KICKING MOTION DIFFERENCE BETWEEN AFFECTED ARM POSITION

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This study analysed the difference of motion between affected arm position in Para-Taekwondo roundhouse kick (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) Distribution of using arm for helping upper torso and pelvis rotation was depending on unaffected arm; ii) P-TKD-L (affected frontal arm) firstly generate upper torso rotation; and iii) As for kicking speed, P-TKD-R (affected rear arm) was the same as TKD with whip-like-motion. Considered together, our data suggests that affected arm position affected mechanisms of upper torso and pelvis rotation and generating kicking speed. However, Para-subject could control his asymmetry arm for executing roundhouse kick.

KEY WORDS: martial arts, arm amputee, kicking techniques, unilateral arm

INTRODUCTION: Paralympic sports for athletes with physical disabilities or intellectual impairments are getting major. The research articles of Paralympic sports were also increased after 2012 London Paralympic Games. The athletes with disabilities can control their body appropriately to perform. Para-Taekwondo is one of the Paralympic sports which is included in 2020 Tokyo Paralympic Games and martial arts that mainly use kicking techniques for limb deficiency and arm amputee athletes. Para-Taekwondo is also similar to Taekwondo, which is one of Olympic sports because its rules are almost the same as Taekwondo except kicking to head. In Taekwondo, executing roundhouse kicks is basic technique (Kinoshita & Fujii, 2014). A roundhouse kick has a circular motion which involves kicking with the rear leg. Taekwondo athletes can kick with both legs symmetrically (Tang et al., 2007), while Para-athletes especially with unilateral amputation might have different mechanisms of executing roundhouse kick because of affected arm position. 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 (2017) also stated that the total angular momentum around vertical axis of both roundhouse kick of Taekwondo and roundhouse kicks of Para-Taekwondo had almost the same patterns and had almost the same peak values instead of affected arm position affected upper extremities' angular momentum. However, pattern of kicking speed had difference according to affected arm position because of asymmetry. Thus, limb deficiency and arm amputee athletes make angular momentum and control their rotation and execute the roundhouse kick with compensatory motion. However, affected arm position might limit the making kicking speed. In this study, we focused on the mechanisms of making kicking speed 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 clarify the difference of motion according to affected arm position in Para-Taekwondo roundhouse kick.

METHODS: One Japanese national Para-Taekwondo athlete (as the same as Kinoshita and Fujii, 2017) and thirty-five Japanese Taekwondo athletes (27 male, 8 female, Age: 20.8±2.6 yr., 1.71±0.07 m, 62±8.5 kg, Experience: 3.8±4.1 yr.) 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 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+, 250Hz or Motion Analysis MAC3D Systems, 200Hz) 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). In order to compare to Taekwondo roundhouse kick which had as the almost same kicking speed and duration time as Para-Taekwondo roundhouse kick, we chose the seven Taekwondo athletes based on minimum and maximum kicking speed at impact and duration time of P-TKD-R and L(TKD: 13.74±1.0 m/s, 0.556±0.038 s, P-TKD-R: 14.39±0.50 m/s, 0.547±0.036 s, P-TKD-L: 12.32±0.47 m/s, 0.473±0.050 s). The analysis events and motion phases were as the same as previous study (Kinoshita and Fujii, 2017). We calculated kinematics data and mechanical energy flow (Winter and Robertson, 1978).

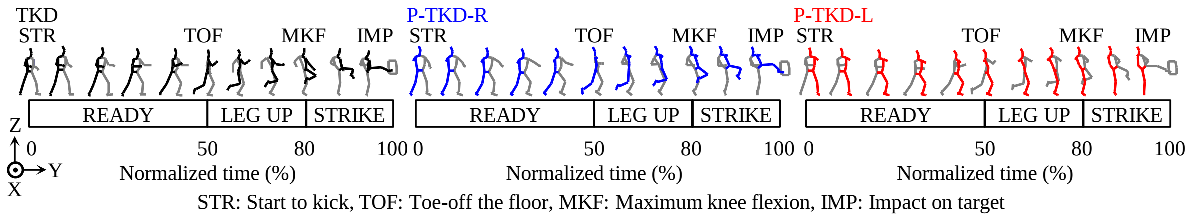

Figure 1 Roundhouse kick during three, TKD, P-TKD-R, and P-TKD-L conditions.

