THE ANALYSIS OF ANGULAR MOMENTUM OF SIDE-VOLLEY SOCCER SHOTS PERFORMED AT THREE BALL-HEIGHT

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The purpose of this study was to examine side-volley soccer shots performed at three ball-height. Five amateur, right leg dominant, male soccer players (height = 173 ± 2.86 cm; weight = 68 ± 6.04 kg; age = 20.5 ± 0.5 yrs) participated in this study. Two electrically synchronized high-speed video cameras (Redlake) were used to sample the kicking motion at 250 Hz. By the three-dimensional cinematographic technical analysis, the kicking leg was modeled as a three-link kinetic chain composed of thigh, shank, and foot, from which angular velocities and angular momentum were computed. Significantly greater ball velocity and foot velocity were achieved in kicking lower ball-height, with a shorter leg-swing time. The foot moment of inertia exhibited a high value in side-volley shot performed at the lower ball-height. These results indicated that the side-volley soccer shots performed at the lower ball-height would made higher value of foot angular momentum, and benefited ball velocity.

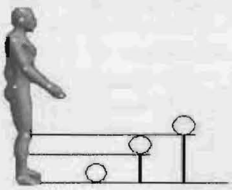
KEY WORDS: side-volley shot, soccer kick, dynamic.

INTRODUCTION: Kicking is the most widely studied skill in soccer (Lees & Nolan, 1998). Among many forms of kicking, players use the most appropriate one depending on the nature and intent, similar to shooting skills. As a matter of fact, it's the same concept as shooting skills. Scoring goals is the single most difficult task in soccer. Success depends on several factors, one of which is the ability to shoot powerfully and accurately with either foot (Joseph, 1999). However, in the process of balls being kicked, passed, hits on the ground, human bodies, and the goal would cause them to bounce or drop. So that the chances of kicking volley-ball or punt-ball were increased, and it's definitely worthwhile to identify the proficient volley shot skills. Mccrudden and Reilly (1991) discussed on EMG analysis a comparison of the punt-kick and drop-kick, examining the kicking leg muscle strength and anaerobic power. They did not specify set up a ball-height of the punt-kick and drop-kick. Then different hitting would caused the different parameters of kinematics and kinetics. For example a high angular velocity of the lower leg means a high foot velocity and this is important in the production of a well-struck kick (Adrian, 1996). However, angular momentum was derived as the moment of linear momentum. The purpose of this study was to investigat the kicking leg swing (left heel landing the floor to the right instep impacting the ball) mechanics at side-volley soccer shots performed at three ball-height by three-dimensional cinematographic technique.

METHODS: Five amateur male soccer players (height=173±2.86 cm; weight=68±6.04 kg; age=20.5±0.5 yrs) participated in this study and all preferred to kick the ball using the right leg. After a short period of warm-up, they were instructed to perform side -volley shots at three ball-height (Figure 1), using their preferred leg(right) with maximum effort, to the center of hand ball goal, which was located at a distance of 11m in front of them. The subjects were asked to perform the kick five times at each ball height at an approach angle of 45 degree taking three steps Two electrically synchronized high-speed video cameras (Redlake) were used to sample the kicking motion at 250 Hz. For calibrating the performance area, a calibration frame with 17 control points was videotaped before the trials. A digitizing system (Kwon3D 3.0) was used to automatically digitize the anatomical body landmarks, including, middle head, right and left sides of the head, shoulders, elbows, wrists, hips, knees, ankles, heels, toes. The center of the ball was also digitized in its initial, stationary position and in all of the available frames after it left the foot (five frames) (Nunome, Asai, Ikegami & Sakurai, 2002). Each trial was digitized from the left heel (supporting leg) landing on the floor to the right instep impacting the ball. Since each segment contributed two terms to the angular momentum of the whole body, one term was called the local angular momentum and another called the remote angular momentum. The first term described rotation of the segment about its own center of gravity, whereas the second, the remote angular momentum, corresponded to the angular momentum created by the segment's center of gravity rotating about the total body's center of gravity. Therefore, the angular momentum of the foot segment was calculated by equation (1).

$$L_f = I_f \cdot \omega_f + \left| \vec{r_f} \cdot m_f \vec{v_f} \right| \quad (1)$$

In equation (1), where I_f was the moment of inertia (in $kg \cdot m^2$) of the segment of foot about its center of gravity, v_f is the velocity vector of segment (in $m/\sec$), ω_f was the angular velocity of the segment of foot (in rad/s) and m_f was the segment's mass (in kg) (Graham, Gordon & Saunders, 2004). The segment model used the Dempster (1955) parameters.



