KINETIC ANALYSIS OF THE SUPPORT LEG IN SOCCER INSTEP KICKING

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The purpose of the present study was to illustrate the kinetic aspect of the support leg during soccer instep kicking. The motion was captured together with the ground reaction force using a motion capture system. Moments and angular velocities of ankle, knee and hip joint for the support leg were calculated. The ankle joint was passively rotated three-dimensionally, during which these motions were counteracted to the joint moments. The knee joint motion, likewise, counteracted to the joint moment from the instant of the touch-down to just before ball impact. It is likely that the ankle and knee joints have a role in attenuating the impact of landing. In contrast, positive power due to the knee and hip extension moments appeared just before ball impact. It can be assumed that those motions may serve to lift the body thereby indirectly contributing the kick leg swing.

KEY WORDS: joint, moment, Torque, angular velocity, three-dimensional.

INTRODUCTION: Good kicking technique is an important skill of a soccer player. Understanding the biomechanics of soccer kicking, therefore, is particularly important for guiding and monitoring the training process (Kellis & Katis, 2007). Among numerous types of kicking, instep kicking is one of the most fundamental and common techniques when a faster and more powerful ball needs to be generated. Likewise, the instep kicking is, without doubt, the most widely studied soccer specific technique (Lees & Nolan, 1998) and has attracted a vast amount of researchers' attention to date.
While much is known about the biomechanics of the kicking leg (Levanon & Dapena, 1998; Nunome, Asai, Ikegami & Sakurai, 2002; Nunome, Ikegami, Kozakai, Apriantono & Sano, 2006), the support leg has received little interest in the research literature (Kellis, Katis & Gissis; 2004; Lee, Asai, Andersen, Nunome & Sterzing 2010). Lees, Steward, Rahmana & Barton (2009) reported the support leg kinetics during kicking. However, to date, the information of support leg motion was mostly limited within the sagittal plane motion while the instep kicking is characterized by segmental and joint rotations in multiple planes (Kellis & Katis, 2007). We aim to provide evidence which will clarify the kinetic aspects of the support leg in detail as well as its essential functions during kicking. In the present study, an attempt was made to detect the role and efficacy of the support leg motion on the soccer instep kicking motion. The purpose of the present study, therefore, was to illustrate the kinetic aspect of the support leg during soccer instep kicking, using a three dimensional motion analysis.

METHODS: Twelve male experienced (career: 14.6±1.3 y, at least 12y) collegiate soccer players (age: 20.9±0.5 y, height: 170.8±5.3 cm, body mass: 69.0±7.3 kg), from teams in the regional top collegiate league, volunteered to participate in this study. All subjects preferred to kick the ball with their right leg. Their kicking motions were captured using a 10-camera digital optical motion capture system (Vicon Nexus, Vicon Motion Systems, Oxford, UK) at 500Hz. The cameras were fixed on tripods and were placed around the space of analysis (2.5 m×3.5 m×2.0 m). Ground reaction force of the support leg was recorded simultaneously at 1000Hz by a force platform (Type 9281E, Kistler Instruments, Winterthur, Switzerland)

which was set at floor level. The motion capture system and force platform were synchronized electrically.
After an adequate warm-up, subjects were instructed to perform maximum effort instep kicks, of a stationary ball using their preferred leg (right). Kicks were directed to the center of the target placed 6 m away from ball position. The approach run up was standardized to 3 steps. In all trials, the subjects landed their support leg on the bare surface of the force platform. All subjects performed 10 consecutive trials so that 2 successful shots could be selected, both having a good foot-to-ball contact and hitting the center region of the target.
The support leg was modeled as a three-link kinetic chain composed of the foot, the shank and the thigh segment. The resultant joint moment vector of each joint was calculated in accordance with Newton-Euler equation of motion. Ankle joint moment and angular velocity vectors were decomposed into three components: dorsal flexion/plantarflexion, inversion/eversion and adduction/abduction. Knee joint moment and angular velocity vectors were projected onto one axis: extension/flexion. Hip joint moment and angular velocity vectors were separated into three components: adduction/abduction, flexion/extension, and external/internal rotations.
The period from touch-down of the support leg to ball impact was normalized to 100%. Additionally, based on the length of that period, the kicking motion was described from -50% to 100%. The period from -50% to 0% (before touch-down) and that from 0% to 100% (from touch-down to ball impact) were termed flight phase and support phase, respectively.