RESULTS: Figure 2 shows mechanical energy flow according to three motion phases. In this study para-subject has right arm amputation. Thus, affected arm position is rear side in P-TKD-R and frontal side in P-TKD-L (Figure1). In READY phase, larger mechanical energy flowed by joint force power (JFP) of R-ARM of P-TKD-L (-.85 J/kg) flowed out from upper torso. On the other hand, JFP of R-ARM of P-TKD-R (.12 J/kg) and TKD (.043 J/kg) flowed into R-ARM and value of P-TKD-R was larger than that of TKD. The value of mechanical energy flowed by segment torque power (STP) of F-ARM of P-TKD-R (.29 J/kg) was larger than that of TKD (.056 J/kg) and P-TKD-L (.044 J/kg). In LEGUP phase, JFP of R-ARM of TKD (-.20 J/kg) and P-TKD-L (-.23 J/kg) was larger than JFP of F-ARM (TKD: -.040 J/kg, P-TKD-L: -.018 J/kg). On the other hand, only JFP of P-TKD-R had opposite trend (R-ARM: -.10 J/kg, F-ARM: -.13 J/kg). And STP of F-AM of P-TKD-R (.26 J/kg) was larger than that of TKD (.030 J/kg) and P-TKD-L (.084 J/kg). In STRIKE phase, there was no notable characteristics. All value of three conditions were small. Figure 3 shows kinematic parameters during the three conditions. In READY phase, upper torso angular velocity of P-TKD-L (1.49 rad/s) had positive value at start position and was larger than that of TKD (.157 rad/s) and P-TKD-R (-.291 rad/s). Correspondingly, upper torso rotation angle of P-TKD-L was larger during READY phase. On the other hand, upper torso angular velocity of P-TKD-R was almost zero until 20 % normalized time. The patterns of upper torso angular velocity between TKD and P-TKD-R were different, but the amounts of change rate are almost the same at the end of READY phase (TKD:1.05 rad, P-TKD-R:1.16 rad). The patterns of pelvis angular velocity were almost the same. However, the value of P-TKD-L kept larger. In LEGUP phase, upper torso angular velocity of P-TKD-L was decreased sharply. The peak timing and pattern of pelvis angular velocity were totally different between three conditions. The amount of upper torso angle was almost same between three conditions at the end of LEGUP phase (TKD:1.97 rad, P-TKD-R:1.85 rad, P-TKD-L:1.85 rad). In STRIKE phase, the patterns of upper torso angular velocity of P-TKD-R and L were almost the same. The value of pelvis angular velocity of P-TKD-L was small. Additionally, the pattern of kicking speed of P-TKD-L was totally different in this phase.

