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BIOMECHANICAL ANALYSIS OF INSTEP AND TOE-POKE KICKING IN FUTSAL PLAYERS

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Abstract

The aims of this study were to investigate relationships between the angular velocity of the lower limb and the foot velocity during instep and toe-poke kicking and to compare the angular velocity of the lower limb and the foot velocity between instep and toe-poke kicking. Twelve semi-professional futsal players were recruited in this study. Each participant performed instep and toe-poke kicking with the dominant limb to the ball which placed at a kick point (second penalty) of 10m distances from the goal and hit the target (1x1 m), which was centered between the goalposts. Kicking was randomly assigned for each participant and recorded by 6 infrared cameras at 200 Hz. The results found that hip angular velocity was significantly correlated with the foot velocity, similar to knee angular velocity and the foot velocity during instep and toe-poke. Hip angular velocity was significantly different between instep and toe-poke ($p<0.05$). Toe-poke kicking (6.64±0.88 rad/s) recorded higher hip angular velocity than instep kicking (5.68±4.10 rad/s). In conclusion, the angular velocity of the lower limb and the foot velocity were important factors for the ball velocity. Toe-poke was a more successful goal scoring maneuver than instep. However, there were other important factors affecting the ball velocity and accuracy, which was the position of foot-to-ball contact. When futsal players have experienced kicking with instep and toe-poke, they can decide and adjust their skills appropriately in competitive games.

Keywords: Biomechanical analysis, Instep and toe-poke kicking, Futsal players

INTRODUCTION

Futsal is soccer that reduced size (i.e. ball, field, goal) with 5 players on each side of indoor soccer version (i.e. 4 outfield players and 1 goalkeeper), containing high intensity and intermittent activity throughout the competitive games (Naser, Ali & Macadam, 2017). One of the important skills is kicking for shooting, more often with instep and toe-poke, respectively (Althoff & Hennig, 2011; Lapresa, Álvarez, Arana, Garzón & Caballero, 2013).

Main elements in kicking performance are the angular velocity of the lower limb, ball velocity, and accuracy for successful goal scoring (Barbieri, Gobbi, Santiago & Cunha, 2010a; Vieira et al., 2016). In addition, there are other factors that impact ball velocity and accuracy, which are the position of foot-ball contact (Dorge, Andersen, Sørensen & Simonsen 2002; Kellis & Katis, 2007; Nunome Asai, Ikegami & Sakurai, 2002; Nunome, Lake, Georgakis & Stergioulas, 2006b; Santiago, Vieira, Barbieri, Moura, Santana, de Andrade & Cunha, 2016), leg dominant and non-dominant (Barbieri, Gobbi, Santiago & Cunha 2015b; Carey, Smith, Smith, Shepherd, Skriver, Ord & Rutland, 2001; Vieira, Souza Serenza, de Andrade, de Paula Oliveira, Mariano, Santana & Santiago 2016), condition of the ball (stationary or rolling) (Barbieri et al., 2010a; Barbieri et al., 2015b; Egan, Verheul & Savelsbergh, 2007), muscle strength of the thigh muscles (Apriantono, Nunome, Ikegami & Sano, 2006) and distance of kick point (Lapresa et al., 2013).

The angular velocity of the lower limb (hip, knee, and ankle joint) is the first element in kicking performance (Barfield, Kirkendall & Yu, 2002). When futsal players kick a ball quickly or take less time for kicking cycle, the goalkeeper cannot prepare to defend their goal (Dorge et al., 2002). Muscle strength of the thigh muscles is important for the angular velocity of the lower limb (Apriantono et al., 2006). The hip joint flexion-extension causes swinging of leg. Thus, the foot velocity is increased according to the force generated by the muscle (Ozaki, Ohta & Jinji, 2012). There are positive correlations between strength of the thigh muscle and ball velocity (Vieira et al., 2016). According to previous studies the angular velocity of the lower limb determines the foot velocity (Dorge et al., 2002; Shang & Westerhoff., 2005). The correlation coefficients between foot and ball velocity are high (Kellis & Katis., 2007), it indicates that the foot velocity is the main determinant of ball velocity (Egan et al., 2007). The final foot velocity before ball contact and appropriate position of foot-ball contact affect ball velocity and accuracy which had been reported in many literatures (Anderson & Dorge., 2011; Apriantono et al., 2006; Barbieri et al., 2010a; Dorge et al., 2002; Kellis & Katis., 2007; Nunome et al., 2002; Nunome et al., 2006a; Santiago et al., 2016).

