BIOMECHANICAL ANALYSIS OF TAEKWONDO ROUNDHOUSE KICK FOCUSED ON PHASE BEFORE TOE OFF

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The purpose of this study was to clarify the biomechanical taekwondo roundhouse kick (RHK) mechanism of the lower half of the body in the phase before toe off the floor (READY phase) focusing especially on techniques for producing faster kicking speed and shortened time of kicking. The results were summarized as follows: i) motion of hip joint in support leg had relation to the flow of mechanical energy to pelvis, ii) extension of hip joint in support leg produced the translational velocity of pelvis, and iii) players accomplished motion of hip joint extension by providing the torque of hip joint extension in support leg at early time. Taken together, our data suggests that coaches should pay greater attention to support leg and READY phase in order to improve the players' kicking technique for kicking fast and quick.

KEY WORDS: kinematics, kinetics, energetics, fast and quick kicking, support leg.

INTRODUCTION: Taekwondo is a Korean martial arts characterized by a diverse array of kicking techniques. For winning the competition, it is necessary to precisely kick the opponent and score more points. However, in order to kick accurately, a combination of many motion factors, such as kicking speed, time, timing, distance, etc., are required. Therefore, it is critical to clarify the mechanism of kicking techniques affected by these factors. According to previous studies, roundhouse kick (RHK) is one of the most basic and important in all taekwondo kicks (Kim, Kim, & Im, 2011).
Some studies have demonstrated mechanism of RHK concerning the kicking leg in the period from the toe-off to target contact. However, there are few studies and coaching methods related to before the period of toe-off (READY phase). We elucidated that it is likely to have a relationship between pelvis motion in READY phase and kicking speed (Kinoshita, & Fujii, 2014). Motion in the READY phase is critical to kick fast, because the initial motion affects the succeeding motion. The purpose of this research was to analyze the biomechanical mechanisms of the lower half of the body in RHK READY phase, especially the techniques for producing faster kicking speed and shortened time of kicking.

METHODS: Thirteen male Japanese Taekwondo athletes (with age: 21.7±3.3 [yr], height: 1.72±0.05 [m], body mass: 65.2±11.4 [kg], and experience: 6.3±5.3 [yr]) participated in this study after informed consent. The participants had diverse skill levels (national game level-not in particular). Experiment trial consisted of RHK to a target with a preferred leg. The target position was same as the subject's torso. The distance from the front leg to the target was adopted voluntarily (ratio of distance to height is nearly equal). The global coordinate system was defined as shown in Figure 1: Y (anteroposterior) axis was direction to the kicking mitt, Z (longitudinal) axis was the vertical axis, and X (mediolateral) axis was crossing with these two axis at a right angle. We captured the 3D coordinates of the reflective markers on body segments and the target by a motion capture system (Vicon MX+, 250 Hz), and filtered captured data with a Butterworth digital filter (12.5-25 Hz) (Wells and Winter, 1980). The ground reaction force was obtained with both kicking and support leg by force platform (Kistler, 1000 Hz). 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 Figure 1. STR: instant that the speed of whole body center of gravity surpassed 0.5 m/s. TOF: toe off of kicking leg. MKF: maximum knee flexion of the kicking leg. IMP: impact the target. We termed READY phase, LEG UP phase, and STRIKE phase at every

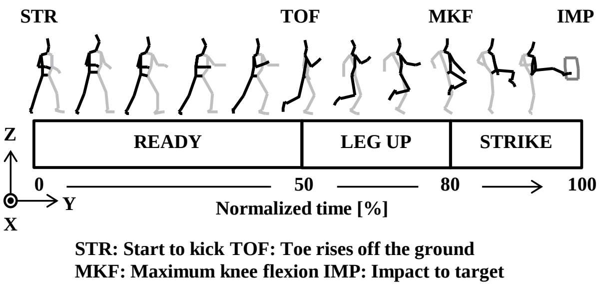

Figure 1: Analysis phase and motion of RHK.

