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KINETICS OF THE SUPPORT LEG JOINTS IN THE SIDE STEP CUTTING TECHNIQUE

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The purposes of this study were to investigate the kinetics of the support leg joints and to identify roles of the joints in the side step technique. Twenty male university ball game players performed three running trials of the cutting direction of 30, 60, and 90° with the side step cutting technique. A force platform technique and three-dimensional motion analysis technique were used. Roles of the ankle, knee, and hip extensors did in the side step cutting technique were similar to those of the straight sprint running. The negative and positive powers exerted by the ankle plantar flexors and knee extensors absorbed and generated the mechanical energy during the support phase in the cutting motion. The hip seemed not to generate great energy but to control the body posture, especially in directions 60° and 90°.

KEY WORDS: cutting, three-dimensional motion analysis, joint kinetics, inverse dynamics.

INTRODUCTION: In most of ball games, players have to change their running direction to keep up with the motions of a ball and players on the same and opposite sides. The technique used to change the direction of running is called cutting motion and considered as one of the most important techniques for ball game players. Although there are some techniques in the cutting motion, the side step cutting technique, in which the direction is changed by planting one foot opposite to the new direction, is one of the most common techniques for ball game players (Figure 1). Although, the support leg plays an important role to change the speed and direction of the center of gravity (CG) velocity during the cutting, it has not been investigated how the support leg joints contribute to change in the speed and direction of the CG. The kinetics of the support leg joints in the side step cutting motion can be useful information to improve cutting performances and design appropriate training programs. Some studies have already addressed the kinetics of the support leg in the cutting motion (McLean et al., 2005; Sigward and Powers, 2007). They discussed the risk of leg injuries in the cutting motion, but they did not determine the effects of the motion technique on cutting performance. Therefore, the purposes of this study were to investigate the kinetics of the support leg joints and to identify roles of the joints in the side step technique.

METHODS: Data Collection and Processing: Twenty male university players of soccer, basketball, rugby, and handball (age, 20.3±0.8yrs; height, 1.76±0.06m; body mass, 73.15±7.69kg) participated in this study. They performed three running trials of the cutting direction of 30, 60, and 90° with the side step cutting technique (Figure 2). The subjects started from the 10 m line to a force platform (9287B, Kistler Instrument AG) and ran through the finish line. They were asked to step on the force platform with a single foot and run through the timing area as quickly as possible. Three dimensional coordinates of 47 retro-reflective markers fixed on the body were collected with Vicon T10 system (Vicon Motion Systems, Ltd.) using eight cameras operating at 250 Hz. The ground reaction forces were obtained with a Kistler force platform embedded in the laboratory floor at a sampling rate of 1000 Hz. These data were captured simultaneously and time-synchronized with the Vicon system. The coordinates were smoothed by a Butterworth digital filter with cut-off frequencies of 7.5 to 12.5 Hz decided by the residual method (Winter, 2004).
The CG coordinates were estimated after the body segment parameters of Japanese athletes (Ae, 1996) and then differentiated for the velocity and acceleration of the CG. The direction change angle was defined as the angle between the horizontal velocity vectors of

the whole body CG at the foot strike and at the toe-off. Joint angular velocity was obtained as the difference in the angular velocities of two adjacent segments composing the joint by subtracting the proximal segment angular velocity from distal one in the global coordinates system, and was transformed into the joint coordinates system. An inverse dynamics approach with a three-rigid-body model consisting of the foot, shank, and thigh segments was used to calculate the joint torques at the ankle, knee, and hip of the support leg. The joint torque power was calculated as a dot product of joint torque and joint angular velocity.

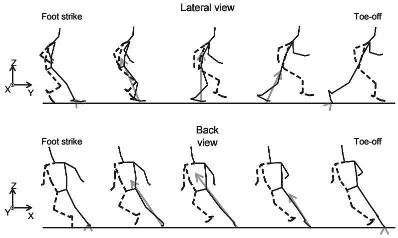

Figure 1: The sequence stick picture and the ground reaction force vector of the side step cutting technique (foot strike to toe-off) in direction 90º (Top, lateral view; bottom, back view).

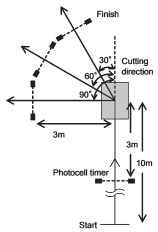

Figure 2: The experimental set-up and three cutting directions.

The joint torque and joint torque power were divided by the subjects' body mass, and normalized by the support time as 100% and then averaged. The ANOVA was used to test effects of the cutting angle with a significant level set 5%. Scheffe's post hoc test was used to determine significant difference among the cutting angles.