Successful goal scoring, kicking the ball to the opposite goal accurately and follow to the desired direction are required (Barbieri et al., 2010a). According to a previous study, when futsal players were instructed to perform a kick accurately, ball velocity was declined to 85% of the maximum ball velocity (Anderson & Dorge., 2011). This decline could be related to the movement control and decrease in the motion of the lower limb (Kellis & Katis., 2007), because players would focus on the appropriate position of the foot-ball contact to ensure the direction of the ball. Therefore, the limitations between ball velocity and accuracy have been indicated.

Currently, there are limited studies about sports biomechanics in futsal context (Huang, Lu & Wu, 2013). In contrast, there are many evidences of soccer research. The sport pattern and skills between futsal and soccer are similar. However, comparison or discussion should be considered carefully because both sports are completely different in several aspects such as surface of the flied, size of the ball and dimensions of the goal (Santiago et al., 2016). Therefore, the results in soccer cannot be used to predict directly to futsal (Vieira et al., 2016). Understanding futsal skills would provide beneficial information to coach and player, and help developing futsal (Naser et al., 2017). Moreover, in the previous studies, there is only analysis of kicking with instep, no analysis of kicking with toe-poke. Thus, in this context, we studied the angular velocity of the lower limb and the foot velocity when kicking with instep and toe-poke in futsal players. Specifically, we examined the correlations between the angular velocity of the lower limb and the foot velocity in both skills and compared the angular velocity of the lower limb and the foot velocity between instep and toe-poke. We hypothesized that the correlation between the angular velocity of the lower limb and the foot velocity would be found in both skills, and comparison of the angular velocity of the lower limb and the foot velocity between instep and toe-poke would be different.

METHODOLOGY

Participants

Twelve semi-professional players (age = 20±2 years; body mass = 69.29±10.50 kg; height = 1.75±0.05 m; power strength (Countermovement jump by G-walk measure) = 4.95 ±1.12 kW) from University team participated in this study (winner the 1st- 3rd at the 46th Thailand University Games). All of participants are the right-foot dominant, confirmed by a practice test (to perform ball kicking to hit the target). The protocol was approved by the Strategic Wisdom and Research Institute, Srinakharinwirot University, Bangkok and we obtained written informed consent from participants after they understood the experimental procedures.

Experimental trails

Participants performed warm-up for 20 minutes (10-minutes specific futsal warm-up followed by 10-minutes kicking balls). Kicking a ball with instep and toe-poke were analyzed. Kicking was randomly assigned for each participant (to perform 5 times/skill, rest 1 min/test). The ball (mass = 400 g; air pressure = 0.5 atm; ftsal ball with standard size was used), and placed at the kick point (second penalty) of a distance of 10 meter from the goal. The kicks were performed to hit the target (1x1 m), which was centered between the goal posts (Figure 1). The participants were instructed to perform ball kicking with maximal ball velocity as possible, and simulate a real competitive game.

Data Collection and processing

Six infrared cameras (Qualisys; OQUS7+ model) at 200 Hz (Figure 1) were set to captured the passive markers, which were placed externally on the participant's total body at the following anatomic landmark by skin marker of Qualisys Plug-in Gait full body modeling at 35 position: Center of Frontal Bone; Right/Left Parietal Bone; Right/Left Acromion Bone; Sternum Bone; Cervical 2; Thoracic 12; Right/Left Public Bone; Center of Sacrum Bone; Right/Left Coronoid Fossa; Right/Left Lateral Epicondyle; Right/Left Medial Epicondyle; Right/Left Lunate Bone; Right/Left Ulna Bone; Right/Left Radial Bone; Right/Left Lateral Cartilage Ligament; Right/Left Center of Patella Bone; Right/Left Head Tibia Bone; Right Metatarsal V Bone; Left Metatarsal III Bone; Right/Left of Calcaneus Bone; Right/Left of Talus Bone (Figure 2.) Qualisys motion capture system was used for the 3D reconstruction of the image sequences. A calibration frame was defined (2x4x2 m) to calibrate the measurement area. For the 3D coordinates, the z-axis was vertical components, and perpendicular to the floor, the y-axis was horizontal components and pointed toward center of the target, and the x-axis was linear components and the vector product of z and y. Butterworth low-pass digital filter with the cutoff frequency at 6 Hz was used for smoothing data. Before starting the protocol, the posture of each participant was calibration in an anatomy position for several seconds in order to connect analysis software program.