RESULTS: Figure 1 shows the change of average (±SD) joint moments and angular velocities of the ankle joint for the support leg. As shown, the ankle experienced a rapid multi-axial motion which did not accompany the action of the joint moments. From the approximate instant of touch-down, the ankle was rapidly forced into plantarflexion and inversion. Right thereafter, the ankle was forced into opposite directions: dorsal flexion and eversion. From the mid support phase, consistent abduction motion appeared toward ball impact. Meanwhile, the ankle joint moments counteracted the ankle joint motions, in which the plantarflexion and inversion moments appeared while the dorsal flexion and eversion motions occurring. Moreover, a slight adduction moment was seen from the earlier part of the support phase (25 %) when the abduction motion was occurring.

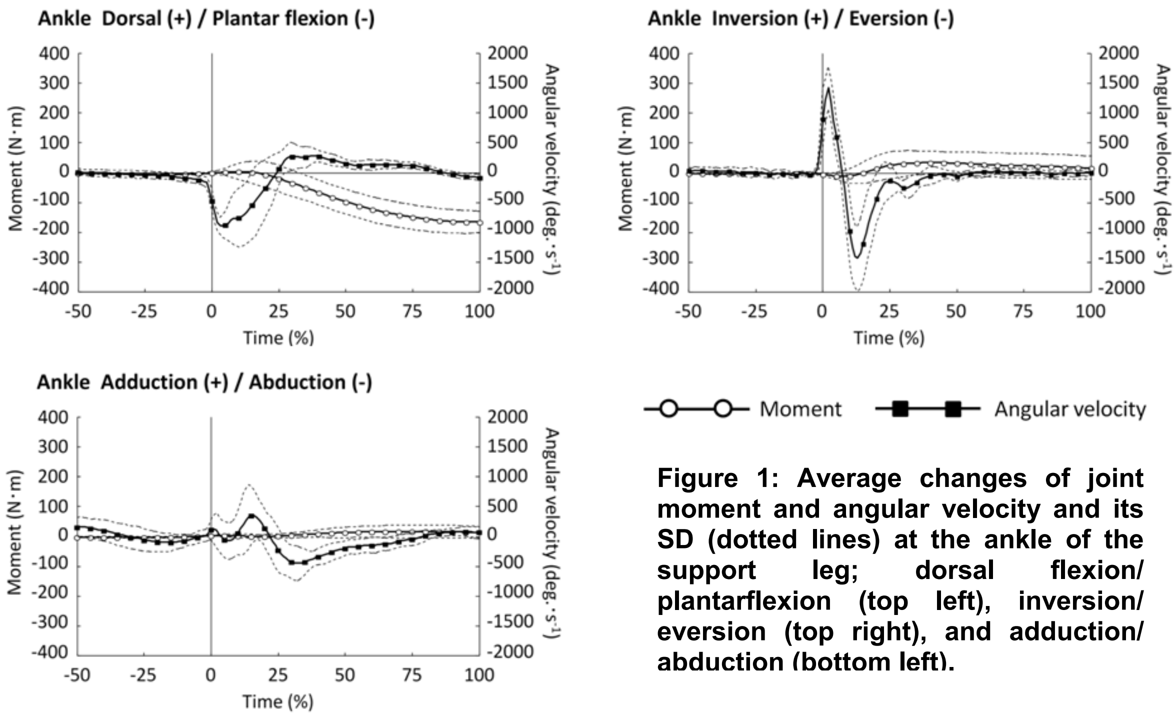

Figure 1: Average changes of joint moment and angular velocity and its SD (dotted lines) at the ankle of the support leg; dorsal flexion/ plantarflexion (top left), inversion/ eversion (top right), and adduction/ abduction (bottom left).