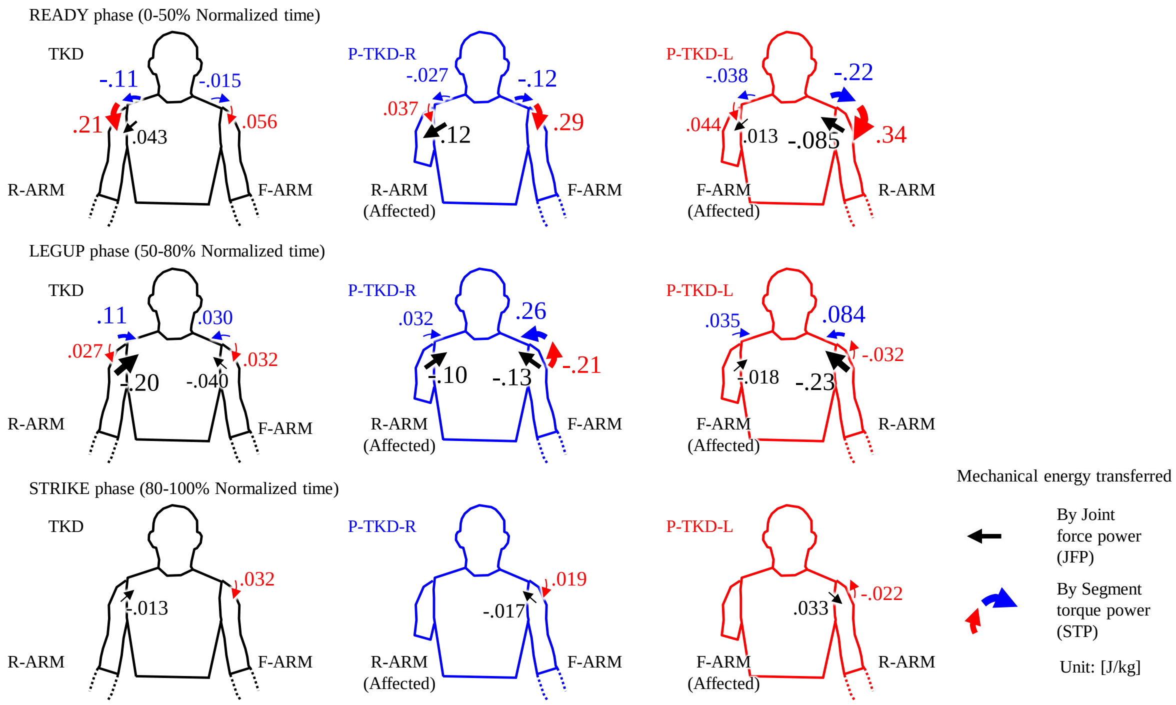

Figure 2 Mechanical energy flow according to motion phases.
Black is TKD, blue is P-TKD-R, and P-TKD-L. Black straight arrow is mechanical energy flow by joint force power (JFP) and blue and red curved arrow is mechanical energy flow by segment torque power (STP). Positive values indicate mechanical energy flow into adjacent segments and negative values indicate mechanical energy flow out from adjacent segments. R-ARM means rear arm (kicking leg side arm) and F-ARM means frontal arm (support leg side arm).