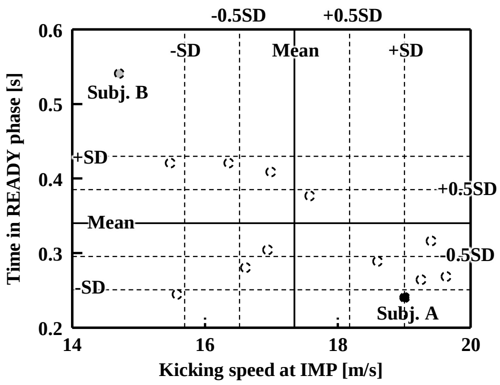

Figure 2: Group selection.

section. To normalize a kicking motion, we defined 0%, 50%, 80%, and 100% time as STR, TOF, MKF, and IMP. The kinematics, kinetics, and energetics data were calculated to evaluate the role of lower half of the body in READY phase to produce kicking speed.

RESULTS: Here, we show the results of mean, subject A (GOOD), and subject B (POOR) grouped by kicking speed at IMP and trial time in READY phase (Fig. 2). Regardless of kicking speed, there are various times in READY phase. Subject A kicked faster than mean and in the shortest time of READY phase. Subject A was also a high level player in Japan. Subject B kicked the slowest and in the longest time of all subjects. STRIKE phase (80-100% time) was the biggest difference between the two subjects' speed. Table 1 showed mechanical energy generation, mechanical energy flow by segment torque power (STP), and joint force power (JFP) in READY phase. Absolute value of subject B, except mechanical energy generation of knee in kicking leg (K-Knee), is small as a whole. We described distinctive mechanical energy flow between segments. For torso, although all subjects generated almost the same value of energy, subject A translated larger energy by STP from pelvis to trunk than the others. For hip joint in kicking leg (K-Hip), subject B generated the smallest energy of all. Generated energy was almost distributed at the thigh, and there was little translation to the pelvis. Mean and subject A translated large energy to the thigh by JFP. Especially, subject A revealed a flow of large energy to the thigh by both STP and JFP. For ankle joint in kicking leg (K-Ankle), mean generated the largest energy translated to foot by STP. Energy translated from foot to shank by JFP was largest among all. For hip joint in support leg (S-Hip), subject A generated the largest energy and subject B generated the smallest energy of all. Generated energy was almost distributed in the range of 40% to 60% (pelvis to thigh). Subject A transferred large energy by JFP from the thigh to pelvis. The segment most concerned to the pelvis was thigh in the support leg, in particular, the hip joint of support leg.

Figure 3 shows the angular velocity of hip joint in support leg (flexion-extension, adduction-abduction, and internal rotation-external rotation). For subject A, the angular velocity of flexion changed extension early, in 20% time. On the contrary, for subject B, the angular velocity of flexion changed extension almost at 40% time. Both subjects A and B had the same angular velocity of flexion or extension at STR and TOF. The angular velocity of adduction almost kept positive value. For subject A, the peak value appeared earlier than the others. For the angular velocity of internal-external rotation, pattern of subject A showed sharp fluctuation.

Figure 4 shows the hip joint torque in support leg and moment of hip joint force in support leg (acted to flexion-extension, adduction-abduction, and internal rotation-external rotation). The absolute value of joint torque or moment of joint force acted flexion-extension was larger than the others. For subject A, joint torque acted extension was becoming large and moment of force acted flexion was growing large, too. The joint torque acted extension was larger than the moment of force acted flexion through this phase.

Table 1: Mechanical energy flow in kicking leg (K-) and support leg (S-).

