HOW TO GET POSTURAL STABILITY IN TAEKWONDO

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The purpose of this study was to evaluate techniques for keeping postural stability in Taekwondo continuous fast kicks. The results were summarized as follows: i) GOOD subjects can control their movement so as to offset the angular momentum of the whole body around the horizontal axis, ii) Good subjects produce smaller angular momentum around the vertical axis to maintain stability, and iii) POOR subjects try to offset the larger angular momentum produced by larger kicking leg motion, iv) Larger kicking motion makes athlete look like POOR. Taken together, our data suggest that coaches should be aware that athletes have to limit these to utilize the knee and hip joints motion of kicking leg and support leg motion to get kicking height and driving force. These motions are also the reason why POOR subjects cannot maintain stability in continuous fast kicks.

KEY WORDS: martial arts, kicking techniques, continuous fast kicks,

INTRODUCTION: Taekwondo is a one of the Korean martial arts characterized by a diverse array of kicks 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, roundhouse kicks are used most frequently until recent times and fast kicks are getting used frequently (Menescardi et al., 2014). A roundhouse kick is basically a circular action, kicking with the rear leg. Some studies have presented the techniques for both increasing kicking speed and decreasing kicking time in a roundhouse kick (Kinoshita & Fujii, 2014; Kinoshita & Fujii, 2015). 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 that hip joint motions of support leg during the phase before toe-off the floor are important to get the kicking speed and shorten the kicking time. On the other hand, a fast kick is basically a linear action, kicking with the front leg, and is sometimes called a lead-leg roundhouse kick. There are no biomechanical studies examining these fast kicks in part because it is not a basic kick and has variations. Menescardi et al. (2014) found that more linear actions such as fast kicks are performed in the final and semifinal rounds compared to preliminary, second and quarterfinal rounds. Continuous fast kicks without floor touch of the kicking leg are performed frequently in high level games such as World championships. Thus techniques of the fast kick are critical to win the high level competitions. In order to successfully execute continuous fast kicks, many factors are required. In this study, firstly, we focused on the techniques of maintaining stability during continuous fast kicks as this is the most critical factor successful continuous kicks without a floor touch of the leg.

METHODS: Fifteen Japanese Taekwondo athletes (male, n=12, female, n= 3) participated in this study after the informed consent. The participants had diverse skill levels. The experiment trial consisted of continuous fast kicks to a moving target with the preferred leg and without touching down of the kicking leg on the floor (Figure 1). The target height was the same as the participants' torso while target speed was the same for all subjects. The target distance conditions were determined voluntary. 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 (Motion Analysis MAC3

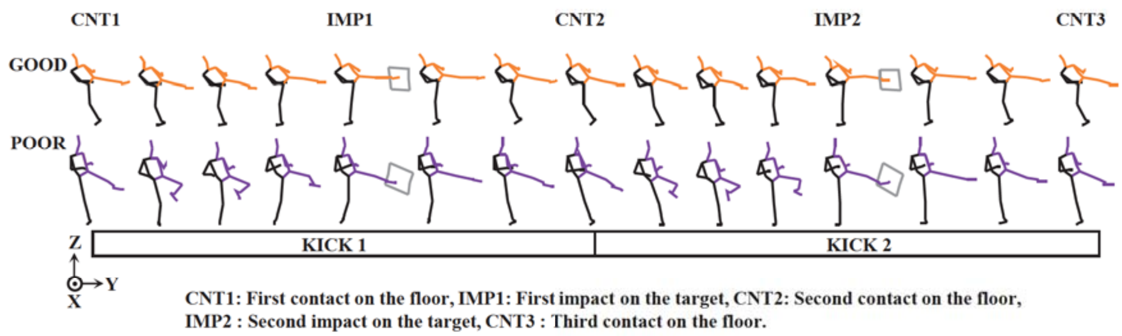

Figure 1: Continuous fast kicks.

D Systems, 200 Hz) and filtered with a Butterworth digital filter (12.5-27 Hz). The ground reaction force was captured by a force plat form (Kistler, 2000 Hz) at the second and third contacts on the floor and down-sampled to 200 Hz to directly align with the kinematic data. The center of gravity and angular momentum data were calculated to indicate postural stability in Taekwondo continuous fast kicks (Dapena, 1978). The root mean squares (RMSs) of whole body angular momentum around horizontal and vertical planes were calculated for evaluation of stability during the skill. Analysis events were defined as follows; first support leg contact on the floor (CNT1), first kicking leg impact on the target (IMP1), second support leg contact on the floor (CNT2), second kicking leg impact on the target (IMP2) and third support leg contact on the floor (CNT3) (Figure 1). Some low-level athletes did not have ability to kick the target at IMP1 or IMP2. In this study, particular athletes were not covered as described later.