RESULTS: The horizontal CG velocity decreased after the foot strike to the mid-support, and then increased toward the toe-off during the support phase of all directions. The magnitudes of the CG velocity at the foot strike were 6.88±0.31 m/s in direction 30°, 5.49±0.46 m/s in direction 60°, 3.82±0.28 m/s in direction 90°. The CG velocity was greater in direction 30° than directions 60° and 90° ($p<0.01$), and in direction 60° than direction 90° ($p<0.01$) at three instants. The direction change angle of the CG velocity was smaller in direction 30° than directions 60° and 90° ($p<0.01$), and smaller in direction 60° than direction 90° ($p<0.01$).
Figure 3 shows averaged patterns of the joint angular velocity (top), joint torque (middle), and joint torque power (bottom) of the ankle (left) and knee (right) of support leg. The ankle joint dorsiflexed after the foot strike and then plantar flexed, and the plantar flexion torque was exerted throughout the support phase in all cutting directions. The peak plantar flexion torque was greater in direction 30° (3.61±0.64Nm/kg) than directions 60° (3.19±0.54Nm/kg) and 90° (2.83±0.58Nm/kg) ($p<0.01$), and greater in direction 60° than direction 90° ($p<0.05$). The torque power of the ankle joint was negative in the first phase and positive in second phase, and the peak positive power was greater in direction 30° (39.37±10.76W/kg) than directions 60° (30.74±8.34W/kg) and 90° (23.15±7.39W/kg) ($p<0.01$), and greater in direction 60° than direction 90° ($p<0.05$).
The knee joint flexed after the foot strike and began to extend before the mid-support, and the extension torque was exerted almost the support phase, and it peaked around 5% and 40% support time, but there was no significant differences in the peak extension torque among three directions. The knee joint torque power was negative in the first phase and positive in the second phase, but there were no significant differences in the peak extension torque and the peak torque power among three directions.
Figure 4 shows averaged patterns of the joint angular velocity (top), joint torque (middle), and joint torque power (bottom) of the hip flexion/extension (left) and adduction/abduction (right) of support leg. Since the joint torque and torque power of the hip external/internal rotation were much smaller than those of the others, those results were left out here for simplicity. The hip joint extended throughout the support phase and exerted the large extension torque in the first phase and the flexion torque in the second phase. The peak extension torque was greater in directions 30° (4.50±1.29Nm/kg) and 60° (4.53±1.55Nm/kg) than direction 90°

(3.30±1.09Nm/kg), while there were no significant differences in the peak flexion torque. The hip flexion/extension torque power was positive in the first phase and negative in the second phase. The positive peak power was larger in direction 30° (14.11±5.78W/kg) than directions 60° (10.29±5.02W/kg) and 90° (6.44±4.66W/kg) (30°-60°; p<0.05, 30°-90°; p<0.01), and larger in direction 60° than direction 90° (p<0.01). The negative peak power was larger in direction 30° (-15.89±5.93W/kg) than directions 60° (-10.40±3.70W/kg) and 90° (-8.26±4.45W/kg) (p<0.01), and larger in direction 60° than direction 90° (p<0.05).

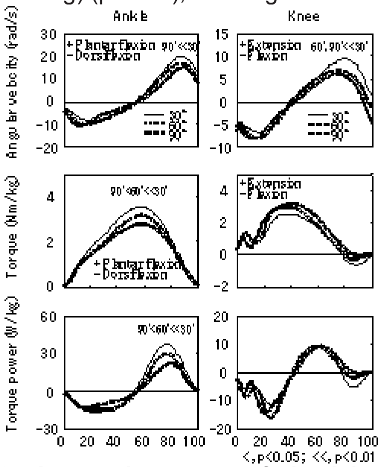

Figure 3: Averaged patterns of the joint angular velocities(top), joint torques (middle), and joint torque powers (bottom) of the ankle (left) and knee (right) of the support leg during the support phase.

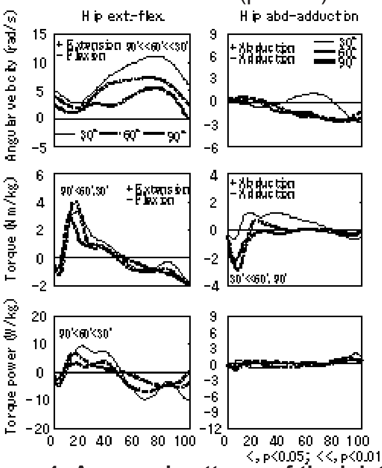

Figure 4: Averaged patterns of the joint angular velocities (top), joint torques (middle), and joint torque powers (bottom) of the hip flexion/extension (left) and adduction/abduction (right) of the support leg during the support phase.

