002), and Wesson (2002). The ratio between the mean values of the variable PCF in different angles of approach is in accordance with the ratio in the results of research conducted by Ozaki and Aoki (2008). According to these authors, the mean value of point of impact, after approach abreast is nearer to the distal end of foot (heel), compared with angled approach. The mean values of variable DFBC in different angles of approach are close to duration of contact time in research conducted by Tsaousidis and Zatsiorsky (1996). According to these authors, the duration of impact time, i.e. the duration of contact between the swing foot and the ball was long (about 16 ms). The results of the one-way ANOVA, are in accordance with results of research conducted by Scurr and Hall (2009), in regard to differences in velocity of ball motion, after hitting the ball at different angles of approach. According to their mentioned study, statistically significant differences in the velocity of the ball after a kick did not exist.

Concerning this research, there was no statistically significant difference in linear ball velocity after the kick and in contact time between foot and ball, after different angles of approach. However, there are certain ranges in values of examined variables, within which the accuracy was achieved: mean value of linear ball velocity after kick ranged between 15.79 $m \cdot s^{-1}$ and 16.37 $m \cdot s^{-1}$ and mean value of contact time between foot and ball ranged between .0173s and .0175s. Furthermore, although the angle of attack of the swing foot significantly differed, compared to angle of approach of soccer player (0, 30 and 60 degrees), subjects automatically set their swing foot in an almost similar position before the kick and hit the target. Therefore, in addition to previously mentioned mean value of angle of attack swing foot is ranged between 66.94 deg and 74.77 deg. However, conflicting findings, various factors, and different values of the examined variables reported in the literature do not allow safe conclusions about general conditions that need to be accomplished in order to increase the accuracy of in inside-foot soccer kick.

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APPENDIX

Figure 5. The platform.

Figure 6. The side view of platform.