KINEMATIC ANALYSIS OF SOCCER INSIDE KICK MOTION FOR STATIONARY BALL AND PROJECTED BALL

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The purpose of this study was to analyse the inside kick motion kinematically under the mimic situation of a soccer game, by comparing the motion of kicking the stationary ball on the ground with the motion of kicking the ball projected from the launcher machine. Five male university soccer players conducted inside kicks under the two conditions of the stationary ball and the projected ball. The kicking motion were collected with an optical motion capture system. From the results of this study, the following were suggested as a motion to kick a projected ball. 1) Adjustment of hip joint adduction-abduction and knee flexion-extension were important so as to correspond the swing trajectory to the ball. 2) It is important to kick an upper part of ball.

KEYWORDS: kick performance, impact position, ball rotation, moving ball.

INTRODUCTION: In the soccer game, attackers are required to attack quickly while avoiding the pressure from defender. Breaking through the opponent's defence with quick passes is one of the effective means for attackers. In the case of a short distance pass, the main kick motion is the inside kick. The inside kick is kick motion in a shorter time than the instep kick which is frequently used in the games (Nunome, 1999). Previous studies investigated the mechanism of inside kick (Bono et al., 2013; Kawamoto, Miyagi, Ohashi & Fukashiro, 2006; Togari, Asami & Kikuchi, 1972). However, in most of the previous studies, the motion of kicking the stationary ball was investigated. In the actual game, there are few situations of kicking a stationary ball such as a set play, and there are many situations where a pass from a teammate player is kicked toward another player. In order to evaluate the inside kick motion more accurately, it is necessary to analyse the motion as a series of actions including the process leading up to the kick motion.
The purpose of this study was to analyse kinematically the inside kick motion under the mimic situation of soccer game, by comparing the motion of kicking the stationary ball on the ground to the motion with kicking the ball projected from the launcher machine.

METHODS: Five male university soccer players (Mean ± SD of height: 1.72 ± 0.08 m, mass 65.4 ± 5.8 kg) participated in this study. Participants were instructed to perform an inside kick with the dominant leg aiming at the centre of two pylons (1.5 m width) placed 7 m ahead of the participant. They were also asked to perform the inside kick with instruction as follows: (1) kicking a ball as fast as possible with a high ball speed, (2) kicking a ball without float trajectory, (3) kicking a ball as accurately as possible to pass between the two pylons. Two conditions, kicking stationary ball (SB) condition and kicking projected ball (PB) condition were set (the launcher machine to the position 10 m ahead at 45° to the right of the participant), and 10 trials were analysed under each condition. Under both conditions, the trials in which the ball was passed between the two pylons and a trial that participant's introspection was good, were regarded as successful trials.
The unit vector obtained by the cross product of the unit vector of ball speed vector direction and the z-axis of the global coordinate system was defined as the SP axis. The rotational speed of the ball was evaluated by the inner product of the SP axis and the vector of ball angular velocity. In addition, the average values of the rotational speed 2 ms before and after the ball impact (Imp) were calculated. Further, to evaluate the impact position of the ball, the position of the centre of gravity (CG) of the kick leg foot with respect to the ball centre at the time of impact was calculated.

Three-dimensional coordinate values of the kicking motion were collected by an optical motion capture system (VICON-MX, Vicon Motion Systems, 20 cameras, 500Hz). Three-dimensional marker locations were smoothed using a Butterworth low-pass filter with optimal cut-off frequencies (10-45 Hz), which were determined by the residual error method (Wells & Winter, 1980). The analysis phase was set from the kicking leg toe off (KLoff) to Imp. The normalization of time was made so that KLoff was 0%, the supporting leg heel contact 50%, and Imp 100%.
Paired t-test was used for the statistical processing. Statistical significance level was set at $p<0.05$.

RESULTS: Figure 1 shows the average curve (± SD) of the kicking leg joint angle under both conditions. The changing patterns of the joint angle were almost similar under both conditions. In comparison with SB condition, the hip joint flexion-extension, hip joint abduction, knee joint flexion, ankle joint plantar-dorsiflexion were small under PB condition. In particular, the hip joint extension was hardly observed under PB condition as seen under SB condition. Above all, the SD of the hip joint abduction-adduction and knee joint flexion-extension were large at 50-100% under PB condition.
Figure 2 shows the positional relationship between the CG of the foot and the ball centre at Imp in both conditions. Under SB condition, participants were kicking around the ball centre. On the other hand, under PB condition they were kicking the upper part of the ball.
Table 1 shows the average values (± SD) of rotation speed of the ball under both conditions. Under PB condition, the rotation speed of the ball after Imp was smaller than before Imp.