For the adduction/abduction, different patterns were found between direction 30° and directions 60° and 90°. The hip in directions 60° and 90° adducted after the 30% support time, while small adduction velocity was seen in direction 30°. The hip in directions 60° and 90° exerted the large adduction torque immediately after the foot strike, but no great adduction/abduction torque was exerted. In direction 30°, the hip exerted abduction torque after the 20% support time. The peak adduction torque was smaller in direction 30° (-1.43±1.13Nm/kg) than directions 60° (-3.49±1.47Nm/kg) and 90° (-3.19±1.31Nm/kg) (p<0.01). The hip adduction/abduction torque power was changed around zero throughout the support phase, and there were no significant differences in the torque powers.

DISCUSSION: The ankle plantar flexors exerted the negative and positive powers during the support phase in all directions. These indicate that the ankle contributed to absorb the mechanical energy of the body in the first phase and generate it in the second phase.

The knee extensors exerted the negative and positive powers, indicating that the knee extensors contributed to absorb the mechanical energy of the body in the first phase and generate the mechanical energy to accelerate the body center of gravity in the second phase. These results were similar to results of Neptune et al. (1999), reported that the eccentric contraction of the knee extensors contributed to decelerate the body center of gravity in the braking phase and its concentric contraction helped to accelerate the body in the propulsive phase in cutting motion.

The hip extensors exerted the positive power in the first phase. Since the foot contact with the ground in front of the body, viewed in the sagittal plane, the moment of the ground reaction forces, especially the vertical component about the hip joint was applied. Therefore, the hip extension torque would be extended to prevent the hip joint from collapsing immediately after the foot strike. Since the knee extension torque decreased after 10 %

support time and the hip extension torque peaked about 15% support time, the hip extensors would compensate for the decrease in the knee extension torque to support the body. The hip extensors exerted the positive power in the first phase and the flexors exerted the negative power in the second phase. These results suggest that the hip contributed to maintain the mechanical energy and speed of the center of gravity in the first phase and constrain hyper-extension of the hip in the second phase and the early recovery phase. Ae et al. (1986) investigated the kinetics of the leg joints in sprint running. They revealed that the ankle and knee extensors exerted the negative power in the first phase and positive power in the second phase, although the hip extensors exerted the positive power after the foot strike and then exerted negative power. The results of the kinetics of the support leg joints in this study and investigations on sprint running indicate that roles of the leg joints during the cutting motion were similar to those of the straight sprint running.
It was expected that the abduction torque at the hip would be exerted to increase the inward ground reaction force and to change the direction of the CG velocity. However, the hip exerted the adduction torque immediately after the foot strike, especially in directions 60° and 90°. Since the subjects with foot planting outside in cutting motion leaned their support leg inward, the abduction moment of the vertical ground reaction force was supposed to be applied around the hip joint. Therefore, the hip adduction torque would be exerted to prevent the hip joint from collapsing and stabilize the body immediately after the foot strike. The inward ground reaction force peaked about 50% support time, and the ankle and knee exerted the large extension torques around the mid-support. While the hip flexion/extension torque was close to zero about 50% support time. These results suggest that the ankle and knee contributed to increase the inward ground reaction force rather than the hip joint because the support leg leaned inward. The hip may play a role to control the posture, especially in directions 60° and 90°. On the other hand, the hip exerted the abduction torque after 10% support time in direction 30°. Since the peak extension torque of the knee was smaller in direction 30° than direction 90°, the hip may have had to exert the abduction torque to compensate the small torque of the knee and to increase the inward ground reaction force. In addition, the hip adduction velocity decreased after 30 % support time and the hip abducted in direction 30°. This change of the hip adduction/abduction velocity suggests that the large abduction torque of the hip joint in direction 30° increased the abduction velocity.

CONCLUSIONS: Roles of the ankle, knee, and hip extensors did in the side step cutting technique were similar to those of the straight sprint running. The negative and positive powers exerted by the ankle plantar flexors and knee extensors absorbed and generated the mechanical energy during the support phase in the cutting motion. The hip seemed not to generate great energy but to control the body posture, especially in directions 60° and 90°. In direction 30°, however, since the knee extension torque was smaller than direction 90°, the hip exerted the abduction torque to compensate the small torque of the knee and to increase the inward ground reaction force.

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