A KINEMATIC STUDY ON HOW TO KICK QUICKLY IN TAEKWONDO

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The purpose of this study was to evaluate techniques for increasing kicking speed in a Taekwondo roundhouse kick according to different target distance conditions. The results were summarized as follows: i) With short condition, there was no significant correlation between kicking speed and pelvic speed; ii) Good subjects attained greater extension angular velocity of the knee joint with individual kinematic chain technique regardless of different distance conditions; and iii) subjects changed motion of the support leg in order to adapt the translational motion according to different distance conditions. Taken together, our data suggest that coaches should pay greater attention to the support leg when adapting the technique for kicking distance as well as the motions of the pelvis and hip joint of the kicking leg when adapting the technique to increase kicking speed.

KEY WORDS: martial arts, kicking techniques, target distance, kinematic chain.

INTRODUCTION: Taekwondo is a form of Korean martial arts and has been an Olympic event since 2000. With the latest Taekwondo rules, Taekwondo athletes have to kick their opponents more accurately to score more points and win games. In competitions, athletes are required to adjust their distance to opponents while increasing kicking speed. The distance to opponents is defined as the relation between athletes, which can constantly change. According to previous studies, a roundhouse kick (RHK) is one of the kicks used most frequently in competitions. Some studies have presented techniques for both increasing kicking speed and decreasing kicking time (Kinoshita & Fujii, 2014; Kinoshita & Fujii, 2015), and the kinematic mechanisms of different target distances (Kim, Kwon, Yenuga, & Kwon, 2010). Kinoshita & Fujii (2014) stated that it is critical to have a greater extension angular velocity of the knee joint with effective patterns of both left rotation angular velocity of the lower torso and flexion angular velocity of the hip joint to kick at a faster speed and with a shorter time. Kinoshita & Fujii (2015) elucidated the possibility of a relationship between pelvic speed at the moment the toe leaves the floor and kicking speed. Kim et al. (2010) concluded that the adjustment to different target distances was mainly accomplished through pivot hip displacements of the support leg, hip flexion of the kicking leg, and left rotation of the pelvis; target distance mainly affected the reach control function of the pelvis and the linear balance function of the trunk. However, they did not clarify how to kick quickly according to different target distances. The purpose of this study was to evaluate techniques of increasing kicking speed in a Taekwondo RHK with kinematic data according to three different target distance conditions.

METHODS: Thirteen male Japanese Taekwondo athletes, who were also included in our previous studies (Kinoshita & Fujii, 2014; Kinoshita & Fujii, 2015), participated in this study after the informed consent. The participants had diverse skill levels. The experiment trial consisted of an RHK to a target with a preferred leg. The target height was the same as the participants' torso. There were three target distance conditions (Figure 1: Short; 0.68±0.06 [m], Normal; 0.90±0.07 [m], and Long; 1.15±0.09 [m]). The target distance conditions were determined according to participants' leg lengths. The global coordinate system was defined as shown in Figure 1. The 3D coordinates of the reflective markers placed on body segments and the target were captured by a motion capture system (Vicon MX+, 250 Hz) and filtered with a Butterworth digital filter (12.5-25 Hz). The RHK was divided into three phases with four events as shown in Figure 1. The four events were as follows: STR, the instant that the

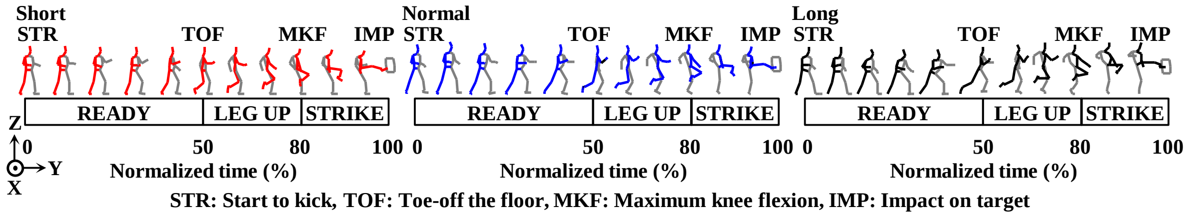


Figure 1: Motion of RHK in three different distance conditions.

speed of the body center of gravity surpassed 0.5 m/s; TOF, toe of kicking leg took off the floor; MKF, maximum knee flexion of the kicking leg; and IMP, impact on the target. To normalize a kicking motion, STR, TOF, MKF, and IMP were defined as 0%, 50%, 80%, and 100% time respectively. READY, LEG UP, and STRIKE phases were termed, respectively. The kinematics data were calculated to evaluate the movements of body segments and joints for increasing kicking speed according to different distances.