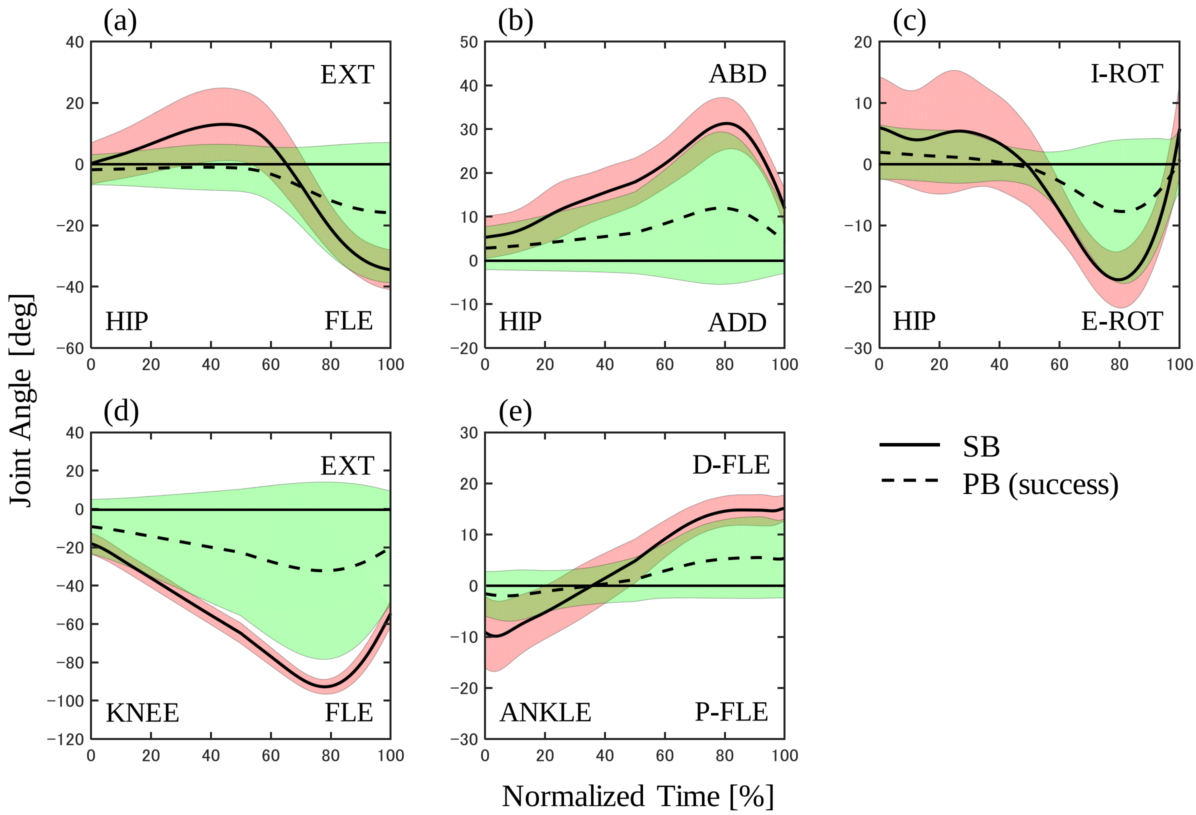

Figure 1: The average curve (±SD) of the kicking leg joint angle.

