SUMMARY
The purpose of this study was to investigate whether there is a detrimental instant to response time of Taekwondo kicks when athletes execute their rhythmic hop as a preparatory motion in sparring. Twelve male collegiate Taekwondo athletes performed the roundhouse kick and back kick, respectively, as soon as possible when detecting an external stimulus. An external stimulus (a flash-on of a light) was triggered randomly. The combined signs of the body center of mass (CM)’s relative height and velocity at the instant of detecting an external stimulus was categorized into four groups and the response times were statistically compared among groups. For the back kick, the instant of detecting an external stimulus in the middle of downward hop motion with a lower CM position (G4) showed a significantly longer response time than that in the middle of upward with a higher CM position (G1). Therefore, athletes should be careful on their rhythmic hop as a preparatory motion in sparring in order to avoid the detrimental instant to the response time for the back kick.

INTRODUCTION
Taekwondo, as a combat sport in Olympic Games, requires rapid response to an external stimulus for winning a competition [1, 2]. A shorter response time may allow a kicker to perform intended attacks successfully to obtain points, as well as to avoid an opponent’s attack successfully. Therefore, athletes always pay attention to opponent’s footwork (e.g., rhythmic hopping) and/or trunk motion (e.g., shoulder gestures of initiating kicks) carefully in sparring in order to determine the best instant of either attacking or escaping.

According to personal interviews with elite athletes, some of elite athletes do not execute their rhythmic hop intentionally as a preparatory motion because they believe rhythmic hop would be detrimental to response time according to the instant of detecting an external stimulus. If they have to meet an opponent’s attack in the middle of upward hop motion (i.e., upward motion of the body center of mass (CM)), it is believed that the response time would take a longer than that in the middle of downward hop motion (i.e., downward motion of the body CM). This would be because the CM has to travel vertically more prior to the countermovement action for the kick. However, no scientific investigation has answered this question.

The purpose of this study was therefore to investigate whether there is a detrimental instant to response time of Taekwondo kicks during preparatory rhythmic hop used in sparring.

METHODS
Twelve male collegiate Taekwondo athletes (age 20.4±8.4 years, mass 71.9±8.4 kg, height 1.80±0.04 m; mean±s) participated in the study. All of the participants have been practicing Taekwondo for more than seven years (10.6±3.2 years) 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.

Full body kinematics, sampled at 200 Hz, was obtained using a six-camera motion tracking system (Hawk® Digital Real Time System, Motion Analysis System). 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 [3], and to quantify the motions of lower extremities. A hand-held pad (All-Star®, Tae Hwa Sports), having one reflective marker on it, was used as the target. A custom-made red light-emitting diode (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. An assistant held the target with one hand and, with the other hand, held a red close to the target. The height of the target was adjusted according to the abdominal level of the participant.

After warming up, the participant stood barefoot on the floor with the kicking foot behind the supporting foot. The participants were asked to perform their comfortable rhythmic hop as a preparatory motion before kicking and 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. 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. For each type of kick, three trials were performed.

Dependent variables were defined as follows. Response time was measured from the onset of a LED flashing to foot contact with the target. The vertical position of the body CM at the instant of a LED flash-on during rhythmic hop was selected and was normalized with respect to the mean vertical position of the body CM in the fight stance during no hop. In addition, CM velocity at the instant of a LED flash-on was calculated. Then the combined signs of relative CM height and CM velocity of an individual trial was categorized into four different groups according to its value (Table 1). Kruskal-Wallis one-way analysis of variance (ANOVA) on response time was used because the sample size of each group was small and different and the assumption of normalization was not met in some groups.

RESULTS AND DISCUSSION

![Figure 2](image)

Figure 2: Comparison of response times among four different groups of the CM relative height and CM velocity at the instant of detecting an external stimulus. Parenthesis indicates sample size of each group. * indicates a significant mean difference between two levels (P<0.05).

Regarding different instants of detecting an external stimulus, Kruskal-Wallis ANOVA showed no effect on the response time of the roundhouse kick ($\chi^2(3)=5.23$, P=0.154) but a significant effect on the back kick ($\chi^2(3)=8.41$, P=0.038) (Figure 2). For the back kick, the response time of G1 (0.70±0.08 s), indicating upward hop motion at the higher CM location, was significantly shorter than the response time of G4 (0.81±0.08 s), showing downward hop motion at the lower CM location (P<0.05).

This result might be because participants inevitable had to hop one more before a countermovement action in G4 condition. In addition, the reaction time (0.18 s to 0.2 s) [4, 5] 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. For both kicks, G1 condition showed the shortest response time.

The results on different instants of detecting an external stimulus provide athletes and coaches with practical implications 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 and located at lower position 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 and located at higher position. From the perspective of defense, athletes should be careful on their rhythmic hop because the specific combination of relative CM height and CM velocity at the moment of detecting an external signal may be detrimental to the response time of the back kick.

CONCLUSIONS

The present study revealed the detrimental instant to the response time of the back kick during commonly-used rhythmic hop in sparring. Since the instant of detecting an external stimulus in the middle of downward hop motion with a lower CM position induces a longer response time, athletes should be careful on their rhythmic hop in sparring.

ACKNOWLEDGEMENTS

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REFERENCES


Table 1: Tables may extend across both columns, and those should be included at the bottom of the proceeding.

<table>
<thead>
<tr>
<th>Group</th>
<th>Relative CM height</th>
<th>CM velocity</th>
<th>Motion description</th>
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<tr>
<td>G1</td>
<td>+</td>
<td>+</td>
<td>Upward hop motion at the higher CM height than the CM height of the fight stance</td>
</tr>
<tr>
<td>G2</td>
<td>+</td>
<td>–</td>
<td>Downward hop motion at the higher CM height than the CM height of the fight stance</td>
</tr>
<tr>
<td>G3</td>
<td>–</td>
<td>+</td>
<td>Upward hop motion at the lower CM height than the CM height of the fight stance</td>
</tr>
<tr>
<td>G4</td>
<td>–</td>
<td>–</td>
<td>Downward hop motion at the lower CM height than the CM height of the fight stance</td>
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