RESULTS: Figure 2 showed the average kicking speed at IMP according to three different distance conditions. In all conditions, kicking speed was almost 17 [m/s]. There was no significant difference in kicking speed among the three distance conditions. Figure 3 showed the relationship between kicking speed at IMP and pelvic speed at TOF in all subjects according to three distance conditions. With Normal and Long conditions there was a positive correlation between kicking speed and pelvic speed (Normal: $r=0.7250$, $p<0.01$ and Long: $r=0.7915$, $p<0.01$). With Short condition, there was no correlation between these parameters. All subjects could kick the target with the same kicking speed, regardless of distance conditions. Table 1 provided the kicking speed at IMP and pelvic speed at TOF in two representative subjects (Subj. A and B) and the average magnitude in all subjects. Both subj. A and B had a greater kicking speed in all conditions. Subj. B also had a greater pelvic speed in all conditions. On the other hand, subj. A had the lowest pelvic speed among all subjects with only Short condition. Figure 4 showed the angular velocities (pelvis: left rotation/right rotation; hip joint of kicking leg: flexion/extension; and knee joint of kicking leg: extension/flexion) of subj. A and B. Both subj. A and B had a greater extension angular velocity of the knee joint at IMP in all conditions. The patterns of angular velocities were similar with every condition among the individuals. This tendency was represented in all subjects (not shown here). Subj. A maintained greater flexion angular velocity of the hip joint

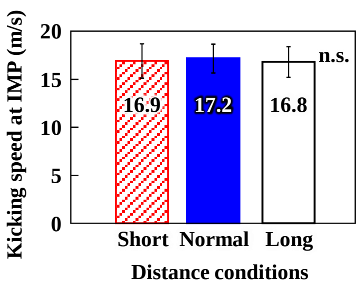


Figure 2: Average kicking speed at IMP.

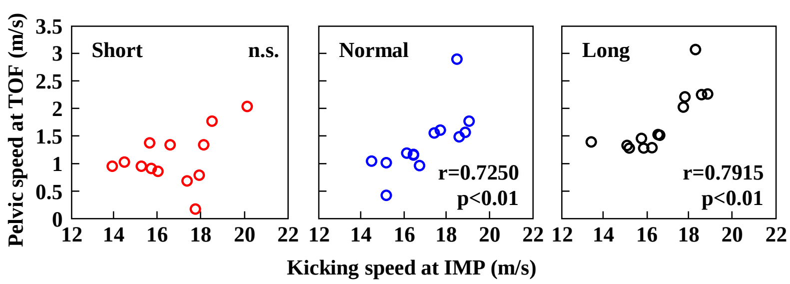


Figure 3: Kicking speed at IMP and pelvic speed at TOF in all subjects according to three distance conditions.

Table 1
Kicking speed and pelvic speed of selected subjects and average magnitudes

Conditions	Kicking speed (m/s)			Pelvic speed (m/s)		
	Subj. A	Subj. B	Mean	Subj. A	Subj. B	Mean
Short	17.9	18.3	16.9±1.8	0.2	1.4	1.1±0.5
Normal	19.0	19.2	17.2±1.5	1.6	1.8	1.4±0.6
Long	19.1	18.8	16.8±1.6	2.3	2.3	1.8±0.6

