

THE ANALYSIS OF KINEMATICAL CHARACTERISTICS IN TAEKWONDO ROUNDHOUSE KICK

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The purpose of this study was to analyze the kinematical characteristics of lower torso and kicking leg in Taekwondo roundhouse kick (RHK), which was characterized by kicking speed and continuous kicking. The results were summarized as follows: 1) The kicking speed pattern was similar between the two subjects at 90% time of RHK. 2) One subject produced kicking speed mainly by the movements of hip joint and knee joint, while the other by the movements of lower torso and knee joint. 3) The movement of lower torso for the latter subject had a larger range of motion than the other, which had the disadvantage for the continuous kicking. Thus, RHK techniques for both kicking speed and continuous kicking are influenced by the presence of whipping like motion which is characterized by the limited lower torso movement and the faster movement of lower limb joints.

KEY WORDS: martial arts, kinematical contribution, whipping like motion, kicking speed, continuous kicking

INTRODUCTION: Taekwondo is one of the Olympic events and famous for characteristic of various kicking techniques. To win the competition, it is necessary to kick the opponent's lower torso or head and score more points. Previous studies show that a greater number of roundhouse kick (RHK) was recorded in Taekwondo competition (Falco, Landeo, Menescardi, Bermejo, & Estevan, 2012). The RHK has been investigated under various experimental conditions (Kim, Kim, & Im, 2011; Kim, Kwon, Yenuga, & Kwon, 2010), and is considered as a primary technique for Taekwondo beginners to practice. In addition, the techniques to kick at a high speed and kick continuously with quick motion are very important techniques to win the competition. Then, it is important to clarify their biomechanical mechanisms. The purpose of this study was to analyze the kinematical characteristics of lower torso and kicking leg joints in Taekwondo RHK, especially the techniques for producing faster kicking speed and kicking continuously with quick motion.

METHODS: Three male and three female Japanese Taekwondo athletes (age: 20-28 years, height: 157-183 cm, weight: 49-68 kg, and experience: 2-10 years) participated in this study with an informed consent. Experiment attempt was RHK to a kicking mitt with a preferred leg. The height of kicking was same as subject's torso. The distance from the front leg to a kicking mitt was adopted voluntarily (distance/height: 0.57 ± 0.05). The global coordinate system was defined as shown in figure 1; Y (anteroposterior) axis was direction to the kicking mitt, Z (longitudinal) axis was vertically axis, and X (mediolateral) axis was crossing with these two axis at right angle. The 3D coordinates of the reflective markers on body segments and the kicking mitt were measured by a motion capture system (Vicon MX+, 250Hz), and were filtered with a Butterworth digital filter (10-15Hz). In order to unify a preferred leg, the subject kicking with a left leg was converted to kicking with a right leg. The RHK was divided into three phases with four events as shown in Figure1, start (STR) was defined as an instant that the speed of whole body center of gravity surpassed 0.1m/s or an instant of minimum speed of whole body center of gravity, toe off of kicking leg (TOF), maximum knee flexion of the kicking leg (MKF), and impact (IMP). To normalize a kicking motion, we defined 0%, 50%, 80%, and 100% time as STR, TOF, MKF, and IMP respectively. The following data were calculated; kicking speed, joint angles, joint angular velocities of kicking leg, kicking speed produced by movements of lower torso and joint of kicking leg (kinematical contribution). The kicking speed

was defined as a speed of the head of third metatarsal bone. The kinematical contribution was calculated by the mathematical model proposed in the previous studies (Sprigings, Marshall, Elliott, & Jennings, 1994).

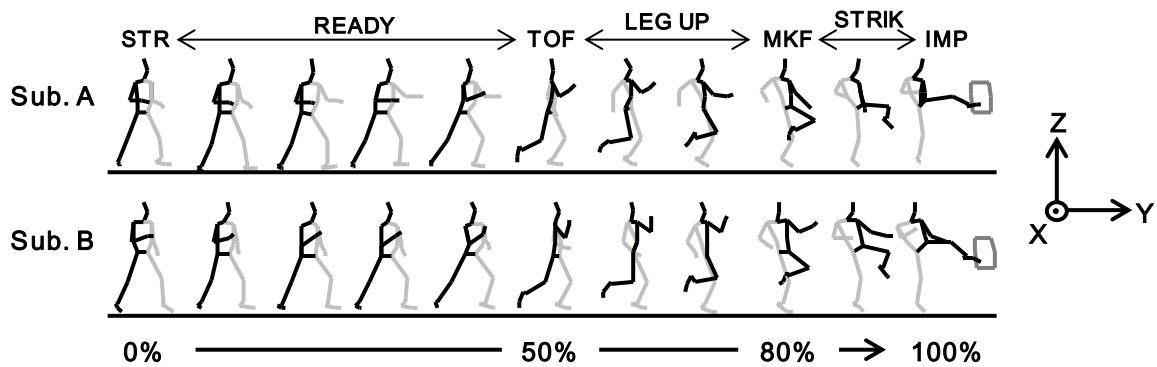


Figure 1: The motion of roundhouse kick in Taekwondo .