Joint	Segment	Mean: Generation [J/kg]	Mean: By segment torque power [J/kg]	Mean: By joint force power [J/kg]	Subject. A: Generation [J/kg]	Subject. A: By segment torque power [J/kg]	Subject. A: By joint force power [J/kg]	Subject. B: Generation [J/kg]	Subject. B: By segment torque power [J/kg]	Subject. B: By joint force power [J/kg]
Torso	TRUNK		0.38			0.47			0.36	
		0.19		0.01	0.17		-0.15	0.14		-0.05
	PELVIS		-0.19			-0.30			-0.22	
K-Hip	PELVIS		0.06			0.05			0.11	
		0.34		0.41	0.37		0.47	0.24		0.20
	THIGH		0.28			0.33			0.13	
K-Knee	THIGH		0.15			0.12			0.22	
		0.22		0.05	0.09		0.18	0.34		0.01
	SHANK		0.08			-0.02			0.12	
K-Ankle	SHANK		-0.23			-0.18			-0.20	
		0.60		-0.63	0.53		-0.52	0.38		-0.49
	FOOT		0.84			0.71			0.58	
S-Hip	PELVIS		0.34			0.43			0.23	
		0.83		-0.42	1.04		-0.67	0.57		-0.27
	THIGH		0.49			0.61			0.34	
S-Knee	THIGH		0.02			0.01			0.00	
		0.05		0.12	0.05		-0.01	0.08		0.07
	SHANK		0.03			0.04			0.08	
S-Ankle	SHANK		-0.14			-0.19			-0.09	
		-0.06		-0.01	0.04		-0.15	-0.09		0.07
	FOOT		0.08			0.23			0.00	

Generation: Generation (+), Absorption (-)
Translation by STP and JFP: Energy flow in adjacent segments (+), Energy flow out of adjacent segments (-)

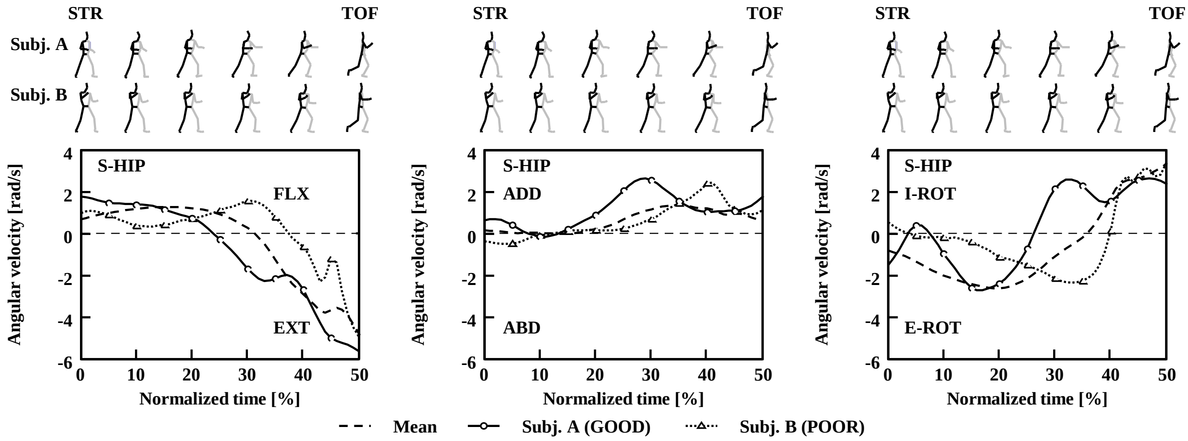

Figure 3: Angular velocity of hip joint in support leg.

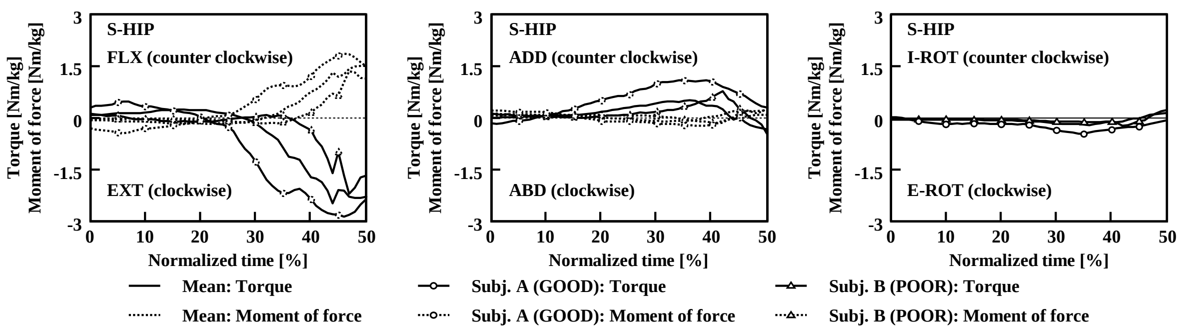

Figure 4: Hip joint torque and moment of hip joint force in support leg.