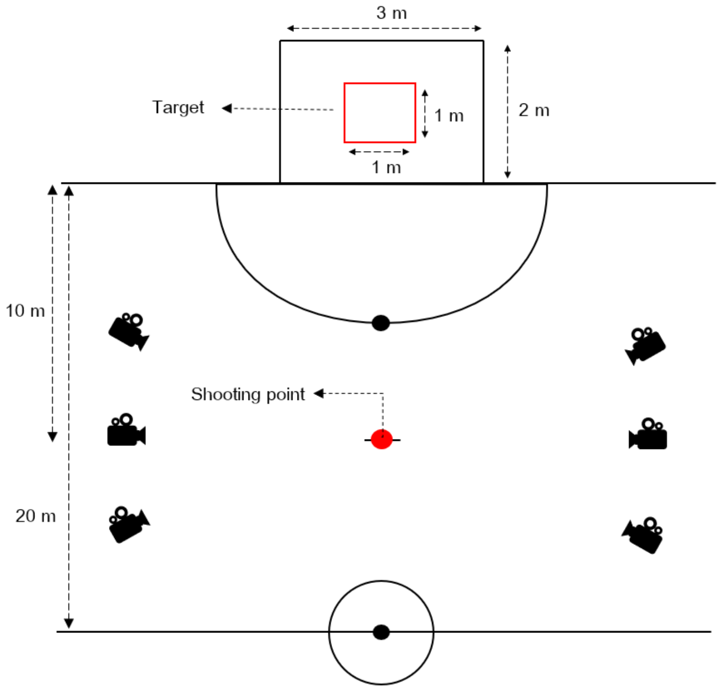

Figure 1. Model diagram

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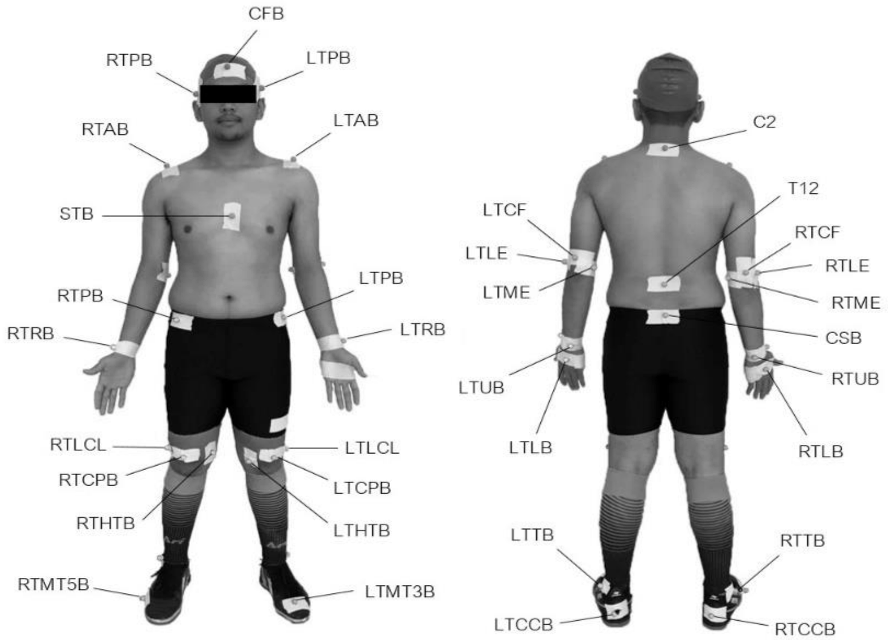

Figure 2. Anatomic landmark by skin marker of Qualisys Plug-in Gait full body modeling.

Data Analysis

In this study, the kicking cycle was analyzed from toe-off of kicking limb through pre-foot-ball contact; support phase (65% of the movement), and full contact of foot and ball to the frame that foot released the ball; contact phase (35% of the movement) (Figure 3) (Barbieri et al., 2010a). For the analysis, the support phase was selected (Vieira et al., 2016) due to before the foot-ball contact could indicate kinematics data (Nunome et al., 2006b). After data collection, the sequences of images were transferred to computer. Data obtained was analyzed using Qualisys Track Manager Software. Only the kick that hit the target, was analyzed in order to receive absolute accuracy. The dependent variables were explained as follows: *Angular joint velocity*; it was calculated from the maximum values at the joint angle axes in each time (Barbieri et al., 2015b), and expressed in radian per second (rad/s). *Foot velocity;* the distal phalanx of the right metatarsal V bone marker was calculated from maximum values of full movement before ball contact to assess foot velocity (Dorge et al., 2002). *Successful goal scoring*; the balls that hit the target accurately, which was defined at center of the goal. A frame (1x1m) was used to the target area. Accuracy was recorded to confirm for successful goal scoring in each time. The percentage of success was calculated from number of the ball hitting the target divided by total number of kicking test and multiply by 100, using the following equation:

$$\%\text{Successful goal scoring} = \frac{\text{number of the ball hitting the target}}{\text{total number of kicking tests}} \times 100$$

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Figure 3. Kicking cycle (Barbieri, Gobbi, Santiago & Cunha, 2010a).