RESULTS: We showed the results of two male subjects among the six subjects. The speed and contribution patterns of female subjects are similar to those of male subjects. Subject A and subject B are high level players in Japan. The kicking speed of subject A is fastest among the subjects. In addition, the pattern of contribution is different from the average data. While not only the kicking speed but also the contribution of subject B is similar to the average data. Table 1 showed the kicking time in every phase (READY: from STR to TOF, LEG UP: from TOF to MKF, STRIK: from MKF to IMP) and the kicking speed at the instant of every event. Although the time of READY was different between the two subjects, the time of LEG UP and STRIK were almost same. We focused on the LEG UP and STRIK phases in order to investigate the mechanism of producing faster kicking speed, since the kicking speed at TOF was almost 0 m/s. Although subject A had a little bit lower kicking speed at MKF, subject A had the faster kicking speed at IMP. The difference of the kicking speed between the two subjects at IMP was 2.5 m/s. Figure 2 showed the kicking speed produced by movement of lower torso and joint of kicking leg. The pattern of kicking speed was similar during the first half of LEG UP. Although subject B had the larger kicking speed at 70% time than subject A, the kicking speed of subject A increased rapidly after 70% time. Figure 3 showed the contribution of lower torso, hip joint, and knee joint movement to kicking speed. Considering Figure 3 with Figure 1, the kicking speed generation was considered as follows. The contribution of lower torso and kicking leg joints movement to kicking speed was influenced by the angular velocity, distance from every joint to the point of the head of third metatarsal bone. For subject A, the contribution of lower torso forward-backward tilting was large at 65% time. As soon as the contribution of forward-backward tilting decreased sharply after 65% time, the contribution of hip joint flexion-extension increased rapidly. The contributions of lower torso left-right rotation and hip joint flexion-extension produced mainly the kicking speed thereafter. The contribution of hip joint flexion-extension increased again rapidly at 90% time, since the contribution of lower torso left-right rotation decreased sharply. In the knee joint, the contribution of flexion-extension increased rapidly before MKF. The contribution of hip joint flexion-extension, internal-external rotation, and knee joint flexion-extension produced a great part of kicking speed at IMP. On the other hand, for subject B, the contribution of lower torso left-right rotation increased until 60%. The contribution of lower torso left-right rotation increased continuously nevertheless the angular velocity of lower torso left rotation was constant from 60% time to 75% time. The contribution of hip joint flexion-extension and internal-external rotation was large at first nevertheless these produced little kicking speed at IMP. In knee joint, similar to subject A, the contribution of knee joint flexion-extension produced the kicking speed after MKF. The contribution of lower torso left-right leaning, left-right rotation, hip joint adduction-abduction, and knee joint flexion-extension produced a great part of kicking speed at IMP.

Table 1
The kicking time in every phase [s] and the kicking speed in every event [m/s].

Sub	Kicking time [s]				Sub	Kicking speed [m/s]			
	READY	LEG UP	STRIK	TOTAL		STR	TOF	MKF	IMP
A	0.244	0.124	0.072	0.432	A	0.2	4.6	10.8	19.0
B	0.284	0.124	0.076	0.476	B	0.1	4.5	11.3	16.5
Ave (SD)	0.353 (0.089)	0.125 (0.016)	0.081 (0.008)	0.551 (0.106)	Ave (SD)	0.1 (0.1)	4.3 (0.7)	10.3 (1.3)	16.2 (2.0)

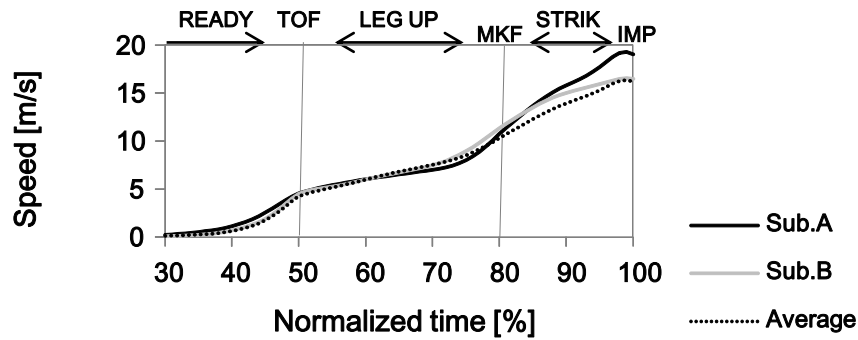


Figure 2: The pattern of kicking speed.