Height A: the static ball placed on the ground.
Height B: the static ball placed on the soft cylinder at 1/2high of knee joint.
Height C: the static ball placed on the soft cylinder at high of knee joint.

Figure 1 The side-volley shots performed at three ball-height.

RESULTS AND DISCUSSION: Table 1 shows the max ball and foot velocities for side-volley shots performed at three ball-height. The ball velocity of side-volley shots performed at lower ball-height was slower than that performed at higher ball-height. Asami and Nolte (1983) examined ball to foot velocity ratios obtained during rigid foot impacts. The ball to foot velocity ratios of their study displayed the higher the ball-position the less ratio was, suggesting that the higher ball-height at which side -volley shots were performed the less rigid the impacts was. During the swing phase, the side-volley shots performed at higher ball-height utilized more time than lower ball-height (0.13 ± 0.01sec, 0.14±0.01se, 0.16±0.01sec).

Table 1 The peak velocity of stricking limb and ball before impact.

Ball-position	Thigh CM (m/sec)	Shank CM (m/sec)	Foot CM (m/sec)	Ball (m/sec)	BALL/ FOOT CM
Height A	5.91 ± 0.36	8.75 ± 0.46	12.69 ± 0.33	12.38 ± 0.28	0.95 ± 0.04
Height B	6.31 ± 0.52	9.15 ± 0.57	12.1 ± 0.46	11.69 ± 0.57	0.93 ± 0.04
Height C	6.38 ± 0.31	9.26 ± 0.45	11.59 ± 0.31	10.33 ± 0.79	0.86 ± 0.06

As kicking the ball-height was elevated, there was a decreased trend of foot angular momentum before ball impact(Figure 2), and angular momentum was multiplied angular velocities by the moment of inertia. Figure 3 and Figure 4 show the side-volley shots performed at higher ball-height had greater foot angular velocity and lowest foot moment of inertia. As a result, the side-volley shots performed at lower ball-height benefited by the foot moment of inertia and high foot angular momentum increasing ball velocity. Thus the high ball velocity and decreased swing time was found for kicking at the lower ball height.

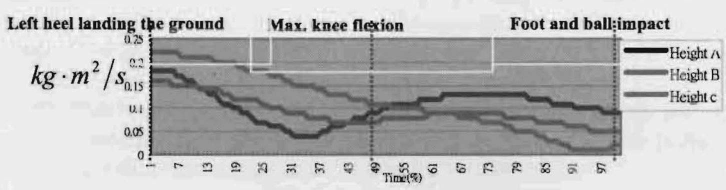


Figure 2 Foot angular momentum before ball impact.

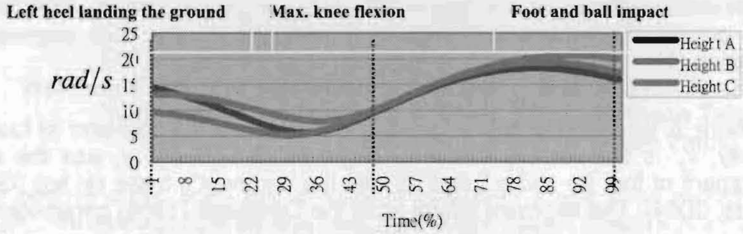


Figure 3 Foot angular velocity before ball impact.

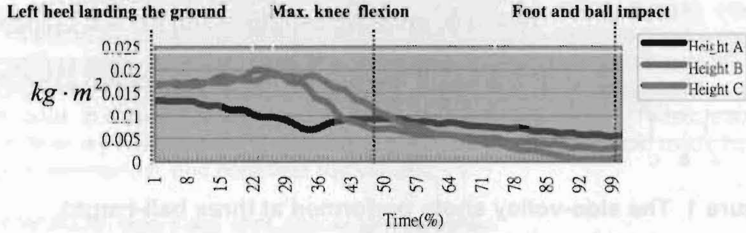


Figure 4 Foot moment of inertia before ball impact.

CONCLUSION: In the present study, the high velocity of ball appeared at kicking the lower ball-height, and it also expended less swing time than kicking higher ball-height.

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