COMPARISON OF BALL IMPACT CHARACTERISTICS BETWEEN SIDE-FOOT AND INSTEP KICKING IN SOCCER

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The purpose of this study was to describe the kinematic characteristics during ball impact of soccer side-foot kicking. The foot and ball motions during ball impact phase of the instep and side-foot kicking were captured for two professional footballers using two ultra-high-speed cameras at 2000Hz. In the instep kicking, the foot was forced into plantar flexion, abduction and eversion by ball contact. On the other hand, in the side-foot kicking, the passive plantar flexion motion was drastically restricted compared to that of instep kicking. Although the foot and ball velocity of the side-foot kicking were lower than those of the instep kicking, the efficiency of ball impact of the side-foot kicking approximately corresponded with that of the instep kicking. The complicated ball impact characteristics of side-foot kicking in highly skilled footballers were illustrated by ultra-high-speed images.

KEY WORDS: ultra-high-speed sampling, 3D foot motion, ball impact quality.

INTRODUCTION:

In soccer, the players usually kick the ball with various parts of the foot depending on the situation. Among a variety of kicks, the side-foot kicking is the most frequently used when the players kick the ball more precisely (e.g. short pass or shot), whereas the instep kicking is used when a faster ball speed is required (e.g. long pass or shot). Although many biomechanical studies have examined the soccer kicks, most were done on the full instep kicking. Consequently, to date, the number of the previous studies focused on the side-foot kicking is limited; Levanon & Dapena (1998) and Nunome et al. (2002) reported kinematic and kinetic characteristics of kicking limb until ball impact from comparison with instep kicking, respectively.

Recently, impact phase kinematics of the instep kicking was clearly illustrated by Nunome et al. (2006a) and detailed foot and ball motion and their interaction during ball contact were revealed by Shinkai et al., (2008) using ultra-high-speed video images. However, these aspects have never been qualified for the side-foot kicking. Thus, the foot behaviour of the side-foot kicks during ball impact is not well understood.

The purpose of the present study was to describe the ball impact kinematics of the side-foot kicking through a comparison of that of the instep kicking using ultra-high-speed sampling.

METHOD:

Subjects and Data Sampling: Two Japanese professional male soccer players (Subject A; age: 21 years, height: 182 cm, body mass: 76.4 kg, Subject B; age: 24 years, height: 169 cm, body mass: 68.5 kg) participated in the present study. Subjects were instructed to kick a stationary ball using side-foot and instep kicking aiming at a target (0.88 m square) set in the middle bottom of a soccer goal 5 m ahead with free approach running. Two successful shots that hit the target were selected from each subject and kick for analysis. A FIFA approved size five soccer ball (mass: 0.43kg) was used and its inflation was controlled throughout the trials at 900 g/cm^2. Two electrically synchronized ultra-high-speed video cameras (Photoron Ltd., FASTCAM-512 PCI) were used to capture the shank, foot and ball motion of both kicking. The two ultra-high-speed video cameras were located in the diagonally kicking leg side and diagonally backward and its sampling rate was set at 2000 Hz to capture the foot and ball behaviour adequately during ball impact phase. White hemisphere markers were fixed securely onto several anatomical landmarks on the lateral side of kicking limb: head of fibula, lateral malleolus, lateral side of calcaneus, fifth metatarsal base and fifth metatarsal head (Figure 1).

Data Analysis Procedure: After the three-dimensional coordinates of each marker was obtained using DLT method (Abdel-Aziz & Karara, 1971), tri-axial angular motion of the foot (plantar / dorsal flexion, abduction / adduction, inversion / eversion) was calculated. As shown Figure 1, the segment vector of shank (S_{Shank}) pointing from lateral malleolus toward head of fibula and segment vector of foot (S_{Foot}) pointing from lateral side of calcaneus toward fifth metatarsal head were defined. The plantar / dorsal flexion angle was defined as the angle between S_{Shank} and S_{Foot} on the plane perpendicular to the vector (V_{FS}) made by the vector product of S_{Shank} and S_{Foot}. The abduction / adduction angle was defined as the angle between the Y axis (back and forth direction) and the vector (V_F) defined by the vector product of vector pointing from lateral side of calcaneus toward lateral malleolus and S_{Foot} on the plane perpendicular to S_{Shank}. The inversion / eversion angle was defined as the angle between S_{Shank} and V_F on the plane perpendicular to vector defined by the vector product of S_{Shank} and V_{FS}. After each angle was calculated, angular displacements of the foot that the angles of the foot at the instant of the initial ball contact were defined as criterion value were also computed.
The contact time of the foot with the ball was measured from the number of the frames in which the contact between them was observed from lateral side image. Foot and ball velocity were represented by the velocity of the fifth metatarsal base and the centre of the ball, respectively. Both velocities were computed as the average of 10 ms just before and after ball contact from those raw coordinates of horizontal and vertical components. Moreover, the ball-foot velocity ratio provided an index of efficiency of ball impact was represented by the ratio of ball velocity to foot velocity. The attack angle of the foot at the instant of ball contact was defined as the angles between foot velocity vector and V_F on the plane perpendicular to S_{Foot}. All angle data were smoothed by a fourth-order Butterworth digital low-pass filter at 200 Hz of cut-off frequency.