Statistical analysis

The angular velocity of the lower limb (hip, knee and ankle joint) and the foot velocity was calculated from means, standard deviations, maximum and minimum at the joint angle axes. The Shapiro-Wilk test confirmed the normal distribution data. The Pearson Product Moment Correlation was used to examine the correlation between the angular velocity of the lower limb and the foot velocity in both skills. Independent sample t-test was used to verify the differences of the angular velocity of the lower limb and the foot velocity between instep and toe-poke. An alpha lever of 0.05 was used.

RESULTS

The angular velocity of the hip, knee and ankle joint were flexion and extension movements. The foot velocity was frontal plane. Means, standard deviations, maximum and minimum values of the angular velocity of the lower limb (hip, knee and ankle joint) and the foot velocity with instep and toe-poke were presented in Table 1. The Pearson Correlation indicated the correlation between the angular velocity of the hip joint and the foot velocity by kicking with instep ($p = 0.032$) and also between the angular velocity of the knee joint and the foot velocity ($p = 0.048$). In the same way, with toe-poke, indicated the correlation between the angular velocity of the hip joint and the foot velocity ($p = 0.001$) and between the angular velocity of the knee joint and the foot velocity ($p = 0.010$) (Table 2). The relative angular velocity of the ankle and the foot velocity in both skills was not found. Independent sample t-test found significant difference between both skills in the angular velocity of the hip joint ($p<0.05$), the angular velocity of the hip joint with toe-poke was greater than instep. However, there was no difference in the angular velocity of the knee, ankle joint and the foot velocity. Successful goal scoring was calculated from total number of kicking test comparing with number of the ball hitting the target. In case of accuracy, percentage of kicking with toe-poke (61.67%) was greater than instep (45.00%) (Table 1).

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Table 1: The means, standard deviations, maximum and minimum of the angular velocity of the lower limb (hip, knee, ankle joint), the foot velocity and percentage of successful goal scoring between instep and toe-poke.

	Angular velocity (rad/s)				%
	Hip joint (flexion-extension)	Knee joint (flexion-extension)	Ankle joint (flexion-extension)	Foot velocity (m/s)	Successful goal scoring
Instep	5.68±0.80 (4.10 – 7.45)	22.99±2.01 (19.32 – 27.82)	11.77±3.75 (7.21 – 18.85)	13.54±0.55 (12.60 – 14.80)	45.00 %
Toe-poke	6.64±0.88 (5.27 – 8.55)	23.88±1.83 (20.07 – 28.05)	11.62±4.70 (3.16 – 22.43)	14.22±0.76 (12.80 – 15.86)	61.67 %
P-values	.031*	.21	.68	.12	

* Significant difference (P<0.05)

Table 2: The correlations between the angular velocity of the lower limb (hip, knee, ankle joint), and the foot velocity with instep and toe-poke.

The correlations		Angular velocity of hip joint	Angular velocity of knee joint	Angular velocity of ankle joint
Foot velocity	Instep	.468*	.426*	-.213
	Toe-poke	.545**	.472**	.039

*Significant correlation (P<0.05)
** Significant correlation(P<0.01)

DISCUSSION

This study of the angular velocity of the hip and knee joint variables indicated that there was the angular velocity in support phase, which was in line with the previous studies (Barbieri et al., 2010a; 2015b; Huang et al., 2013; Nunome et al., 2006a) which the hip joint flexion-extension depends on muscle strength of the thigh muscles (Apriantono et al., 2006). Muscles power strength training is an important method to increase the angular joint velocity (Vieira et al., 2016). Maximum angular velocity of the hip and knee joint occurred before the foot-ball contact according with the foot velocity. From the results, it confirmed the summary of the previous studies that the angular velocity of the lower limb determines the foot velocity (Dorge et al., 2002; Shan & Westerhoff, 2005). The foot velocity variables, the average values were 13.54 m/s and 14.22 m/s with instep and toe-poke, respectively (Barbieri et al., 2015). In football studies, there was no difference in the foot velocity between professional and amateur athletes (Egan et al., 2007). There is also no study comparing skills or performance based on the level of athletes in futsal context.

