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Effects of Rhythmic Hop on Response Times and Kicking Velocities of Taekwondo Kicks

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ABSTRACT

Most athletes execute rhythmic hop as a preparatory motion in Taekwondo sparring. The purpose of this study was to investigate the effect of rhythmic hop on the response times and kicking velocities of Taekwondo kicks. Twelve male elite Taekwondo athletes performed a roundhouse kick and a back kick as fast as possible immediately after seeing an external stimulus in rhythmic hop and in no hop, respectively. The three-dimensional marker data of the whole body were measured at sampling rate of 200 Hz. Paired t-tests were used to compare dependent measures between hop and no hop conditions. Results indicated that the rhythmic hop did not affect response time statistically but improved the kicking velocity significantly than no hop did. Different instants of detecting an external stimulus in rhythmic hop for the back kick showed significantly different response times. Conclusively, rhythmic hop is recommendable for the purpose of kicking velocity, but not for the purpose of response time. Athletes should be careful in executing rhythmic hop as their preparatory motions for the back kick, since the response time could be shortened or lengthened according to the instant of detecting an external stimulus.

Keywords : Response Time, Kicking Velocity, Rhythmic Hop, Taekwondo

I. Introduction

Taekwondo, as a combat sport in Olympic Games, requires rapid response to an external stimulus and fast kicking velocity for winning a competition. A shorter response time may allow a kicker to perform intended attacks successfully to obtain points as well as a faster kicking velocity may allow a kicker to give a strong impulse on an opponent. Thus, previous studies on the Taekwondo kick have primarily focused on the response time, the movement time, or execution time (Boey & Xie, 2002; Falco et al., 2009; Hermann, Scholz, Vieten, & Kohloeffel, 2008; Nien, Chuang, & Chung, 2004; Pieter & Heijmans, 2003; Shiang & Chou, 1998; Tang, Chang, & Nien, 2007) and the kicking velocity (Shiang & Chou, 1998; Tang et al., 2007) of the roundhouse kick which is the most popular kick in Taekwondo sparring. The response time is defined as the time difference from the instant of an external stimulus to the impact of kicking, which included reaction time and movement time together (Kim, 2010).

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In some sports requiring a rapid response time, a preparatory motion (pre-movement) before executing a goal-directed movement has improved the quality of the movement (Uzu, Shinya, & Oda, 2009). In Taekwondo sparring most athletes practically use rhythmic hop as a preparatory motion while they are waiting for attacks and dodging in response to an opponent's action. This rhythmic hop is performed by repeatedly flexing and extending the hip, knee, and ankle joints slightly while remaining in the same place on the floor. Since rhythmic hop mechanically induces a prestretch potentiation of leg muscles (Aura & Komi, 1986; Bosco, Komi, & Ito, 1981; Komi, 1984) and functional stretch reflex (Melvill-Jones & Watt, 1971) in stretch-shortening cycle, it may affect the quality of the kicking movement to a certain extent than no hop does.

According to personal interviews with elite athletes, some of the elite athletes do not execute rhythmic hop intentionally in sparring because they believe rhythmic hop would be detrimental to response time in some defensive situations. However, no scientific investigation has answered this question.

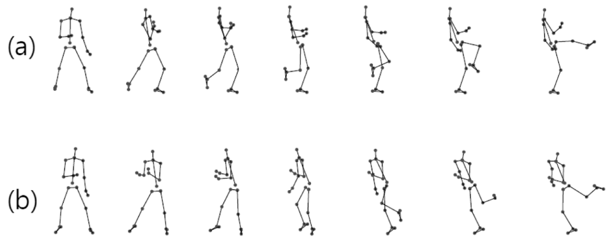

Figure 1. Sequential figures of two different Taekwondo kicks. (a) Roundhouse kick and (b) Back kick

The primary purpose of this study was therefore to investigate the effect of commonly-used rhythmic hop on the response times and kicking velocities of two Taekwondo kicks. Two kicks were the roundhouse kick and back kick, which represent popular techniques in Taekwondo sparring for the purposes of attacking and counterattacking (Figure 1). The second research question was to explore whether response time for a goal-directed kick depends on the instant of detecting an external stimulus in rhythmic hop.