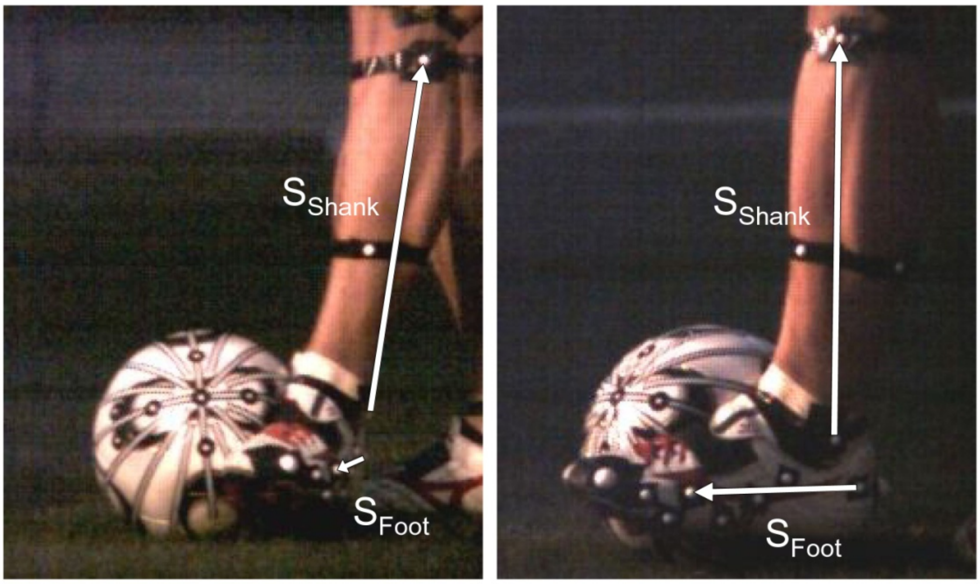

Figure1: Typical images of ball contact in side-foot kicking from the lateral side view (left) and backward view (right) and the definition of segment vector of shank and foot.

RESULTS:
All parameters are summarized in Table 1. In the side-foot kicking, the foot contacted with the ball slightly longer than the instep kicking. The foot and ball velocity of the side-foot kicking were lower than those of the instep kicking, however, the reduction of the foot

velocity by ball impact and efficiency of ball impact (ball-foot velocity ratio) were similar for both kicks. From the result of attack angle, the side-foot kicking of subject A was represented a typical motion that the foot hit the ball squarely with its inside aspect, whereas the subject B hit the ball with a hybrid position of the foot: between the instep and inside aspects. Figure 2 shows typical changes (subject A) of three-dimensional foot angular displacement of the instep and side-foot kicking during ball impact. As shown, remarkable differences between the two types of kicking were found. In the case of the side-foot kicking, the passive plantar flexion motion especially was considerably restricted compared to that of the instep kicking. This trend was commonly observed for both subjects.

Table 1: All kinematic parameters related to the foot and ball.

	Instep kicks (Mean ± SD)		Side-foot kicks (Mean ± SD)	
	Sub. A	Sub. B	Sub. A	Sub. B
Attack angle (°)	125.5 ± 2.0	110.0 ± 0.1	174.2 ± 1.9	141.7 ± 11.4
Contact time (ms)	8.3 ± 0.4	8.8 ± 0.4	9.3 ± 0.4	9.3 ± 0.4
Angular displacement (°)				
Plantar (+) / Dorsal (-) flexion	7.0 ± 1.6	10.1 ± 0.1	-0.4 ± 0.6	4.8 ± 1.5
Abduction (+) / Adduction (-)	4.1 ± 1.4	5.9 ± 0.2	5.5 ± 1.7	15.2 ± 0.1
Inversion (+) / Eversion (-)	-5.3 ± 0.2	-2.7 ± 0.5	-1.8 ± 3.6	-3.2 ± 0.3
Foot velocity				
before impact (m/s)	21.9 ± 0.4	24.3 ± 0.1	18.5 ± 0.03	21.8 ± 0.7
after impact (m/s)	14.5 ± 0.3	16.0 ± 0.4	12.6 ± 0.2	14.6 ± 0.4
reduction rate	33.7 ± 2.7	34.2 ± 1.4	31.9 ± 1.2	33.1 ± 0.1
Ball velocity (m/s)	30.8 ± 1.1	33.8 ± 0.4	26.0 ± 0.05	31.5 ± 3.1
Ball-Foot velocity ratio	1.41 ± 0.08	1.39 ± 0.02	1.40 ± 0.00	1.44 ± 0.10