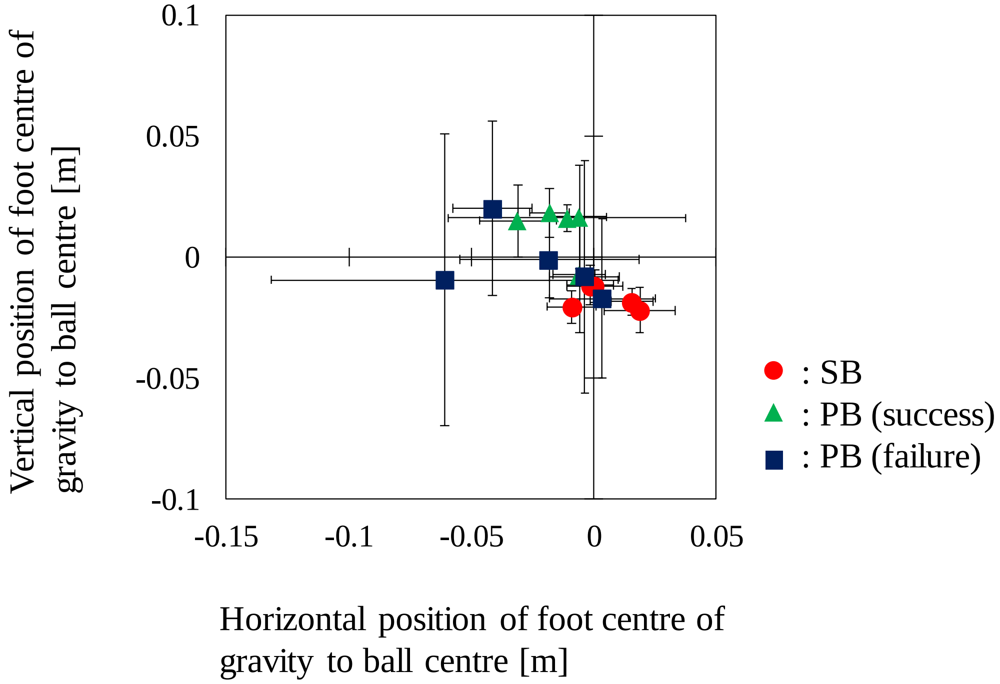

Figure 2: The positional relationship between the CG of the foot and the ball centre at Imp.

Table 1: The average rotation speed (±SD) of the ball under both conditions.

	SB	PB (success)
Rotation speed before Imp (rps)	0.0	8.53 (2.11) *
Rotation speed after Imp (rps)	1.36 (0.96)	1.60 (2.41)

∗ : Significantly different from after Imp (*p*<0.01)

DISCUSSION: Figure 1(a) and 1(b) suggested that the back swing was compact under PB condition. This result agrees with the previous findings that soccer players make a compact motion and perform the kick with emphasis on accuracy when kicking the ground ball (Bono et al., 2002). When kicking a stationary ball such as a set play, since there is no restriction on the movement from KLoff to Imp, it is possible to perform a kick motion to acquire a high foot speed by largely extending and abducting the hip joint. In contrast, when kicking a projected ball, it was speculated that the back swing was compact by suppressing hip joint extension and abduction to match the timing of Imp between the foot and the ball. Also, it was considered that participants hardly flex the knee joint during the forward swing in order to adjust the timing of Imp in a limited time and to prevent their foot speed become too fast under PB condition (Figure 1(d)). In addition, it is assumed that the hip joint abduction-adduction and knee joint flexion-extension affect the adjustment to correspond the swing trajectory to the ball at the time of the forward swing (Figure 1(b) and 1(d)). Moreover, it was inferred that the swing was performed with the ankle joint fixed and rigidified in order to stabilize the direction of kicking out (Figure 1(e)). This seems to have led to a reduction in the joint degree of freedom under PB condition.

Under SB condition, the ball is stationary and has no rotation, therefore it is easy to perform the accurate kick aiming at the target by kicking near the ball centre. In contrast, under PB condition, participants must kick the top spinning ball toward them. In this case, if they kick the lower part of the ball, there is a possibility that the ball has backspin rotation and floats after Imp. However, the ball did not have backspin rotation, and the rotation of the ball was slight (Table 1). Thus, it was presumed that the top spin rotation has occurred by kicking the upper part of the ball, and the ball rotation after Imp was suppressed under PB condition.

CONCLUSION: Soccer players were most likely to take a strategy in which the back swing is compact by reducing the hip joint extension and abduction, and adjusting the hip joint adduction-abduction, knee joint flexion-extension, when kicking a ball without a trap as seen in the game. It was considered that the players performed an accurate pass by kicking the upper part of ball so that the ball did not float.

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