II. Methods

1. Participants

Twelve male collegiate Taekwondo athletes (age 20.4±8.4 yrs, mass 71.9±8.4 kg, height 1.80±0.04 m) participated in the study. All of the participants have been practicing Taekwondo for more than seven years (10.6±3.2 yrs) and all have black belts of the 4th Dan and above. Participants reported no neurological and musculoskeletal deficits at the time of data collection. All participants signed a written informed consent form, and the study protocol was approved by the ethics committee of the University.

2. Experimental Setup

Full body kinematics, sampled at 200 Hz, was obtained using a six-camera motion tracking system (Hawk® Digital Real Time System, Motion Analysis System, USA; Figure 2). A 15-component link-segment model, consisting of 40 reflective markers, was used to estimate the location of the body CM based on the estimated body segment parameters (De Leva, 1996), and to quantify the motions of lower extremities. Those markers were attached on the following anatomical landmarks of both limbs, trunk, and head: toe, heel, medial and lateral malleolus, medial and lateral femoral condyles, thigh, shank, anterior superior iliac spine, poster superior iliac spine, acromion process, medial and lateral epicondyles, medial and lateral styloid processes, hand, upper arm, and head. The toe and medial markers in upper and lower limbs were removed after a static trial to facilitate dynamic kicking movement.

A hand-held pad (All-Star®, Tae Hwa Sports, Korea), having one reflective marker on it, was used as the target. Movement of the marker was used to determine the onset of foot contact to the target. An assistant held the target with one hand, and with the other hand, held a custom-made red light-emitting diode (LED) close to the target (Figure 2). A custom-made LED was designed to be a trigger for the participants to detect a cue signal for kicking (an external stimulus) and was synchronized with the motion data by the help of analog-to-digital board (NI USB 6525, National Instruments, USA). The height of the target was adjusted according to the abdominal level of the participant. It was determined by the height of the participant's navel in the fighting stance.

3. Procedures

After warming up, the participant stood barefoot on the floor with the kicking foot behind the supporting foot. Then the participant got into a fight stance with a comfortable distance between their feet and with slightly bent knees. The participants were asked to perform their comfortable rhythmic hop as a preparatory motion or not to perform rhythmic

Figure 2. Experimental set-up, target with a marker, and LED for trigger signal to a kicker

hop (control condition), according to the designated condition. For the control condition, participants were not allowed to make any bouncing motions before detecting a trigger signal (a LED flash-on), and allowed only to perform a countermovement action from the fight stance position when they received a LED flash-on. Participants were required to execute the designated kick as fast as possible toward the target and as much as similar to sparring type of kicking when the custom-made LED flashed. There was no verbal command to initiate kicking. For each type of the kick, three trials were performed. The orders of preparatory condition and type of kick were randomly selected in advance. The investigator pressed the trigger switch at random intervals (almost between 1 s and 4 s) after saying 'ready', in order to prevent participants from initiating a kicking motion before the onset of a LED flash-on and to create a randomized onset instant. A two-minute break was given prior to moving on to the next type of kick.

4. Data Analysis

Analysis was performed by a commertial software of Matlab® (version 2009R, The MathWorks™, USA) after a digital filtering process (a second-order zero-lag Butterworth low-pass filter with a cutoff frequency of 8 Hz). Dependent variables were defined as follows. Response time was measured from the onset of a LED flashing to foot contact with the target (Figure 3; Kim, 2010). Since it was very difficult to divide response time into reaction time and movement time during the kicking procedure as a result of hopping motion or body motion prior to toe-off the ground, this study focused on the response time only. The event of foot contact was determined when the linear velocity of the target marker passed 5% of its peak linear resultant velocity (Fradet, Lee, & Dounskaia, 2008). The kicking velocity was the peak magnitude of resultant linear velocity of the virtual toe marker during kicking, which represented the maximum performance of kicking. In most cases the moment of foot

