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HOW TO DEAL WITH ROTATION IN PARA-TAEKWONDO

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This study analysed the techniques of dealing with rotational motion in Para-Taekwondo roundhouse kicks (right leg kick with right affected rear arm/P-TKD-R and left leg kick with right affected frontal arm/P-TKD-L) compared with a Taekwondo roundhouse kick (TKD). The results were summarized as follows: i) Kicking speed patterns were different between TKD and P-TKD-L; and ii) Amount of frontal arm angular momentum around the X- and Z-axes were different during three conditions (TKD/P-TKD-R/L) because of compensatory motion. Considered together, our data suggests that the affected arm position, in turn, might affect the roundhouse kick mechanism. However the frontal position of the unaffected arm might be a minor effect of the asymmetry arm because the frontal arm can control the rotation of the upper torso.

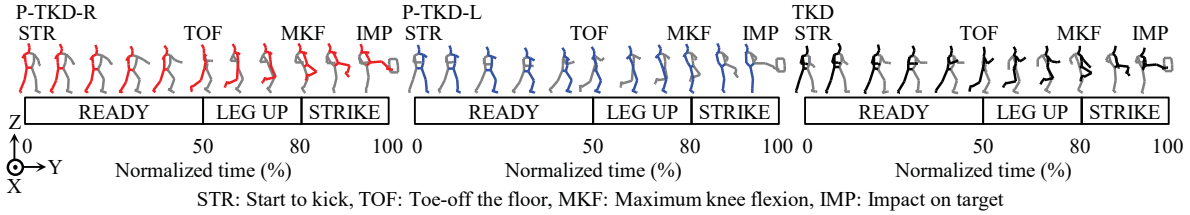
KEY WORDS: martial arts, kicking techniques, angular momentum, arm amputee

INTRODUCTION: Para-Taekwondo is one of the martial arts that mainly use kicking techniques for limb deficiency and arm amputee athletes. It will be included in the 2020 Tokyo Paralympic Games program. In Taekwondo competitions, roundhouse kicks were used most frequently until recent times (Menescardi et al., 2014). Para-Taekwondo has the same situation because its rules are almost the same as Taekwondo except kicking to head. A roundhouse kick has a circular action which involves kicking with the rear leg. The previous study presented the techniques for both increasing kicking speed and decreasing kicking time in a roundhouse kick (Kinoshita & Fujii, 2014). 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. Thus the roundhouse kick is needed the techniques of dealing with rotation in order to be successfully executed. And angular momentum indicates the parameter of rotation (Dapena, 1978). However limb deficiency and arm amputee athletes do not use their arms for controlling their rotation and execute the roundhouse kick without compensatory motion. Taekwondo athletes can kick with both legs symmetrically (Tang et al., 2007), while Para-athletes especially with unilateral amputation have different mechanisms of executing roundhouse kick because of affected arm position. In this study, we first focused on the angular momentum during a roundhouse kick, as this is the most critical factor of successful roundhouse kick for Taekwondo and Para-Taekwondo athletes. The purpose of this study was to analyse the techniques for dealing with rotational motion in Para-Taekwondo roundhouse kicks compared with the Taekwondo roundhouse kick.

METHODS: One Japanese national Para-Taekwondo athlete (Table 1) and thirty-five Japanese Taekwondo athletes (male, n=27, female, n=8) participated in this study after the informed consent. Taekwondo participants had diverse skill levels. The experiment trial consisted of a roundhouse kick to a target with both right and left legs for a Para-Taekwondo athlete (P-TKD-R, P-TKD-L). The affected arm position of this Para-Taekwondo athlete was the rear side in P-TKD-R condition and frontal side in P-TKD-L condition. Thirty-five Taekwondo athletes executed roundhouse kick to a target with a preferred leg (TKD) (Figure 1). The target height was the same as the participants' torso. The target distance conditions were determined voluntarily. The global coordinate system was defined as shown in Figure 1. The 3D coordinates of the reflective markers placed on the body segments and target were captured by a motion capture system (Vicon MX+ or Motion Analysis MAC3D Systems)