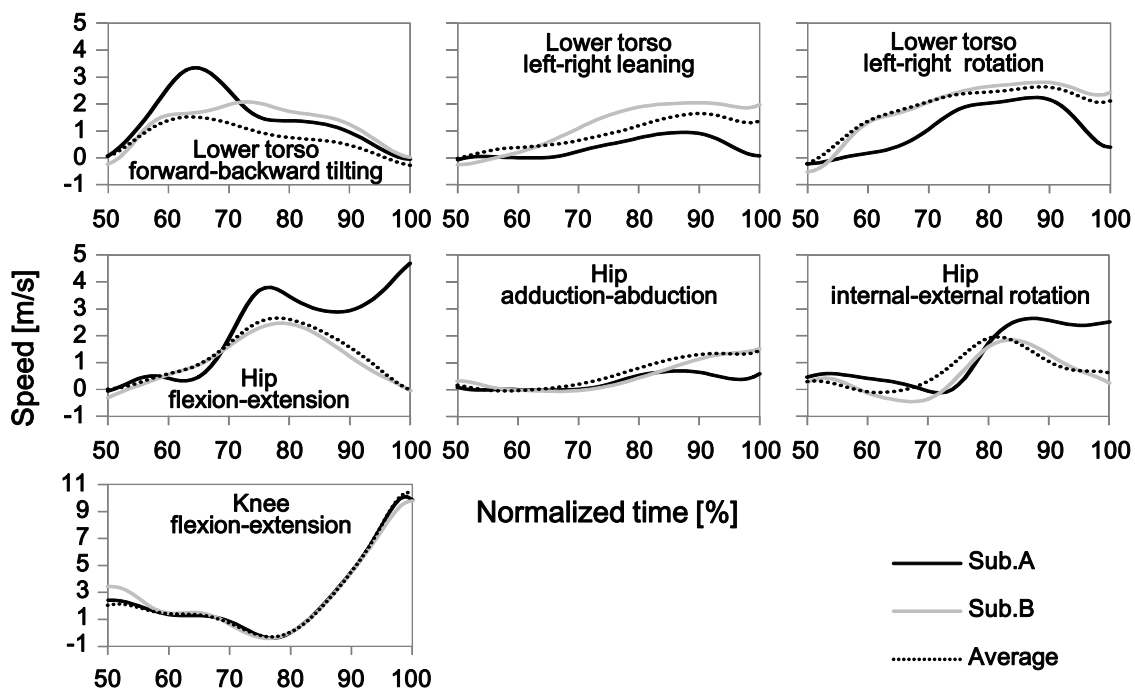


Figure 3: The contribution of lower torso, hip joint, and knee joint movement to kicking speed .

DISCUSSION: Considering the contribution of lower torso and kicking leg joints to kicking speed, the classification of kicking speed was different between the two subjects nevertheless value and pattern of kicking speed were similar until 90% time. Subject A had faster kicking speed after 90% time. Difference of kicking speed at IMP was influenced by the contribution of lower torso and hip joint movement since the contribution of knee joint movement to kicking speed was almost similar among the two subjects. For subject A, the greater part of kicking speed was produced by the angular velocities of lower torso backward tilting and left rotation, and hip joint flexion until around MKF. Thereafter, the angular velocities of hip joint flexion, hip

joint internal rotation, and knee joint extension produced the greater part of kicking speed at IMP. On the other hand, for subject B, the greater part of kicking speed was produced by the angular velocities of lower torso backward tilting, left rotation, hip joint flexion, and internal rotation until around MKF. Thereafter the angular velocities of lower torso left lateral leaning, left rotation, and knee joint extension produced the greater part of kicking speed at IMP. Especially, for subject A the contribution of hip joint flexion-extension was increased rapidly with the rapid hip joint flexion, which was caused by the rapid decrease in the angular velocity of lower torso backward tilting around 60% time. In addition, the contribution of hip joint flexion-extension was increased rapidly again with the rapid hip joint flexion, which was caused by the rapid decrease in the angular velocity of lower torso left rotation at 90% time. According to these things, it is inferred that subject A performed so-called "whipping like motion". In contrast, it is considered that subject B did not performed whipping like motion since the every contribution and joint angular velocity did not fluctuate sharply. The presence or absence of whipping like motion affected the difference of kicking speed at IMP. In the case of technique for kicking continuously with quick motion, it seemed easier for subject A to recover balance for next kicking after IMP since the angular velocity of lower torso was less at IMP. It is difficult to decelerate a large angular velocity of lower torso of which mass and moment of inertia are large. On the other hand, it is difficult for subject B to decelerate the movement of lower torso and to recover balance for next kicking after IMP since the angular velocity of lower torso is larger than subject A. Considering techniques for producing faster kicking speed and kicking continuously with quick motion, subject A has the better techniques of RHK in Taekwondo.

CONCLUSION: Based on the results and discussion above, technique for producing faster kicking speed in Taekwondo is deemed as whipping like motion with the limited lower torso movement and the faster movement of lower limb joints. On the other hand, technique for kicking continuously with quick motion is described as less movement of lower torso in order to being easier to recover balance after IMP. In order to analyze the motion after IMP in detail, it is necessary to investigate kinematics and kinetics including the movements after IMP and to intend to kick continuously with quick motion.

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