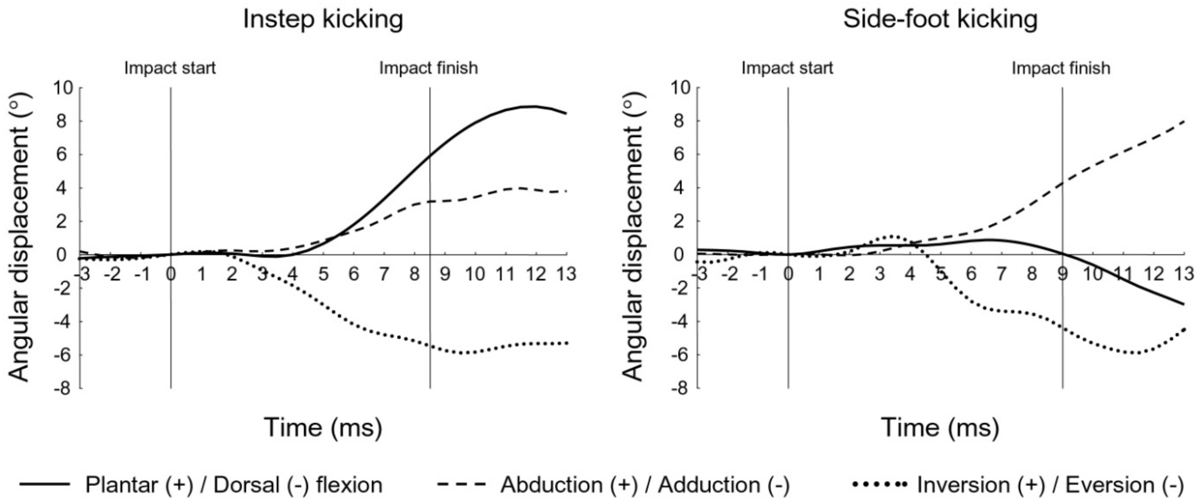

Figure 2: Comparison of the typical changes (subject A) of the three-dimensional foot angular displacement during ball impact phase between instep (left) and side-foot (right) kicking.

DISCUSSION:

The first advantage of the present study is to present the impact phase kinematics of skilful professional soccer players who belong to the top division of the national league. In the present study, both the ball velocities of instep and side-foot kicking showed higher values than those reported by Levanon & Dapena (1998) for collegiate players and Nunome et al. (2002) for high school players. Moreover, the ball speed of the instep kicking observed in the present study was similar to those reported by Nunome et al. (2006b) for highly skilled club players. This result may represent the high kicking skill level of the subjects. From the results of the reduction rate of foot velocity and ball-foot velocity ratio, it can be interpreted that the ball impact quality of side-foot kicking was similar with that of instep kicking. Levanon & Dapena (1998) and Nunome et al. (2002) suggested that the slower ball velocity observed in

the side-foot kicking was not due to the quality of ball impact but due almost exclusively to the slower velocity of the foot just before ball contact. Similar aspects were confirmed for highly skilled professional players.
Another characteristic of the present study is that the foot motion in ball impact phase was captured by ultra-high-speed sampling. This procedure succeeded in describing a complicated feature of the foot motion of the two types of kick. In the case of the instep kicking, the foot was forced into plantar flexion, abduction and eversion by contacting with the ball. This feature of the foot motion corresponded with that reported by Shinkai et al. (2008). In contrast, in the side-foot kicking, the plantar flexion motion was restricted drastically compared to that of instep kicking (Table 1 and Figure 2). It is clear that the difference of the ball impacting part of the foot between the two kicks is most likely responsible for the difference in the passive foot angular motion during ball impact.
In the present study, the subjects were instructed to kick the ball using instep and side-foot kicking. However, from the results of attack angle at the instant of ball impact, two different kicking styles were detected in the side-foot kicking; the subject A hit the ball squarely with medial aspect of the foot while the subject B hit the ball with the intermediate aspect between instep and inside of the foot. It can be speculated that the subject A and B used a different style of the side-foot kicking technique with different priority; the subject A and B placed more emphasis on accuracy and speed of the ball, respectively.

CONCLUSION:
Impact phase kinematics of side-foot kicking in high level professional soccer players was revealed in detailed time-series data. The various form of side-foot kicking was observed for each player. Complicated passive foot motion of side-foot kicking which different from that of instep kicking was clearly described whereas the quality of ball impact was similar for both kicks.

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