Table 1
Characteristics of Para-Taekwondo athlete

Basic Information	Gender	Sport Class	Weight Division	World ranking
	Male	K44	-61kg	18
Impairment Conditions	Type of Impairment	Affected side	Length of affected arm [cm]	Length of unaffected arm [cm]
	Upper arm amputation	Right	25.1	31.5



STR: Start to kick, TOF: Toe-off the floor, MKF: Maximum knee flexion, IMP: Impact on target

Figure 1 Roundhouse kick during three, P-TKD-R, P-TKD-L, and TKD conditions.

and filtered using a Butterworth digital filter (12.5-27 Hz). The body segment inertia parameters of the affected arm were estimated from a previous study (Ae, 1996). The angular momentum (AM) data was calculated to indicate the parameters of rotation (Dapena, 1978) and divided by the body weight to normalize it. All P-TKD-R/L data is the mean value of every three trials. And all TKD data is the mean value of thirty-five Taekwondo participants'. The analysis events were defined as follows: STR, the instant that the 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.

RESULTS: Figure 2 represents the kicking speed at impact and the duration time from STR to IMP. In TKD, there was a tendency by participants who could kick with a high speed to kick within a short duration of time. However in P-TKD-R/L, there were opposite tendencies. Figure 3 shows the time series data of the kicking speed during three conditions, P-TKD-R, P-TKD-L, and TKD. The pattern of the kicking speed in P-TKD-R was almost same as that of TKD. On the other hand, in P-TKD-L, the kicking speed was increased after 80% time. Figure 4 indicates AM around X-axis during the three conditions. (a) shows total (dashed line), rare arm (solid line), and frontal arm (dotted line) data, (b) shows kicking leg (solid line) and support leg (dotted line) data, and (c) shows upper torso (solid line) and pelvis (dotted line). In P-TKD-R, the affected arm is the rear arm, and in P-TKD-L, the affected arm is the frontal arm. Total AM of P-TKD-L was smaller than any other conditions between 10 to 30% time. Simultaneously the support leg AM of P-TKD-L had a minus value. The frontal arm (unaffected arm) AM of P-TKD-R was the largest and had a peak value at TOF. The frontal arm AM of TKD and that (affected arm) of P-TKD-L had almost the same patterns. The upper torso AM of P-TKD-R had a minus value from 30% to TOF. The pelvis AM of all conditions had almost the same value. Only the rear arm AM of TKD had a minus value after 60% time. Figure 5 indicates the AM around Z-axis during three conditions. Every line of (a), (b), and (c) is as the same as Figure 4. In P-TKD-L, data was inverted for aligning. The total AM of all the conditions had almost the same patterns and had peak values at TOF. After TOF, the total AM reached a fixed value. The AM of P-TKD-L was the smallest after TOF. Frontal arm (unaffected arm) AM of P-TKD-R increased sharply from 30% time to TOF. The peak rear arm (unaffected arm) AM around TOF of P-TKD-L was larger than the frontal arm (affected) AM. While, TKD and P-TKD-R had opposite tendency. Only the rear arm AM of TKD had a minus value after 70% time. The kicking leg AM of three conditions had almost the same patterns until MKF. After MKF that of TKD and P-TKD-R increased and P-TKD-L decreased. Upper torso and pelvis of all conditions had almost the same values during roundhouse kick.

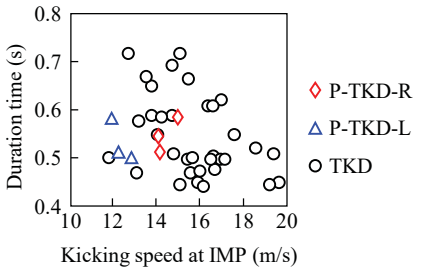


Figure 2 Kicking speed at impact and duration time from STR to IMP.

