BIOMECHANICAL ANALYSIS OF SAVING MOTION FOR SOCCER GOALKEEPERS FOCUSED ON THE FUNCTION OF LOWER EXTREMITIES

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The purpose of this study was to clarify the function of the lower extremities during the saving motion of a goal keeper (GK). Eleven male university GKs dived toward a ball thrown 3.5 m ahead. Three-dimensional (3D) coordinates and ground reaction forces were obtained with a 3D motion capture system (250 Hz) and 2 force platforms (1000 Hz). The novel findings in this study are summarized as follows: (1) hip extension of the contralateral side leg to the ball is an important motion in the Pre phase and (2) exertion of extension torque at the hip in the early Transition phase has an important role for controlling backward leaning of the thigh during the saving motion.

KEY WORDS: soccer, goal keeper, saving motion, hip extension torque.

INTRODUCTION: In addition to scoring a goal, preventing the opponent from scoring is a key factor for winning a soccer game. One of the roles of the goalkeeper (GK) is to prevent goals. The GK dives toward the ball kicked by opponents to save a goal. According to previous studies, during the take-off phase of the saving motion, the contralateral side (CS) leg controls the magnitude of power, and the ball-side (BS) leg controls both the magnitude and the direction of power to dive directly towards the ball, depending on the ball height (Matsukura and Asai, 2013). Furthermore, Matsukura and Asai (2013) also reported that extension torque at the knee and ankle in CS leg is important to accelerate the center of gravity (CG). However, the function of the hip joint in the CS leg is unclear. Therefore, the purpose of this study was to clarify the function of the lower extremities, especially the CS hip joint, during the saving motion of a GK.

METHODS: Eleven male university GKs (height 1.78 ± 0.04 m, body mass 70.9 ± 5.6 kg) volunteered for the present study. This study was approved by the University of Tsukuba Ethics Committee. Figure 1 shows an overview of the experimental set-up of the present study. We asked the subjects to stand at the specified position on the force platforms and, after a preparatory motion, to dive toward a ball thrown 3.5 m ahead. We asked subjects to jump lightly as a preparatory motion before the saving motion. The throwing direction of the ball (leftward or rightward) was instructed randomly. The global coordinate system was defined as follows: the Y (anteroposterior)-axis was the direction from the subject to the thrower, the Z (longitudinal)-axis was the vertical axis, and the X (mediolateral)-axis crossed with the Y- and Z-axes at a right angle. Ground reaction forces (GRFs) of both legs were obtained with 2 force platforms (9287B, 9287C, Kistler) at 1000 Hz. Three-dimensional (3D) coordinates of 47 reflective markers on a body and 4 reflective markers on a ball were collected using a motion analysis system (Vicon MX+, Vicon) at 250 Hz. GRFs and 3D coordinates were time-synchronized in the motion analysis system. One trial in which each subject showed the best rightward save was selected for further analysis. For these analyses, we defined the right leg as the BS leg and the left leg as the CS leg. 3D coordinates of the markers were smoothened using a fourth-order Butterworth low-pass-digital-filter at cut-off frequencies based on the residual method of Wells and Winter (1980). The cut-off frequencies ranged from 8 to 25 Hz. The ball center was estimated from the reflective markers on the ball using the least-square method. Figure 2 shows the motion events and phases for saving motion as follows. OFF: defined as the instant at which CS or BS leg leaves the ground in the preparatory motion; STR: defined as the instant of 0.4 s to OFF; CSon: defined as the instant at which the CS leg touches the ground after the preparatory motion; CSoff: defined as the instant at which the CS leg leaves the ground after CSon; BSon: defined as the instant at

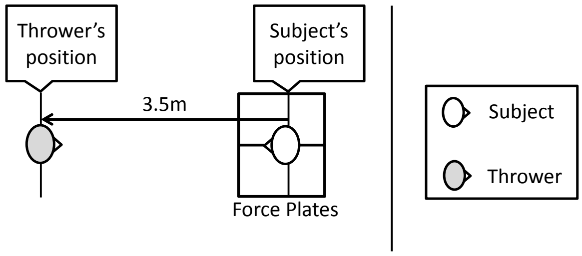


Figure 1 Experimental set up (over view)