This study found the correlation between the angular velocity of the hip joint and the foot velocity as well as the correlation between the angular velocity of the knee joint and the foot velocity with instep and toe-poke. The flexion and extension of hip and knee joint caused the movement of the lower limb and the force generated to increase the foot velocity (Ozaki et al., 2012). The results of this study confirmed the previous study that the angular velocity of the lower limb determines the foot velocity (Dorge et al., 2002; Shan & Westerhoff., 2005). However, no correlation were found between the angular velocity of the ankle and the foot velocity. This may be because of different the characteristics of skills and the position of the foot-ball contact between instep and toe-poke. The movement of the ankle joint showed the adjustments according to the ball condition and skills. For example, in kicking with instep, the ankle would be stretched for plantar flexion, thus, instep area would touch the ball and in kicking with toe-poke, the ankle would be tilted for dorsiflexion, the toe would touch the ball. Due to futsal players can control their foot so that perfect touching and appropriate position of the foot-ball contact affect to ball velocity and accuracy (Barbieri et al., 2010).

With regard to the second hypothesis, it was partially confirmed. In a comparison of the angular velocity of the hip joint between both skills, significant difference was found ($p<0.05$), the angular velocity of the hip joint with toe-poke was greater than instep. However, there was no difference between both skills for the angular velocity of the knee and ankle joint. Regarding the velocity of kicking the ball of kicking performance, value of kicking with toe-poke was greater than instep. Therefore, futsal players can spend less time for leg swinging or the kicking cycle thus making the toe-poke is more advantageous for successful goal scoring than instep.

For the comparison of the foot velocity between instep and toe-poke, no significant difference for foot velocity was found. Considering from the results, we found that average of the foot velocity of toe-poke was greater than instep. According to the previous studies, there are high correlation coefficients between the foot and ball velocity, it can be predicted that there is no difference of ball velocity for instep and toe-poke. This is due to players would focus on accuracy and control the movement of the lower limb which affect to reduce the foot velocity (Kellis & Katis., 2007) for appropriate position of foot-ball contact. Therefore, the limitations between ball velocity and accuracy have been indicated (Andersen & Dorge, 2011). However, this hypothesis was an inference from the previous study, therefore, it cannot be concluded at all. Moreover, there are also the other factors related to the position of foot-ball contact in both skills (Anderson & Dorge., 2011; Apriantono et al., 2006; Barbieri et al., 2010a; Dorge et al., 2002; Kellis & Katis., 2007; Nunome et al., 2002; Nunome et al., 2006a; Santiago et al., 2016). The characteristics of position of foot-ball contact in kicking with instep and toe-poke are different. For toe-poke, kicks is targeted into the nearest center of the ball because there is little surface area, maximum ball velocity, a few of spin, and accurate straight direction are possible to occur. For instep, kick is performed using instep area to touch the ball with a large surface area. Thus, the ball may spin which reducing ball velocity and making ball curved move. Therefore, players need to predict the direction of the ball (Kellis & Katis., 2007).

Successful goal scoring was calculated from total number of kicking test comparing with the number of the ball hitting the target. The kicking with toe-poke was more accurate than instep, in case of the target was located at the center of the goal. The position of the target affects the motion and the angular velocity of the lower limb (Huang et al., 2013)

Although the findings of this study indicated on the correlations and differences between instep and toe-poke, some limitations were evident. Despite kicking the ball with maximum ball velocity and accuracy, it was difficult to define like a competitive game. We suggested testing on futsal field and setting the target for variety of position of the goal such as top and bottom or right and left. Furthermore, the experiment of ball velocity was explained that it related to kicking performance regarding the initial velocity, final velocity and average velocity. Finally, the position of the target and the values of ball velocity should be considered carefully. Considering these limitations and other factors of kicking performance depending on futsal kicking skills, should be performed with cautiousness.

CONCLUSION

The angular velocity of the lower limb and the foot velocity are important elements the velocity of kicking the ball. For the angular velocity of the hip joint in kicking with toe-poke is greater than with instep. When futsal player spent less time in swinging legs. Therefore, kicking with toe-poke is more advantageous for successful goal scoring than instep, due to the goalkeeper has less time to defend the goal. However, there were the other important factors affecting ball velocity and accuracy, which was the position of the foot-to-ball contact. Between kicking with toe-poke and instep, the characteristics of the foot-ball contact are totally different when futsal players are proficient at both skills. Therefore, they can decide and adjust their skills appropriately in competitive game.

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