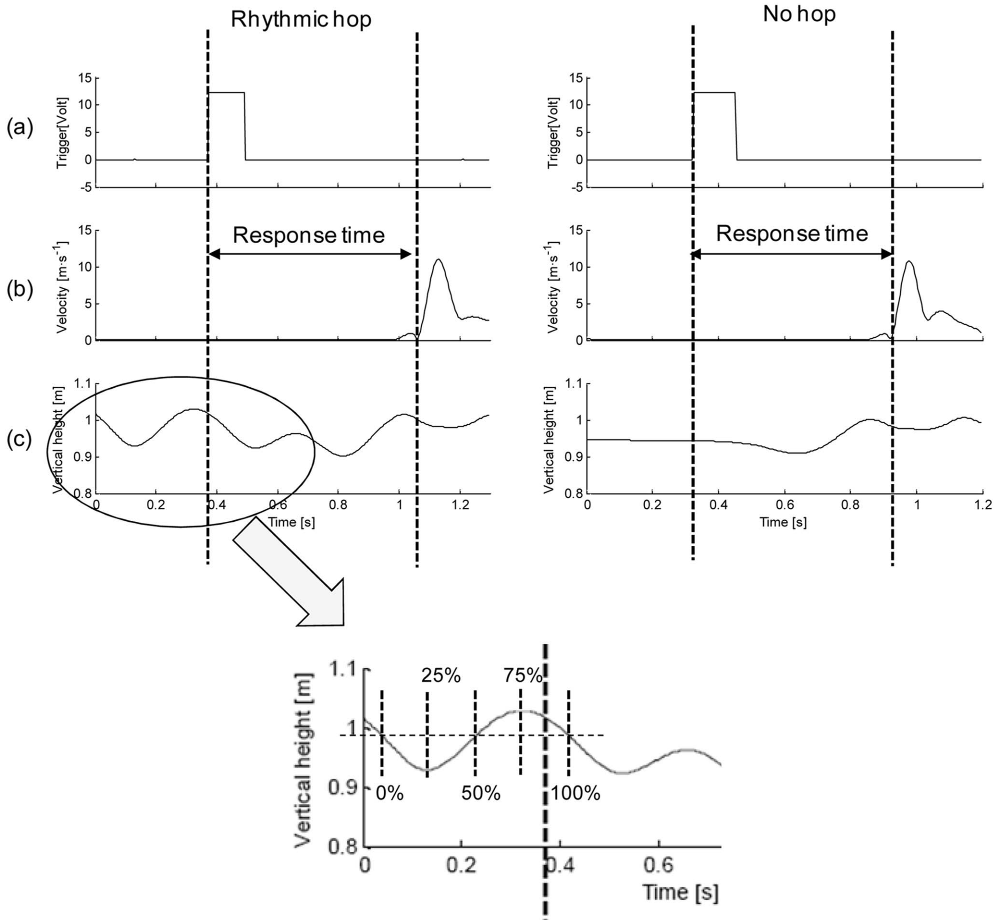

Figure 3. Examples of response time definition in rhythmic hop and no hop conditions. (a) trigger signal, (b) linear velocity profile of the target marker, (c) vertical height of the body center of mass (CM) according to time, and (d) expression of the normalized onset timing of a LED flashing relative to the period of hop

contact occurred immediately after the peak magnitude of kicking velocity. The body CM with respect to global reference frame was calculated by conventional segmentation method (Winter, 1990). For the second research question, the onset timing of a LED flashing was normalized to the period of hop for each subject in order to standardize the independent variable across all subjects. The starting point of the hop (0% of hop period) during continuous fluctuations of the body CM was defined the mid-temporal point from the local maximum vertical point of the CM to the local minimum point of the CM because the countermovement is initiated downward first from the base height (Figure 3).

A mean value for three trials of each participant on response time and kicking velocity was used for separate paired t-tests (rhythmic hop vs. no hop). In order to prevent Type I error, the significance level was adjusted to 0.025 (=0.05/2) due to two different kicks. For the test of the second research question, we used regression analysis in order to see the relationship between the onset of a LED signal relative to the period of hop and the response time of kicking. These analyses were performed using SPSS 15.0 statistical software (IBS, USA).