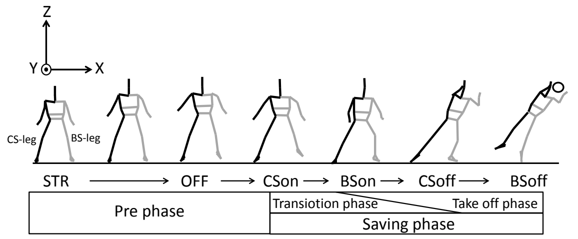


Figure 2 Analysis phases and events

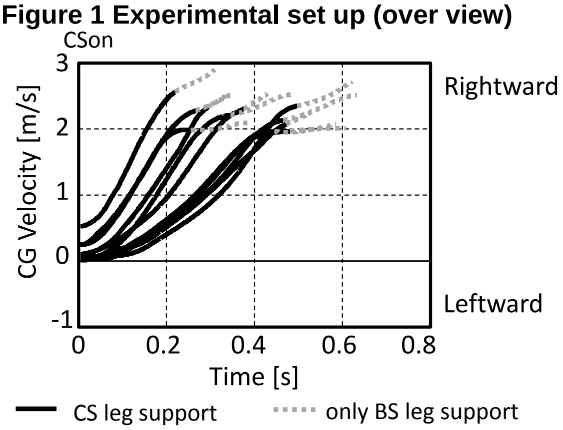


Figure 3 CG velocity during Saving phase

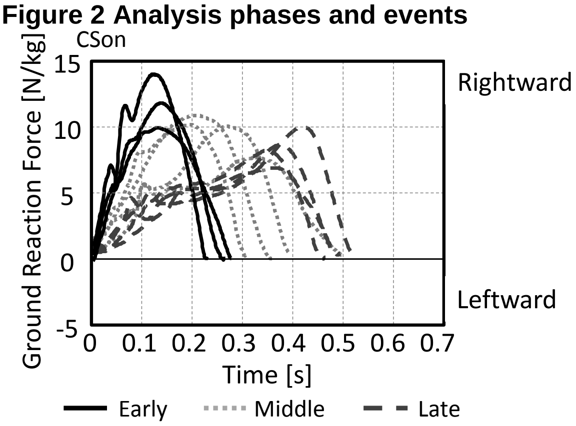
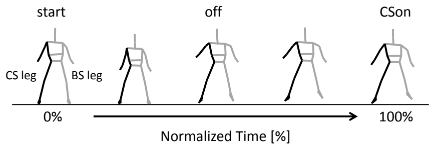


Figure 4 Group selection

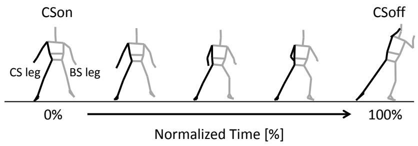
which the BS leg touches the ground after the preparatory motion; and BSoff: defined as the instant at which the BS leg leaves the ground after BSon. Figure 3 shows CG velocity in the mediolateral direction of all subjects during the Saving phase. Average CG velocity of all subjects at BSoff was 2.48 ± 0.29 m/s. All subjects achieved the greatest CG velocity in the CS leg support phase (solid line). Since it is considered that the CS leg has an important role in the saving motion, we focused on the function of the CS leg. We divided the Saving phase into two phases as follows: the Transition phase was CSon to CSoff, and the Take-off phase was BSon to BSoff. To normalize the Pre phase and the Transition phase, we defined 0–100% in each phase. Kinematic and kinetic data were calculated to evaluate the function of the CS leg in the Pre and Transition phases.