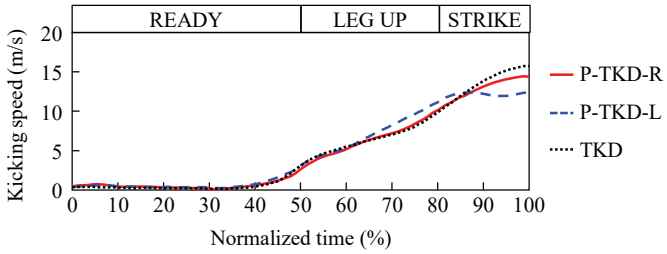


Figure 3 Time series data of kicking speed during three groups.

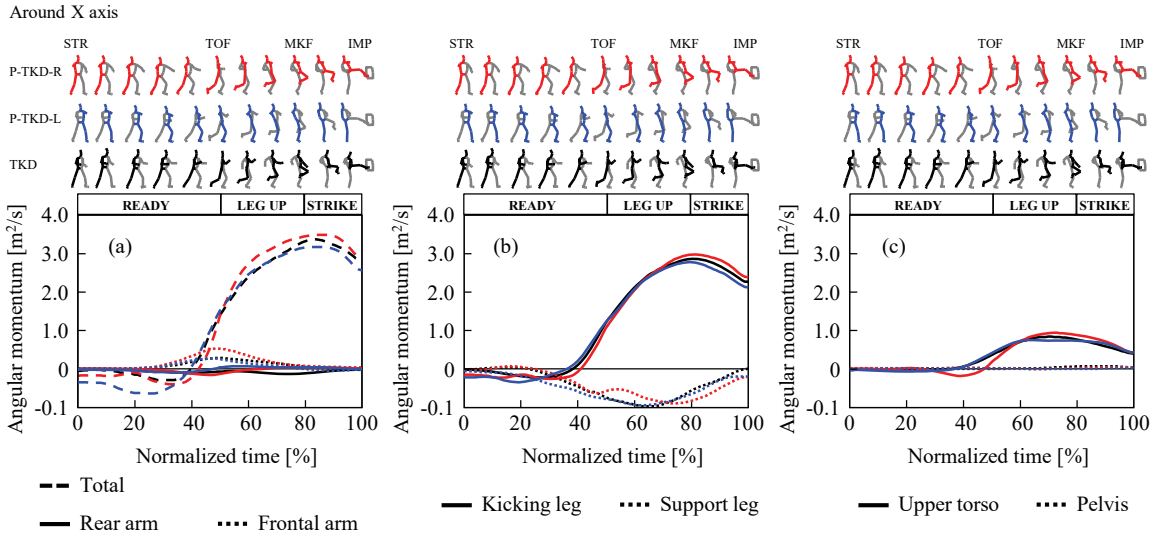


Figure 4 Angular momentum around X-axis during three conditions. Red line is P-TKD-R, blue line is P-TKD-L, black line is TKD.