III. Results

1. Effect of rhythmic hop on response time and kicking velocity

Table 1 presented results of response times and kicking velocities of the roundhouse kick and back kick across all participants. The mean period of hop across all participants were 0.36±0.03 s. Paired t-tests for each kick revealed no effect of rhythmic hop on the response times (p=.19 and p=.32 for the roundhouse kick and back kick, respectively), although mean response times of two kicks in rhythmic hop were reduced. However, kicking velocity was significantly affected by rhythmic hop (p<.025; Table 1). The roundhouse kick velocity (15.5±1.6 m/s) and back kick velocity (11.6±1.0 m/s) were significantly enhanced to 15.9±1.7 m/s and 12.2±0.8 m/s due to rhythmic hop.

2. Influence of the different instant of detecting an external stimulus on response time

Results of regression analysis showed no relationship of the onset timing of a LED signal and the response time of the roundhouse kick (R^2=.0951 for the linear fit, p>.05) but a significant relationship with the response time of the back kick (R^2=.3142 for the quadratic fit, p=.003) (Figure 4 and Table 2). For the back kick, the quadratic equation (U-shape) fits well the scattered results of the response time across the normalized onset timing of a LED flashing. The region of starting hop motion (around 0 to 22% of normalized time) indicated decreased response time with increasing onset timing of a LED signal and that of ending hop motion (around 80 to 100% of normalized time) showed increased response time with increasing onset timing of a LED signal.

These regions of onset timing revealed the downward motion of the body CM in rhythmic hop. However, the region around 30 to 70% of normalized time, implying the upward motion of the body CM, showed shorter response time than other timing regions.

IV. Discussion

The present study illustrated the effect of commonly-used rhythmic hop as a preparatory motion in Taekwondo sparring. Rhythmic hop did not improve response times in two different Taekwondo kicks. Although rhythmic hop showed slightly shorter response times for both kicks, results were not statistically sufficient. This result might be attributed to larger standard deviations than mean differences within subjects between two preparatory motions, which would reduce the effect size. The large standard deviations might be partially caused by randomness of triggering an external stimulus in this experiment or/and the variance of the simple reaction time. Since the mean simple reaction time of young people for light stimuli has been ranged 0.18 s to 0.20 s (Galton, 1899; Welford, 1980; Woodworth, 1954), we consider that the variance of the onset time of an external stimulus might be encompassed by the variance of the normal

Table 1. Comparison of response times and kicking velocities between rhythmic hop and no hop conditions (mean ± SD)

	Rhythmic hop	No hop	t	p	Cohen's d
Response time[s]					
Roundhouse kick	0.71±0.07	0.73±0.08	-1.40	.19	-.404
Back kick	0.73±0.08	0.75±0.08	-1.04	.32	-.300
Kicking velocity [m/s]					
Roundhouse kick	15.9±1.7	15.5±1.6	2.60	.02*	.751
Back kick	12.2±0.8	11.6±1.0	2.98	.01*	.860

Note: *indicates statistical differences between rhythmic hop and no hop for p<.025.

Table 2. ANOVA table by regression analysis for the roundhouse kick and back kick.

	df	SS	MS	F	Sig. F
Roundhouse kick (linear)					
Regression	1	0.042	0.042	3.50	.07
Residual	33	0.394	0.012		
Roundhouse kick (quadratic)					
Regression	2	0.042	0.021	1.67	.20
Residual	32	0.394	0.012		
Back kick (linear)					
Regression	1	0.007	0.007	0.88	.35
Residual	32	0.249	0.008		
Back kick (quadratic)					
Regression	2	0.080	0.040	7.09	.003*
Residual	31	0.175	0.006		

Note: df = degree of freedom, SS = sum of square, MS = mean square, F = Fisher's ratio, and Sig. F = significance F. * indicates a significant fit of the model with scattered data.