RESULTS: In previous studies, GKs motion continuously changed from the preparatory motion to the saving motion (Isokawa, Sakuma, Togari, Ohashi, and Suzuki, 1986). In addition, Nunome, Asai, Ikegami, and Sakurai (2002) reported the average ball velocity of the instep kick was 28.0 ± 2.1 m/s. This indicates that shots from the penalty area (16.5 m from the goal) can reach the goal about 0.5 s. Hence, the GK must shorten the movement time during the saving motion. Therefore, we defined the motion that GK translates continuously from the preparatory motion to the saving motion as a “good saving motion”. We classified all subjects into three groups (Early, Middle, and Late) based on the ground time during the Transition phase and timing of peak GRF in the CS leg. Figure 4 shows the mediolateral component of GRF in the CS leg of all subjects during the Transition phase. Figures 5-a and 5-b show the mean of joint torques about the flexion/extension axis of the hip and knee in the CS leg for the Early and Late groups during the Transition phase (a: Early, b: Late). In the hip joint, the Early group exerted a larger extension torque than the Late group (0–50%). In the knee joint, the Late group exerted the extension torque for a longer time during the Transition phase, and the peak value was lower than the Early group. Figures 6-a and 6-b show the mean of joint angles about the flexion/extension axis of the hip and knee in the CS leg for Early and Late groups during the Transition phase (a: Early, b: Late). In the hip joint, the Early group continued to extend during the Transition phase; in contrast, the Late group flexed the hip joint for 0–50% of the Transition phase, then extended the hip joint. Comparing the timing of extension of the hip joint with the knee joint, the hip joint was extended earlier than the knee joint in the Early group. In the Late group, the hip and knee joints extended at the same time.

Pre phase



Transition phase



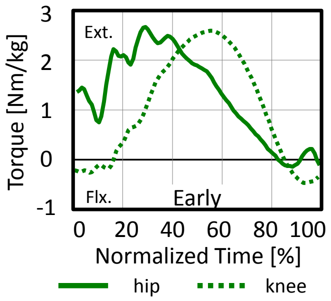


Figure 5-a Joint torques of hip and knee in the CS leg for Early group during the Transition phase

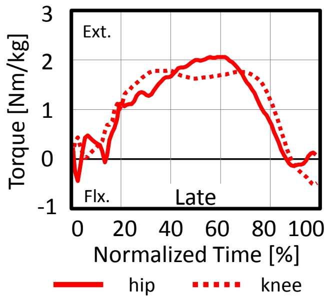


Figure 5-b Joint torques of hip and knee in the CS leg for Late group during the Transition phase

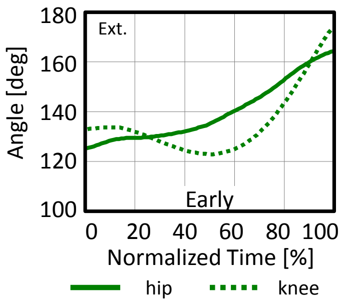


Figure 6-a Joint angles of hip and knee in the CS leg for Early group during the Transition phase

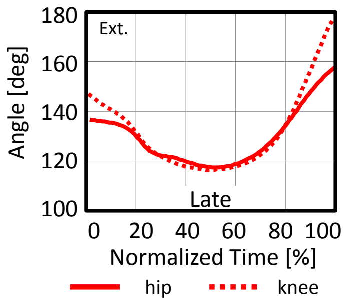


Figure 6-b Joint angles of hip and knee in the CS leg for Late group during the Transition phase

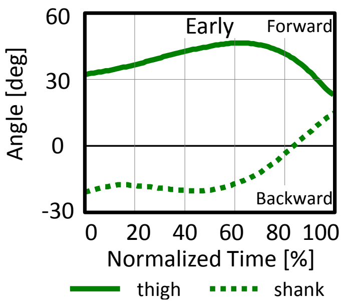


Figure 7-a Segment angles of thigh and shank in the CS leg for Early group during the Transition phase

