Kinematics of side-foot ball stopping technique in soccer

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The present study aimed to illustrate the kinematics of side-foot ball stopping in soccer. Eleven male university soccer players performed side-foot ball stops of an air ball fired from a machine from 10 m away. The ball stopping motion was captured using a 10-camera motion capture system sampling at 500 Hz. The changes of foot and ball linear velocities were computed just before, during and after ball contact. Six joint angular motions of the stopping leg were also calculated. The participants demonstrated a distinct draw back of the foot before ball contact after a gentle forward swing. A rapid knee external rotation was also initiated just after ball contacting, suggesting the knee was passively rotated externally. These kinematic aspects may represent significant motion features required for the side-foot ball stopping technique in soccer.

KEY WORDS: soccer, ball stopping, technique.

INTRODUCTION: Ball stopping forms the foundation of techniques required in soccer and the quality of this technique likely define the skill level of players. From the viewpoint of dynamics, this technique can be regarded as a collision between foot and ball lasting milliseconds. To date, a number of studies have focused on kinematics or dynamics of soccer kicking (Andersen & Dörge, 2011; Nunome et al., 2006). Shinkai et al. (2009) made a novel attempt to illustrate ball impact dynamics during instep kicking using ultra high speed video analysis. However, there has been no study which attempted to reveal the three dimensional kinematics of ball and foot motion during ball stopping technique.

In general, the side-foot ball stopping is the most frequently used technique when precise control of a ball on the ground or in the air is required. Theoretically, ball stopping technique is a mirror phenomenon of ball kicking. To achieve successful ball stopping; to reduce the ball momentum to nearly zero, players dare to draw back the foot and somehow to gain a large effective mass around the foot if the ball velocity is much faster than the foot draw back velocity. However, to date, there is limited information regarding the ball stopping technique and coaching cues about this technique is yet unclear. Therefore, some new evidence is demanded to establish more effective coaching manuals about this technique.

We aimed to illustrate the kinematics of the side-foot ball stopping technique and hypothesized that players combine active and passive motions into successful ball stopping.

METHODS: Eleven male university soccer players (height = 174.7 ± 5.1 cm, mass = 63.5 ± 5.9 kg) were asked to perform the side-foot ball stopping technique to stop a ball launched in the air from a machine (Soccer machine, JUGS Sports, Oregon, USA) positioned 10 m away. The fired ball velocity and trajectory were controlled for all trials by the machine. An approved size five soccer ball (Pelada 405, Molten Corporation, Hiroshima, Japan; diameter = 22 cm, mass = 426 g) was used, and its inflation was controlled at 0.9 bar throughout the experiment. To minimize the effect of the shoe on the action of the foot, the same indoor soccer shoe (Del Mundo WideTT, PUMA, Herzogenaurach, Germany) was used.

The experiment was conducted in an indoor gymnasium, and the floor was covered with an artificial turf mat (2×2 m square). The ball stopping motion was captured using a 10-camera motion capture system (Vicon Nexus, Vicon MotionSystems, Oxford, UK) sampled at 500 Hz. Forty seven reflective markers were attached firmly to body landmarks and nine reflective markers were attached on the ball surface. For player's safety, the body of ball surface makers were made from urethane foam, which was covered by reflective tape.

All participants used their preferred leg (right) to stop the ball. Successful trials were defined as the ball being securely stopped on the artificial turf mat. Six successful trials were selected for each participant for further analysis.

The geometrical centre of the ball was obtained from the ball surface markers using a least-square technique, assuming each marker has the same distance from the ball centre. The foot centre was defined as the centre gravity of the foot. The changes of the linear velocities of foot centre and ball centre were computed from just before, during and after ball contact.

For initial ball contact parameters, the contact point of the foot and the ball (Figure 1) was defined as point of intersection between segment vector of inside-foot (V_{if}) pointing from the lateral side of the calcaneus toward fifth metatarsal head and a perpendicular line lowered to V_{if} from the ball centre. The contact point was normalized by foot length of each participant and shown as relative distance from the lateral side of the calcaneus (0%).

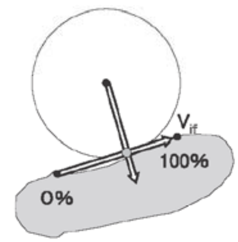

Figure 1: The contact point of the foot and the ball

Furthermore, six joint angles: foot dorsal/plantar flexion, knee flexion/extension, lower leg internal/external rotation (including the foot adduction/abduction), hip flexion/extension, the hip adduction/abduction and the hip internal/external rotation, were calculated from the moments from 0.3 s before to 0.3s after ball contact.

For simplifying the interpretation of results, the stopping motion was divided into three phases. The forward swing phase (FW) was from toe off of the right foot to the end of swinging the leg forward. The draw-back phase (DB) was defined as a time period from the Y velocity of the right foot starting to decrease to the moment before ball contact. After-ball-contact was defined as the follow-through phase (FT).

RESULTS: The linear foot and ball velocities are summarized in Table 1. In all trials, players consistently showed a gentle forward leg swing and then exhibited a draw back of the foot before ball contact. After ball contact, the foot backward velocity was largely emphasized (from -1.46 ± 0.48 to -4.04 ± 0.58 m/s). The players contacted the ball with distal part of the foot (52.4 ± 19.4 %). The average value (± SD) of six joint angles of the right leg is shown in Figure 2. During the forward swing phase, the knee and hip joint angles reached their maximum flexion angle and then continuously extended until ball contact. During the draw back phase, the hip continuously extended while other joints had no appreciable motion. Just after ball contact, the lower leg had a rapid external rotation motion. Also, the hip joint and the knee joint showed a rapid internal rotation and flexion motion, respectively. There was no significant motion for the hip adduction/abduction motion throughout the ball stopping motion.