DISCUSSION: In order to clarify the mechanism of the lower half of the body in RHK READY phase, we refer to the mechanical energy flow data presented in Table 1. Hip joint in support leg generated the largest energy of all joints. Ankle joint and hip joint in kicking leg were large too. However, their differences between subject A and B were not great as the difference of hip joint generation in support leg. Additionally, joints acting to pelvis energy are torso and hip joint in both legs, and segments acting to pelvis energy are trunk and thigh in both legs. For subject A, the energy generated by hip joint in support leg was transferred to the pelvis by STP, and energy was transferred from trunk and thigh in the support leg to pelvis by JFP. Generally, except transfer from trunk to pelvis by JFP, the joints and segments relating transfer to pelvis were same as in subject A.
In this report, we did not provide a figure on the kicking speed, etc. However, utilizing the data reported in our previously published study (Kinoshita & Fujii, 2014), we can summarize the results as follows: i) difference of kicking speed among subjects was becoming large in STRIKE phase, ii) it is likely to have a relationship between pelvis posture at TOF and kicking speed.
According to the present study data, techniques of energy flow concerning thigh motion in support leg have relation to pelvis motion in READY phase. Here, we focused on the hip joint in support leg because it mainly affected the thigh motion in the support leg. In other words, the motion of hip joint in support leg is critical to the kicking technique for kicking fast and quick. Next, we discussed the motion of hip joint in support leg based on Figures 3 and 4. The extension angular velocity and extension torque were getting large after the angular velocity of flexion changed the extension. However, in order to transfer energy efficiently through the hip joint extension in support leg, it is critical to motion of adduction and external rotation before hip joint is extended. This is because, the motion of adduction and external rotation make the posture as it is easy for extension of hip joint to produce the translational velocity of pelvis.
Hence, all motions of hip joint in support leg (extension, adduction, and external rotation) are necessary. As explained above, we have provided a scenario to explain the mechanism of producing pelvis motion in READY phase. It should be noted that there are a lot of instructions about the kicking leg, because it is the main leg for kicking. However, coaches should pay more attention to support leg with an aim to find the coaching method about support leg for kicking fast and quick.

CONCLUSION: This study provided new insight into the mechanism of the lower half of the body in RHK READY phase connecting to the techniques for producing faster kicking speed and shortened time of kicking. A GOOD player kicks by utilizing technique of pelvis motion in the support leg. It is our view that the coaches should pay more attention to support leg and READY phase in order to improve the players' kicking technique for kicking fast and quick.

REFERENCES:

Falco, C., Landeo, R., Menescardi, C., Bermejo, J. L., & Estevan, I. (2012). Match analysis in a university Taekwondo championship. *Advances in Physical Education*, 12, 28-31.
Kim, J. W., Kwon, M. S., Yenuga, S. S., & Kwon, Y. H. (2010). The effect of target distance on pivot hip, trunk, pelvis, and kicking leg kinematics in Taekwondo round house kick. *Sports Biomechanics*, 9, 98-114.
Kim, Y, K., Kim, Y, H., & Im, S, J. (2011). Inter-joint coordination in producing kicking velocity of Taekwondo kicks. *Journal of Sports Science and Medicine*, 10, 31-38.
Kinoshita, M. & Fujii, N. (2014). Biomechanics of Taekwondo roundhouse kick. *Biomechanism*, 22 (in press, in Japanese).
Wells, R, P. & Winter, D, A. (1980). Assessment of signal noise in the kinematics of normal, pathological and sporting gaits. *Human Locomotion*, 1, 36-41.