Figure 2 shows the change of average (±SD) joint moment and angular velocity of the knee for the support leg. Similar to the ankle, the joint moment counteracted the joint motion in most part except the phase immediately before ball impact (after 75 % of the time). During the flight phase, the flexion moment was dominant while the knee was extending toward the touch-down. Soon after the touch-down, the knee joint moment came to generate a large extension moment while the knee was rapidly flexing. Immediately before ball impact, the knee came to extend again while a large extension moment was constantly exhibited.

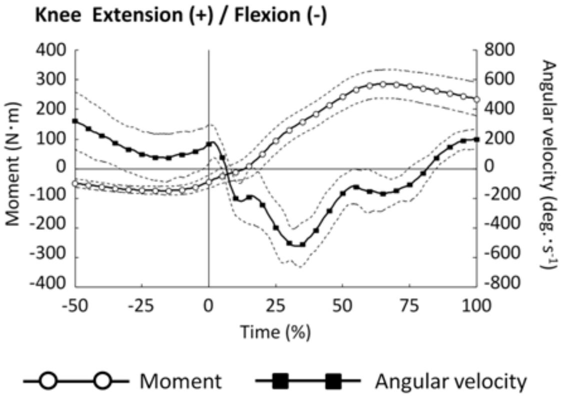

Figure 2: Average change in the joint moment and angular velocity and its SD (dotted lines) at the knee of the support leg; extension/ flexion.

Figure 3 shows the change of average (±SD) joint moments and angular velocities of the hip for the support leg. All through the flight and support phase, the hip constantly exhibited the extension moment recorded as largest moment. Meanwhile, the hip extension motion was maintained except for the earlier part of the support phase (25% to 50%), in which a slight hip flexion motion was observed. There was a noteworthy adduction angular velocity increase during the mid support phase (around 50%). A shift of the joint moment from adduction to abduction occurred simultaneously; however, these magnitudes were not substantially large. From the instant of the touch-down, the hip rapidly forced into external rotation while a slight internal rotation moment was exhibited. Subsequently, a noteworthy internal rotation appeared from the earlier part of the support phase (25 %), still generating a slight internal rotation moment.