during the STRIKE phase and decreased the left rotation of the pelvis rapidly before MKF, regardless of distance conditions. On the other hand, subj. B decreased the flexion angular velocity of the hip joint rapidly before MKF and the left rotation of the pelvis at 90% time for all conditions. There were different angular velocity patterns for pelvis left rotation and hip joint flexion between the two subjects. Figure 5 illustrated the contribution ratio of motion of support leg, pelvis left rotation/right rotation, hip joint flexion/extension, knee joint flexion/extension, and other motions (pelvis flexion/extension and left bending/right bending, hip joint adduction/abduction and internal rotation/external rotation) to all kicking trajectories according to different distance conditions in subj. A, subj. B, and average magnitudes. The contribution of the support leg represented magnitude of the translational motion produced by the support leg. Both subj. A and B increased the ratio of the support leg to all kicking trajectories as with increasing target distance. subj. A decreased the ratio of hip joint flexion/extension while increasing the ratio of support leg. However, Subj. B decreased the ratio of pelvis left rotation/right rotation while increasing the ratio of the support leg.

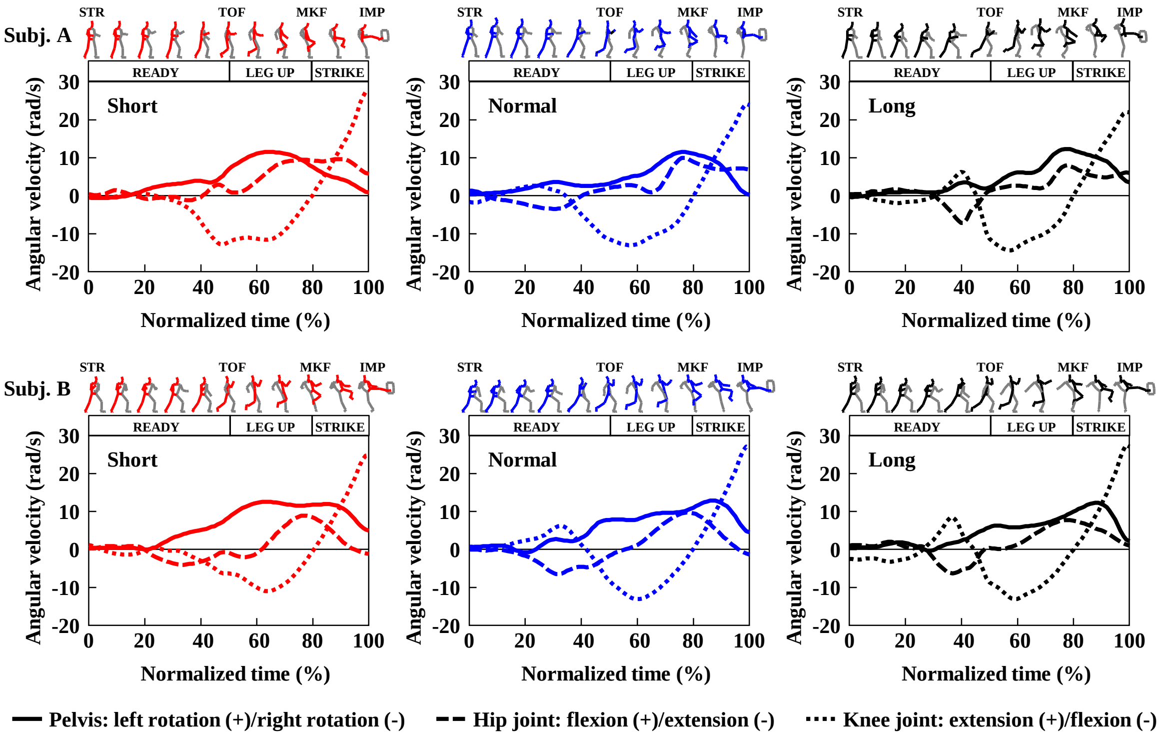
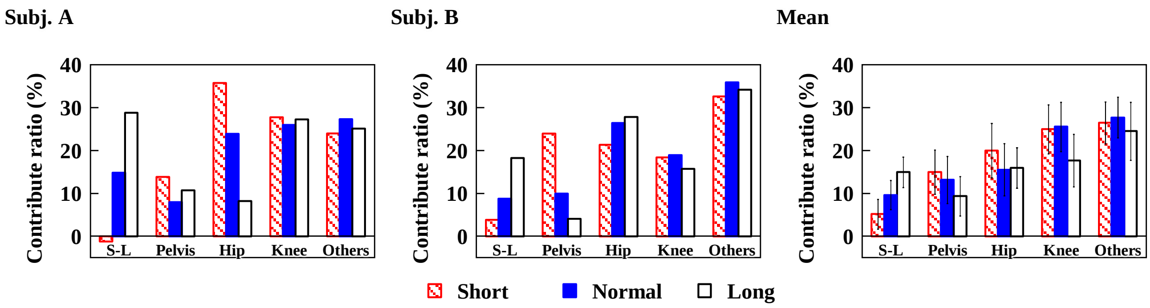