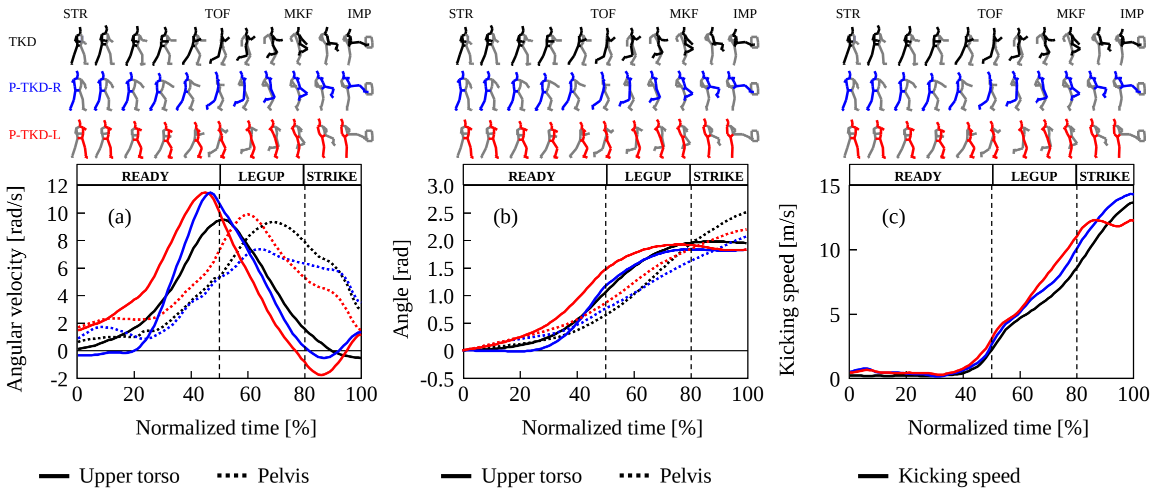

Figure 3 kinematic parameters during the three conditions.
Black line is TKD, blue line is P-TKD-R, and red line is P-TKD-L. (a) shows right-left rotation of upper torso (solid line) and pelvis (dashed line) angular velocity. Positive value is left rotation (right rotation in P-TKD-L) and negative value is right rotation (left rotation in P-TKD-L), (b) shows right-left rotation of upper torso (solid line) and pelvis (dashed line) angle, and (c) shows time series of kicking speed. In P-TKD-L, data was inverted for aligning.

DISCUSSION: Collectively, these results suggest that there are differences according to affected arm position. Here, P-TKD-subject has right arm amputation. Thus, affected arm position is rear side in P-TKD-R and frontal side in P-TKD-L (Figure1). TKD-subjects can use both frontal and rear arms to perform roundhouse kick. On the other hand, P-TKD-subject cannot use affected arm freely. Thus, distribution of JFP and STP was depending on unaffected arm (Figure 2). Because of affected arm position difference, there are difference of influence of upper torso rotation. In roundhouse kick of Taekwondo and Para-Taekwondo, athletes need to generate large rotational angular velocity of torso part for increasing kicking speed. In READY phase, the reason why only P-TKD-L had a large positive value of upper torso angular velocity (Figure 3 (a)) is that P-TKD-L firstly use rear arm (unaffected arm) to generate upper torso rotation. At the time using rear arm, because of restriction of body, upper torso rotated with motion of rear arm. Therefore, only JFP of P-TKD-L of rear arm flowed out from upper torso (Figure 2). On the other hand, P-TKD-R made counter movement with frontal arm (unaffected arm) to help upper torso rotation. The range of motion was larger than rear arm because of no restriction in the direction of movement. Thus, STP of P-TKD-R of frontal arm was larger than that of other conditions (Figure 2) and upper torso angular velocity was increased later (Figure 3 (a)). However, the tendency of using counter movement by frontal arm during READY phase is not good for roundhouse kick because opponents can notice the start of kicks and guard from them (Kinoshita and Fujii, 2017). In LEGUP phase, P-TKD-R uses frontal arm (unaffected motion) to generate upper torso rotation. Thus, large STP of P-TKD-R flowed out from upper torso. P-TKD-L had larger peak value of pelvis rotation angular velocity however, it decreased sharply during this phase (Figure3 (a)) because of prevention of over rotation. Thus, the end of LEGUP phase, all conditions had almost the same value of upper torso rotation angle (Figure 3 (b)). In STRIKE phase, role of arm for generation of motion is small. However, increased kicking speed commonly relates with whip-like-motion. Larger pelvis rotation angular velocity is one of important factors for whip-like-motion. P-TKD-L could not use whip-like-motion effectively because of earlier rotation with unaffected arm motion as we stated above. As for kicking speed, P-TKD-R had the same pattern as TKD (Figure 3 (c)). However, the mechanism of generation for kicking speed is different and using counter movement by frontal arm is not good for roundhouse kick. Additionally, in competition, athletes might have chance to lose their balance if they miss kick to opponents. However, in this study subjects could kick to target and stop their rotation. Thus, we could not find out the role of arm for keep balance. Finally, we need to capture motion data of many more Para-Taekwondo participants to generalize this theory.

CONCLUSION: This study identified the difference of motion between affected arm position in Para-Taekwondo roundhouse kick. Distribution of role for helping upper torso and pelvis rotation was depending on unaffected arm. Taekwondo athletes use both arm in order to generate kicking speed, on the other hand, Para-Taekwondo athlete might use unaffected arm mainly. Additionally, different way to rotate upper torso and pelvis according to affected arm position affected whip-like-motion for generating kicking speed.

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