RESULTS: Figure 2 represents the relationship between the RMSs of time series angular momentums of whole body around horizontal and vertical axes. The groups GOOD (n=6), POOR (n=6), OTHER (n=1), and FAIL (n=2) were selected on the basis of mean values of these two parameters (0.0487 $\pm$ 0.0184 m^2/s around horizontal axis, 0.0208 $\pm$ 0.0078 m^2/s around the vertical axis). Subjects with the exception of FAIL have a positive correlation between them ($r=0.749$, $p<0.05$). FAIL did not have the ability to kick the target at IMP1 or IMP2. Figure 3 shows the relationship between the maximum value of angular momentum of the whole body around the horizontal and vertical axes. All maximum values around the vertical axis of GOOD were smaller than the mean (0.0434 $\pm$ 0.0167 m^2/s). On the other hand, some maximum values around the horizontal plane of GOOD were larger than the mean (0.0988 $\pm$ 0.0249 m^2/s). Subjects, with the exception of FAIL, produced no correlation between values. Figure 4 shows the averaged RMSs of time series angular momentum of every body part and the whole body around the horizontal and vertical axes of both GOOD and POOR. The RMSs of angular momentums of left upper extremity and whole body around horizontal plane in GOOD and POOR were significantly different. The other body parts with the exception of left lower extremity support leg, also showed significant differences. Table 1 represented the root mean squares of time series angular momentum of every body part and the whole body in the averaged GOODs and every POOR (Subj. A, B, C, D, E, and F). All angular momentums around the vertical axis of GOODs were smaller than those of every POOR. On the other hand, the angular momentums around horizontal axis, in right lower extremities, kicking leg (Subj. D) and head and trunk (Subj. A, B, and C) were smaller than the values of GOODs.

DISCUSSION: The purpose of this study was to evaluate techniques for keeping postural stability in Taekwondo continuous fast kicks. As for fast kick, it does not need the rotation elements (averaged maximum angular momentum around vertical axis of fifteen athlete was

0.0434 ± 0.0167 m^2/s), unlike the roundhouse kick that needs circular actions for getting the kicking speed (averaged maximum angular momentum around the vertical axis of thirty-five athletes was 0.1757 ± 0.0325 m^2/s, unpublished data). The maximum angular momentum of the fast kick was about a quarter of that of the roundhouse kick because Taekwondo athletes kick with fore leg in fast kick. However, they have to control their angular momentum around the horizontal axis to adjust the kicking height, and to control their angular momentum around the vertical axis after impacting the target in the case of continuous fast kicks. According to Figure 2, we defined four groups based on angular momentum.

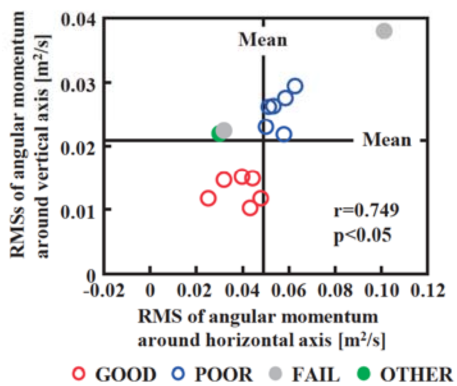

Figure 2 The root mean squares of time series angular momentum of whole body around horizontal and vertical axes.

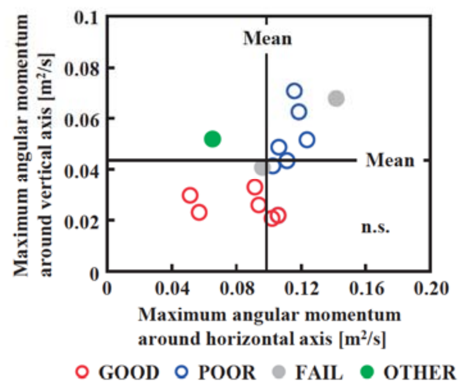

Figure 3 Maximum value of angular momentum of whole body around horizontal and vertical axes.