Figure 4: Angular velocities of pelvis left rotation/right rotation, hip joint flexion/extension, and knee joint flexion/extension according to distance conditions in subj. A and B.



S-L: Motion of support leg, Pelvis: Left rotation/Right rotation of pelvis, Hip: Flexion/Extension of hip joint in kicking leg

Knee: Flexion/Extension of knee joint in kicking leg, Others: The other motions in pelvis and hip joint in kicking leg

Figure 5: Contribution ratio of motion in pelvis and lower extremities to all kicking trajectory according to distance conditions in subj. A, B and average magnitudes.

DISCUSSION: The purpose of this study was to evaluate techniques of increasing kicking speed according to the different target distance conditions. According to Figure 2, kicking speed was almost the same for all distance conditions. This result illustrated that the subjects who participated in this study had their own maximum kicking speed regardless of distance conditions. Kinoshita & Fujii (2015) elucidated the possibility of a relationship between pelvic speed at TOF and kicking speed with Normal condition. In this study, there was no significant relationship between kicking speed at IMP and pelvic speed at TOF only with Short condition, regardless of the same kicking speed in all conditions (Figure 2 and 3). This result demonstrated that the greater translational pelvic speed is related to kicking speed with Normal and Long conditions. In contrast, the pelvic speed was not always an important contribution in Short condition when subjects controlled rotational motion to increase kicking speed. Thus, it was possible to identify the techniques to increase kicking speed according to different distance conditions by comparing subj. A and B who could kick with high speed for all conditions and had different pelvic speeds with Short condition. Kinoshita & Fujii (2014) reported that it was necessary to increase the extension angular velocity of the knee joint of the kicking leg during STRIKE phase. Subj. A and B had a greater extension angular velocity of the knee joint of the kicking leg during STRIKE phase (Figure 4). However they kicked by utilizing different kinematic chains to increase angular velocity. The kinematic chain of subj. A was caused by the rapidly decreasing left rotation of the pelvis before MKF. The kinematic chain of subj. B was caused by the rapidly decreasing flexion of the hip joint before MKF and the rapidly decreasing left rotation of the pelvis at 90 % time. These motions might produce the moment of joint force related to the extension angular velocity of the knee joint in different ways. Thus, in the case of utilizing pelvis left rotation as the source of kinematic chain, pelvic speed at TOF does not play an important role in increase kicking speed, because greater flexion angular velocity of the hip joint compensates for kicking speed. Kim et al. (2010) stated motions of the support leg, hip joint, and pelvis were related to the adaption for distance conditions. The patterns of angular velocity were similar with every distance condition among all individuals, regardless of the kicking speed. According to Figure 4 and 5, subjects did not change the sequence motion of the kicking leg but changed the translational motion produced by the support leg. Thus, in order to improve kicking speed according to different distance conditions, athletes should first train for kicking quickly with a Normal distance condition as kicking by utilizing the good kinematic chain. After they acquire the technique for increasing kicking speed, coaches should pay more attention to the support leg in order to improve athletes' techniques for adapting to different distance conditions.

CONCLUSION: This study identified techniques for increasing kicking speed in a Taekwondo RHK according to different distance conditions. It is our view that coaches should pay more attention to the support leg when adapting the technique for different kicking distances and to the motions of the pelvis and hip joint of the kicking leg when adapting the technique to increase kicking speed.

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