Table 1: Ball and foot velocity parameters

	Average (SD)		
	Before contact	After contact	Velocity-changing
The ball Y velocity (m/s)	-9.73 (0.25)	0.52 (0.46)	10.25 (0.53)
The foot Y velocity (m/s)	-1.46 (0.48)	-4.04 (0.58)	-2.58 (0.36)

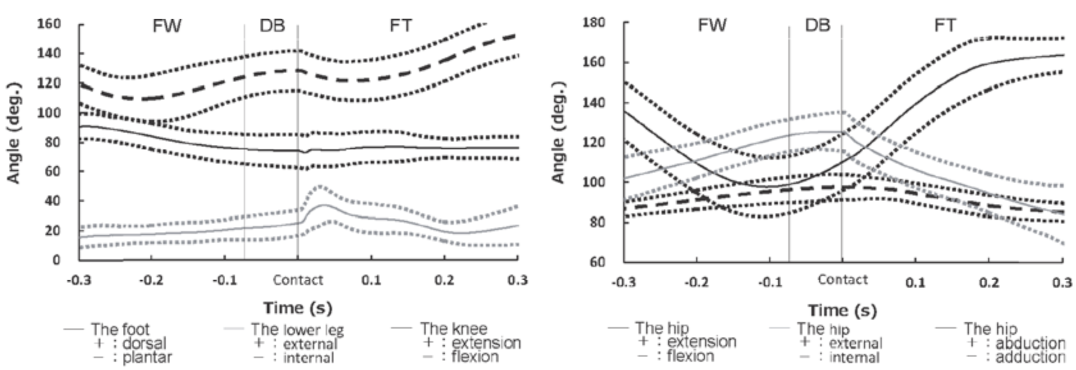

Figure 2: Average values for six joint angles of the right leg.

DISCUSSION: In the present study, we focused on soccer ball stopping technique to illustrate the three dimensional kinematics of the stopping leg. We hypothesized that players would combine active and passive motions into successful ball stopping. The results of present study most likely supported our hypothesis.

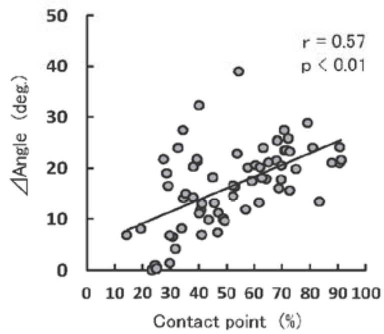

Figure 3: The relationship between the contact point of the foot and the range of lower leg external rotation.

As shown in Figure 2, lower leg experienced a rapid external rotation motion just after ball contact, most likely due to the ball contact force. Figure 3 shows the relationship between the foot contact point and the range of lower leg external rotation. The foot contact point and the range of lower leg external rotation was moderately correlated (r = 0.57). Thus, it is reasonable to assume that the range of lower leg external rotation is influenced by where the foot comes into contact with the ball. If players contact the ball at more distal part of foot, a longer lever arm to the ball contact force will exist, producing a larger moment that will result in the foot (lower leg) being more externally rotated. Likewise, knee flexion and hip internal rotation motions suddenly appeared just after ball contact, suggesting these motions were also produced passively. It can be speculated that players may intentionally utilize these passive motions to attenuate ball impact more effectively during ball stopping.

In contrast, it can be seen that ball contact made little impact on foot dorsal/plantar flexion, hip extension/flexion and hip abduction/adduction motions. As shown in Figure 2, the foot dorsal and hip abduction angles were quite constant throughout the stopping motion. In particular for the foot configuration, it can be considered that the constant foot configuration may help players to form a stable ball contact face thereby minimizing ball diversion during ball stopping. On the other hand, a large angular motion for the hip flexion–extension motion during ball stopping was observed. As the hip extension motion was initiated before ball contact, this must be an active movement produced by the player. There is an argument among coaches about whether players actively draw back the leg when ball stopping or if that motion occurs passively. The present study was the first to illustrate the leg draw back motion is initiated before ball contact. This suggested that the draw back motion is initiated by the active hip extension motion before continuing as a passive motion during ball contact as evidenced by the passive hip internal rotation and knee flexion motions found in this phase.

To date, there is no literature regarding the side-foot stopping technique. Thus, an attempt was made to deepen our understanding for the side-foot stopping motion by comparing with that of side-foot kicking (Nunome et al., 2002). In the side-foot kicking, players utilized the hip axial (external) rotation motion to align and to accelerate the medial side of the foot in the intended kick direction. It can be seen that a reverse of this motion exists in the side-foot stopping where players utilize the hip axial (internal) rotation motion to align and to decelerate the medial side of the foot along the line of the incoming ball. However, there exists some differences between the side-foot kicking and stopping. In general, to contact the ball with the foot centre of gravity has been thought to be an important factor in producing a faster ball velocity. In contrast, the present findings suggest that players do not need to contact the ball with the foot centre of gravity when ball stopping, rather preferring to make contact at a more distal part of the foot to attenuate ball momentum using the external rotation motion as an additional shock absorber.

In the present study, we succeed in illustrating the three dimensional kinematics of the side-foot ball stopping. In addition, we provide some new evidence that can be an effective coaching cue by dividing into active and passive motions from characteristics of the observed kinematics. These kinematic aspects may represent significant motion features required for the side-foot ball stopping technique in soccer.

CONCLUSION:

It can be concluded that: 1) the side-foot ball stopping technique can be divided into intentional and unintentional motions and 2) the two significant motions that are necessary to ball stopping success were hip external rotation motion before ball contact that was used to align the medial side of the foot toward the direction of the incoming ball and the lower leg external rotation that was passively rotated after contact the ball.

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