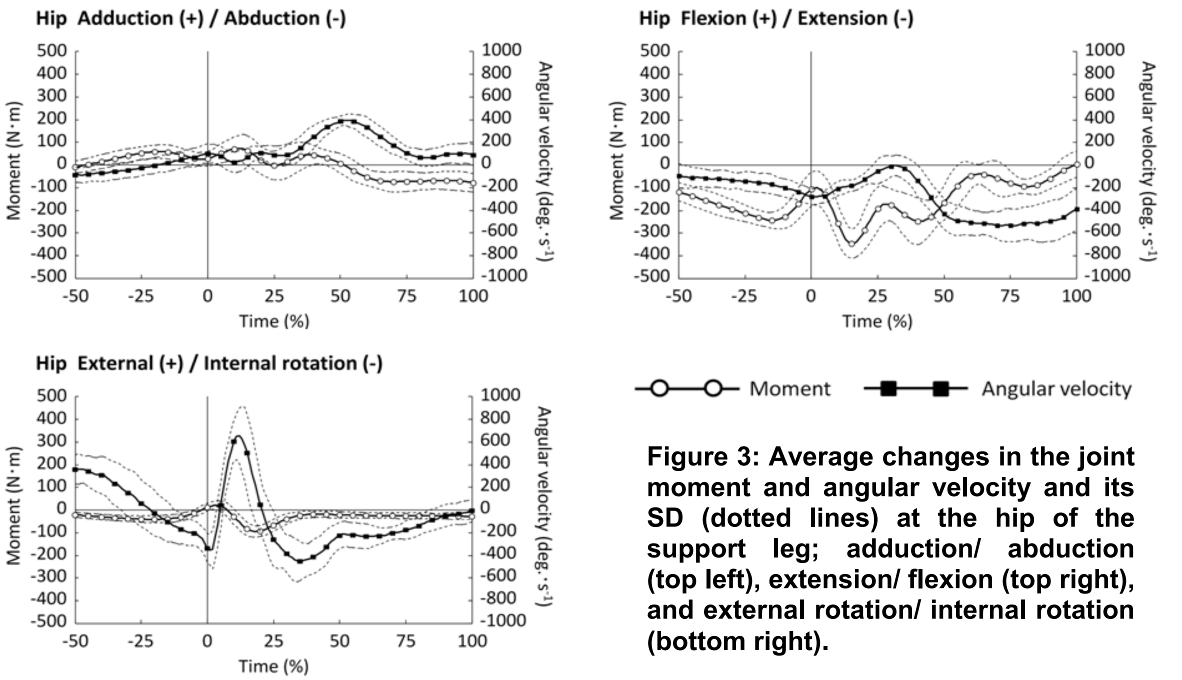

Figure 3: Average changes in the joint moment and angular velocity and its SD (dotted lines) at the hip of the support leg; adduction/ abduction (top left), extension/ flexion (top right), and external rotation/ internal rotation (bottom right).

DISCUSSION: To date, there is only one study (Lees et al. 2009) which showed the joint dynamics of the support leg during kicking. However, the study solely reported the kinetic parameters within the sagittal plane. Thus, of the variables obtained in the present study, the data for ankle dorsal/plantar flexion, knee extension/flexion and hip extension/flexion were comparable to those of the study of Lees et al. (2009). Overall, the general patterns of the joint moments and angular velocities were relatively similar between the two studies.

For the kinetic variables about the coronal, transversal joint axes, there are no available studies to be compared directly with the present study. A rapid ankle inversion/eversion and

hip external rotation motions appeared instantaneously after the touch-down. In contrast, these joints exhibited negligible amount or contrary joint moments in relation to these motions. It is logical to assume that these rapid motions were triggered by the impact peak of the ground reaction force at the instant of landing.
It reasonable to assume that the support leg has two major roles during kicking: to resist the large external force in order to stabilize the body and to transfer the body momentum to the thigh, as the proximal segment. Thereby, it contributes to a proximal–distal sequential motion of the swing leg. The former can be characterized by negative power due to joint moments; in contrast, the latter can be extracted by positive power due to joint moments. In most joints of the support leg, the joint moments were not associated or counteracting the joint motions. As the ankle joint never exhibited positive power throughout the support phase, it can be interpreted that this joint works exclusively for absorbing the large external force from the ground. That role of the ankle joint seems very reasonable because the ankle is the most distal joint that will receive the ground reaction forces first. Furthermore, the muscles to control the ankle joint are typically smaller than the other leg muscles controlling more proximal joints. Immediately before ball impact, the knee and hip flexion motions become to be associated with the knee extension and hip flexion joint moments. These motions suggested there are some positive roles of the support leg on the kicking action. Nunome & Ikegami (2005) demonstrated that linear accelerations (especially upward component) of the hip joint on the swing leg affected positively to increase the lower leg angular velocity. The positive power due to the knee and hip extension moments seen just before ball impact most likely serve to lift the body and added the vertical acceleration of the hip joint of the swing leg.

CONCLUSIONS: It can be concluded that: (1) planter flexion, inversion/ eversion motions of the ankle joint and external rotation motions of the hip joint which suddenly appear just after touch-down were triggered by the impact peak of ground reaction force at the instant of landing. (2) Negative powers produced at the ankle, knee and hip joints acted to absorb the shock of the landing. (3) The knee and hip extension motions immidiatly before ball impact contribute toward accelarating a swing of the kicking leg.

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