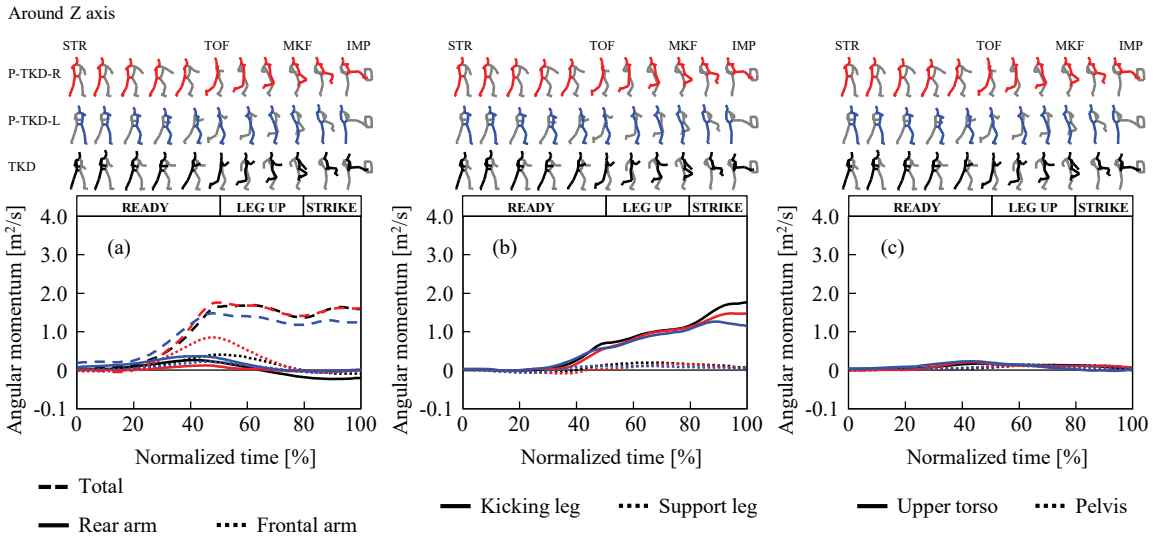


Figure 5 Angular momentum around Z-axis during three conditions. Red line is P-TKD-R, blue line is P-TKD-L, black line is TKD.

DISCUSSION: The reason why P-TKD-R had a longer duration time than P-TKD-L in spite of greater kicking speed (Figure 2) is that P-TKD-R had a longer duration time during READY phase in order to use more reactionary motion and get kicking speed at IMP. Further, we did not show the detailed motion data. However P-TKD-L could not increase the kicking speed

after TOF because of the earlier timing of the pelvic angular velocity of rotation (Figure 3). Thus, according to the affected arm position, a para-athlete has different mechanisms of the roundhouse kick because of asymmetry. The frontal position of the unaffected arm (P-TKD-R) might be little effect of asymmetry. The main purpose of this study was to analysis the techniques for dealing with rotational motion in Para-Taekwondo roundhouse kicks compared with the Taekwondo roundhouse kick. A roundhouse kick to the target needs not only vertical (Figure 5) but horizontal (Figure 4) rotation elements as well, because of kick to torso height. In P-TKD-R, the kick had almost the same AM pattern as TKD except the frontal arm (unaffected arm) AM around X- and Z-axes, upper torso around X-axis, and kicking leg AM around Z-axis. In P-TKD-L as well, the kick had almost the same AM pattern as TKD except the frontal arm (affected arm) and rear arm (unaffected arm) AMs around Z-axis, kicking leg AM around Z-axis, and support leg AM around X-axis. The upper extremities can control large AM through transfer term because of making moment arm from centre of gravity (CG) of the whole body to that of the upper extremity easily. The role of the frontal arm of TKD until MKF is controlling the rotation of the upper torso in order to help rotate the pelvis because the frontal arm can move in the rotational direction freely without body restriction. Thus, P-TKD-R generates large AM before TOF because of the use of more reactionary motion. There was a similar tendency in P-TKD-L. Because of the frontal position of the affected arm, the amount of AM was not much higher than P-TKD-R. Further the rear unaffected arm generated AM because of compensatory motion. However, the tendency of using reactionary motion by arm before TOF is not good for Taekwondo kick because opponents could notice the start of kicks and guard from them. The role of the rear arm of TKD after MKF is to control the rotation of the upper torso in order not to over rotate. Increased kicking speed around MKF commonly relates with whip-like-motion generated by decreased pelvis rotation and hip joint flexion angular velocity. Because of different pelvic rotational angular velocity pattern, there was a difference the kicking leg AM around Z-axis according to the conditions. Further, we did not find the any AM difference between the upper torso and pelvis during the conditions. However, AM difference plays an important role for generating kicking speed (Kinoshita & Fujii, 2014). Making use of only AM might not evaluate the role of the upper torso and pelvic rotation correctly. Finally, we need to capture data of many more Para-Taekwondo participants to generalize this theory.

CONCLUSION: This study identified techniques for dealing with rotational motion in Para-Taekwondo roundhouse kicks. Roundhouse kick mechanisms are different according to the position of the affected arm of a Para-Taekwondo athlete because of asymmetry. Further the frontal position of the unaffected arm might have little effect on rotation because the frontal arm can control the rotation of the upper torso in order to help rotate the pelvis without body restriction easily compared with the rear arm. However the use of much reactionary motion by the fore arm before TOF is not good for roundhouse kicks.

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