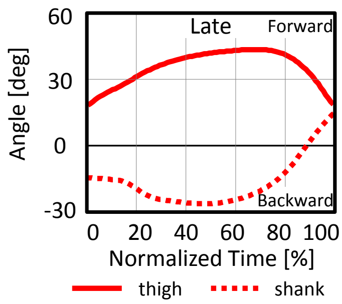


Figure 7-b Segment angles of thigh and shank in the CS leg for Late group during the Transition phase

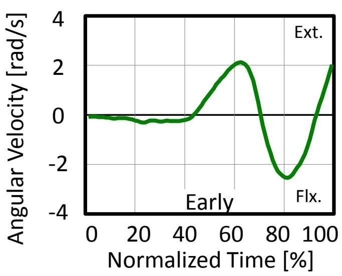


Figure 8-a Joint angular velocities of hip and knee in CS leg for Early group during Transition phase

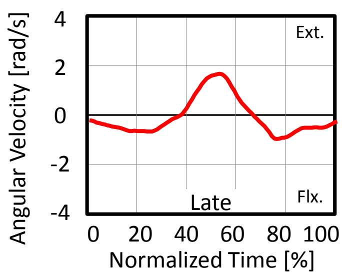


Figure 8-b Joint angular velocities of hip and knee in CS leg for Late group during Transition phase

Figures 7-a and 7-b show the mean of forward/backward lean angles of the thigh and shank in the CS leg for the Early and Late groups during the Transition phase (a: Early, b: Late). In the thigh, the Early group stayed in the backward leaning position for 0–50% of the Transition phase, but the Late group continued to lean backward for 0–50% of the Transition phase, after which both the Early and Late groups changed to a forward leaning position. In the shank, both the Early and Late groups continued to lean forward for 0–70% of the Transition phase and stayed in a forward leaning position during the Transition phase. Figures 8-a and 8-b show the mean of joint angular velocities about the flexion/extension axis of the hip in the CS leg for the Early and Late groups during the Pre phase (a: Early, b: Late). In the terminal Pre phase (90–100%), the Early group increased the extension angular velocity, while the Late group recorded the flexor angular velocity.

DISCUSSION: According to previous studies, in a rebound jump, grounding in a flexed leg position and minimizing eccentric extension torque at the hip were important to obtain a large impulse with a shorter foot contact time (Zushi and Takamatsu,1996). At CSon, the Late group had a more extended position than the Early group. It is assumed that this is one of the reasons that the foot contact time of the Late group was longer than that in the Early group. Furthermore, exertion of eccentric hip extension torque indicates that the hip joint is flexing and that hip joint torque is extending. Kinematically, it is assumed that the thigh leaning backward accompanies hip and knee joint flexion when grounding. Therefore, the thigh leaning backward increases foot contact time. Kinetically, it is assumed that extension torque at the hip helps prevent the thigh from leaning backward when grounding. Thus, exerting extension torque at the hip in the early Transition phase is important to obtain the larger impulse in a shorter time. In the previous study, Matsukura and Asai (2013) reported that extension torque at the knee and ankle in the CS leg is important to accelerate CG during the saving motion of a GK. In addition, we revealed that exerting extension torque at the hip is also important in the early Transition phase. Moreover, as shown in Figure 8-a, the Early group showed increased extension angular velocity in the terminal Pre phase (90–100%). This may help hip extension in the early Transition phase. In addition, grounding with extension of the hip joint may help prevent the thigh from leaning backward in the Transition phase. Hence, it is assumed that extending the hip joint in the preparatory motion during the saving motion of a GK is also important to obtain the large impulse in a shorter time.

CONCLUSIONS: The purpose of this study was to clarify the function of the lower extremities, especially the hip joint in the CS leg, in the saving motion. The new findings in this study are summarized as follows: (1) hip extension of the CS leg is an important motion in the Pre phase, and (2) exertion of extension torque at the hip in the early Transition phase has an important role for controlling backward leaning of the thigh in the saving motion. These findings might be useful to improve a GK's saving motion.

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