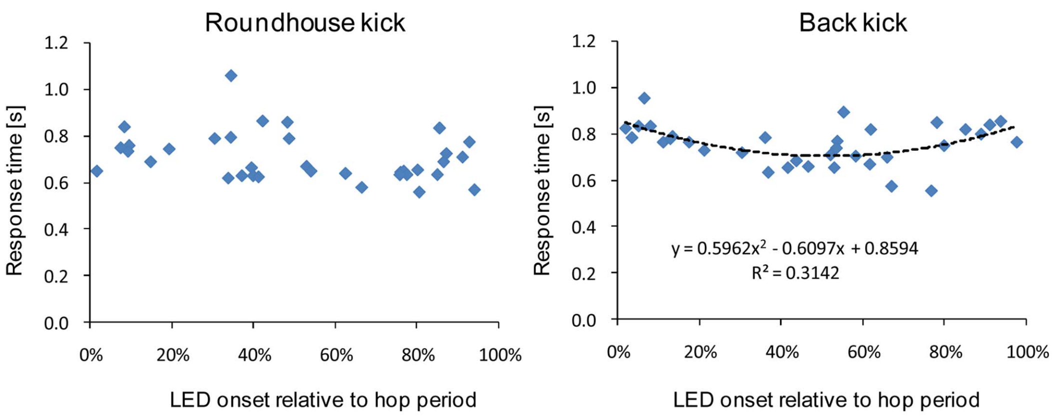

Figure 4. The relationship of the onset timing of a LED flashing relative to the period of hop and the response times of the roundhouse kick and back kick

reaction time. Thus, the group standard deviations of the response times between rhythmic hop and no hop seemed to be similar to each other regardless of different preparatory conditions.

However, rhythmic hop significantly enhanced the kicking velocities of the roundhouse kick and back kick. This result implies that participants utilized mechanical principle(s) better in rhythmic hop than in no hop. Even though we had limited resources in this study, we speculate that rhythmic hop as a preparatory motion might make use of inertia force efficiently than no hop did because of higher kinetic energy at the instant of detecting an external stimulus (i.e., dynamical CM motion than no hop). The higher kinetic energy might stimulate additional potential energy coming from leg muscles easily due to prestretch potentiation in continuous hops (Bosco et al., 1981; Komi, 1984; Aura & Komi, 1986) and to the increased muscle power as a result of strong concentric contraction of stretch-shortening cycle (Kim, 2007).

The result of the second research question was very interesting because it showed a detrimental effect of rhythmic hop to a certain type of kick. We guessed that the response time would be lengthened when participants detected an external stimulus in the middle of upward hop motion than in the middle of downward hop motion. However, for the back kick, the response time when participants detected the signal in the middle of downward hop motion was longer than the response time when they detected it in the middle of upward hop motion. This result might be because participants inevitably had to hop once more before a countermovement action sometimes after detecting an external stimulus in the middle of downward hop motion. The normal reaction time (0.18 s to 0.2 s) might not be enough to avoid a following hop after detecting an external stimulus because a mean hop cycle was 0.36±0.03 s across all participants.

The results on different instants of detecting an external stimulus provide athletes and coaches with practical insights in Taekwondo sparring. From the perspective of offense, a kicker should perform a his/her attack kick when an opponent's CM is in the middle of downward hop motion (i.e., the body CM passing the local maximum vertical point and moving toward the local minimum vertical point) if an opponent is about to execute a counterattack back kick during rhythmic hop. However, a kicker would be better avoid the instant when an opponent's CM is in the middle of upward hop motion (i.e., the time period of the body CM passing the local minimum vertical point and moving toward the local maximum vertical point). From the perspective of defense, athletes should be careful on their rhythmic hop because the rhythmic hop may be detrimental to the response time of the back kick depending on the onset of detecting the signal.

There were a couple of limitations to this study. First, the higher sampling rate (more than 200 Hz) would be better for the investigation of response time of rapid kicking movement because small mean differences of response times across all participants detected in this study should be carefully used to generalize the data. Second, we did not control the hopping frequency as a variable in this experiment. Since the variation of hopping frequency is a factor to affect human performance associated with utilizing the ground reaction force (Farley, Blickhan, Saito, & Taylor, 1991), this factor should be included in a future study.

V. Conclusion

The results of the present study revealed the effect of commonly-used rhythmic hop in Taekwondo on the response times and kicking velocities of the roundhouse kick and back kick. Rhythmic hop gave a positive effect on the kicking velocity across two kicks. However, different instants of detecting an external signal for the back kick in rhythmic hop showed different response times, which could be either an advantage or a disadvantage tactically in Taekwondo sparing. Therefore, athletes should be careful in executing their rhythmic hop as their preparatory motions for the back kick.

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