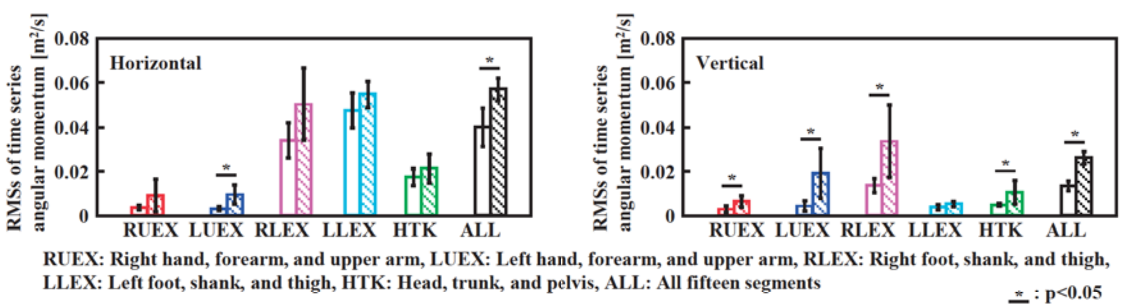

Figure 4 The averaged root mean squares of time series angular momentum of every body part and whole body around horizontal and vertical axes of both GOOD and POOR.

Table 1 The root mean squares of time series angular momentum of every body part and whole body in averaged GOOD (n=6) and every POOR (Subj. A, B, C, D, E, and F).

	Angular momentum around horizontal axis						Angular momentum around vertical axis					
	RUEX	LUEX	RLEX	LLEX	HTK	ALL	RUEX	LUEX	RLEX	LLEX	HTK	ALL
GOOD/ n=6	0.003	0.003	0.033	0.046	0.017	0.039	0.003	0.004	0.013	0.004	0.005	0.013
POOR/A	0.003	0.007	0.046	0.051	0.013*	0.051	0.005	0.014	0.017	0.004	0.005	0.026
POOR/B	0.004	0.004	0.048	0.061	0.016*	0.053	0.003	0.011	0.034	0.005	0.007	0.026
POOR/C	0.006	0.006	0.070	0.059	0.016*	0.058	0.005	0.009	0.034	0.007	0.006	0.022
POOR/D	0.008	0.010	0.028*	0.048	0.029	0.050	0.007	0.015	0.017	0.004	0.015	0.023
POOR/E	0.009	0.015	0.065	0.053	0.026	0.063	0.010	0.023	0.036	0.004	0.010	0.029
POOR/F	0.022	0.013	0.039	0.049	0.024	0.059	0.008	0.039	0.061	0.006	0.018	0.027

*: POOR < GOOD, Unit: [m^2/s]

Figure 2 showed the how much value is away from zero. We cannot change our angular momentum of the whole body without an external force. In this study, the airborne phase of continuous fast kicks exists from taking the foot off the floor to impact on the target. It is possible to disrupt our posture with larger angular momentum of the whole body. Figure 3 showed that even though the maximum angular momentum around the horizontal axis is larger, the RMSs of time series angular momentum of the whole body did not get larger. Some of GOOD maximum angular momentum around the horizontal axis was larger than mean values because subjects have to move forward during continuous fast kicks. In order to move forward, subjects need to get the ground reaction force in the kicking direction. That influenced largely the whole body angular momentum around the horizontal axis. As for the horizontal axis in Figure 4, GOOD had large RMSs of angular momentum similar POOR in every body part, except the left upper extremity. RMSs of angular momentum of the whole body, however, had a significant difference between GOOD and POOR. That seems that GOOD can control their angular momentum around the horizontal axis by offsetting with every body part motion. On the other hand, for the vertical axis (except the left lower extremity support leg), all body parts showed significant differences between the two groups. Thus GOOD do not produce the angular momentum around the vertical axis to limit their movement. Rather it is easier to control the angular momentum around the vertical axis using the impact force produced at contact with the target. A number of possible reasons might explain why POOR could not kick well. Firstly, POOR commonly used their upper extremity in order to offset their larger angular momentum produced by right lower extremity kicking leg. This offsetting motion by the upper extremity makes POOR clumsy because of looking like a large kicking action but lose their guard to enable them to get into this position, even if they can offset the body part angular momentum. Some POOR, however, had smaller RMSs of angular momentum of every body part around the horizontal axis compared to GOOD. For example, subject D produced the smallest value for the right lower extremity motion kicking leg motion, because he used a smaller hip joint motion. He, however, used different way to get the driving force from the support leg by utilising the torso and upper extremity motion. Conversely, subjects A, B, and C had a smaller value of torso motion. These subjects utilized the motion of kicking leg to achieve the kicking height. In any case, if they have larger angular momentum, they have to offset it as explained above. In competition, athletes have to guard their body and head from opponents' attacks. If they try to keep their stability with upper extremities, they can kick but they leave themselves more open to opponents' attack.

CONCLUSION: This study identified techniques for achieving stability in Taekwondo continuous fast kicks. Better players showed different strategies to manage angular momentum around horizontal and vertical axes. Coaches should be aware that athletes have to limit these to utilize the knee joint motion and hip joint motion of kicking leg to kick and get the kicking height. And also consider the support leg motion to get the driving force.

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