THE BIOMECHANICAL ANALYSIS OF THE TAEKWONDO FRONT-LEG AXE-KICK

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The purpose of the study was to analyze the biomechanics of taekwondo front-leg axe-kick. One force plates, two synchronized high-speed cameras were used to measure biomechanical parameters in each phase of the front-leg axe-kick. The results included: 1. The average reaction time and movement time were 0.423 s and 0.327 s, which respectively occupied about 56% and 44% of attack time. 2. The maximum velocity of hip, knee and ankle were 1.74 m/s, 5.25 m/s and 7.43 m/s respectively. When the kicking leg touched the target, the velocity of knee and ankle were 0.78m/s, 1.72m/s, and 4.64m/s respectively. 3. The peak vertical GRF and impulse were 0.96 BW and 77.57N-s. For decreasing the movement time, it's suggested that an athlete should increase the power and flexibility of lower extremities during the training section.

KEY WORDS: taekwondo, axe-kick, biomechanic

INTRODUCTION: Taekwondo is a competitive sport in martial arts. The kicking leg, the unique feature to Taekwondo, is the major attack weapon in the competition (Hon, 1997). Previous studies (Kim, 1988; Chein, 1991; Tsai, 1998) showed that axe-kick was one of the main offensive actions with high percentage of offense, scoring and success during competition. Axe-kick is the main method of face kick, and which can be divided into front-leg axe-kick and back-leg axe-kick. The purpose of the kick is to attack opponent's head and genetrate a powerful and downward force. Recently study (Chen, Chin & Shiang, 2004) showed that front-leg axe-kick was the critical attack action for the percentage of success during competition. Generally, the faster and the more powerful the front-leg axe-kick is the more advantages can be gained. However, there was little study to discuss the biomechanics about front-leg axe-kick. The purpose of this study was to analyze the attack time and ground reaction force (GRF) of kicking leg of front-leg axe-kick.

METHODS: Eight skilled college male Taekwondo athletes (mean age, weight, height and trained experience were 21.12 ± 2.13 years, 66.75 ± 6.52 kg, 173.63 ± 3.74 cm and 11.38 ± 2.62 years respectively) served as subjects for this study. All subjects were standing on a force plate (AMTI, 1250 Hz) by their front leg, and then to kick the target after the signal of light appeared. Two high-speed cameras (Redlake, 125 Hz) were used to determine the three-dimensional kinematics data during action. The reaction time (RT) and movement time (MT) were collected by Bio-pac Systems which was used to synchronize the trigger of force plate and the signal of light. The attack time (AT) was defined as the summation of RT and MT. The motion of front-leg axe-kick (Figure 1) was divided into leg-lifting phrase (from the moment of leg taking off till the moment of minimum joint angles of knee) and leg-downing phrase. The impulse was integrated from the appearing of signal of light to taking off of leg.

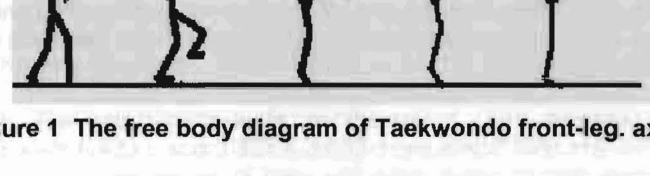

Figure 1 The free body diagram of Taekwondo front-leg. axe-kick.

Table 1 The variables of reaction time, motion time and attack time.

Variables (N=8)	Mean	S.D.	Ratio
RT (s)	0.423	0.049	0.56
MT (s)	0.327	0.026	0.44
AT (s)	0.750	0.069	1.00

The attack time consisted of reaction time and movement time. Table 1 indicated that the averaged time of reaction time (RT) and movement time (MT) were 0.423 ± 0.049 s and 0.327 ± 0.026 s, which were about 44% and 56% of attack time (AT). Based on previous study (Tsai, 1999), the RT, MT and AT of back-leg axe-kick were 0.531 s, 0.355 s and 0.886 s, respectively. The reason that the back leg was used to support body during front-leg axe-kick. Therefore, it was benefit to reduce the duration time of every phase. For open-style competition, the faster of the athletes can react, the more time they could execute the strategy. Therefore, the rapid reaction is the necessary factor for Taekwondo athletes (Chang, 1997).

Table 2 The knee and ankle joint angle at different events.

Variables (N=8)	Knee (M ± S.D.)	Ankle (M ± S.D.)
Angle of takeoff (deg)	134.1 ± 9.8	130.2 ±8.3
Minimum angle (deg)	83.6 ±15.0	106.1 ± 10.4
Angle of impact (deg)	171.2 ±5.1	161.4 ± 6.7

Table 2 showed the joint angle of kicking leg at different event. For increasing the distance of attack, the joint angle of ankle should be gradually decrease after takeoff, and increased the joint angle of ankle before touching the target. According to the theory, $H=I\omega$, if the more reduction on angle of knee, the greater the angular velocity. Thus, the time of front-leg axe-kick is influenced by angle of knee during the motion.

Table 3 The linear velocities of the lower limb at different events.

Variables (N=8)	Takeoff (Mean ± S.D.)	Impact (Mean ± S.D.)	Maxmun (Mean±S.D.)
Hip (m/s)	1.04 ± 0.41	0.78±0.37	1.74
Knee (m/s)	2.85 ± 0.46	1.72±0.27	5.25
Ankle (m/s)	2.91 ±0.38	4.64±1.02	7.43

Table 3 and Figure 2 indicated that the subject's velocities of lower limb in takeoff and touch event. Based on the principle of kinetic chain, the kicking sequence of Taekwondo's motion were the hip, theknee and theankle. By the axe-kick motion style, the Figure 2 showed that hip and knee joints sequenced by kinetic chain principle during leg-lifted phrase, but without sequential accelerating during leg-downed phrase. From the characteristics, the maximum joint velocity werel produced in leg-lifted phrase. Previece study (Lin, 2000) indicated that hip and knee points sequentially accelerated during leg-lifted phrase but the velocity was decreased in leg-downed phrase in order to perform proximal-distal sequence. The velocity of ankle point was usually used to evaluate the kicking effect, and the result was similar with of back-leg axe-kick (Tsai, 1999).

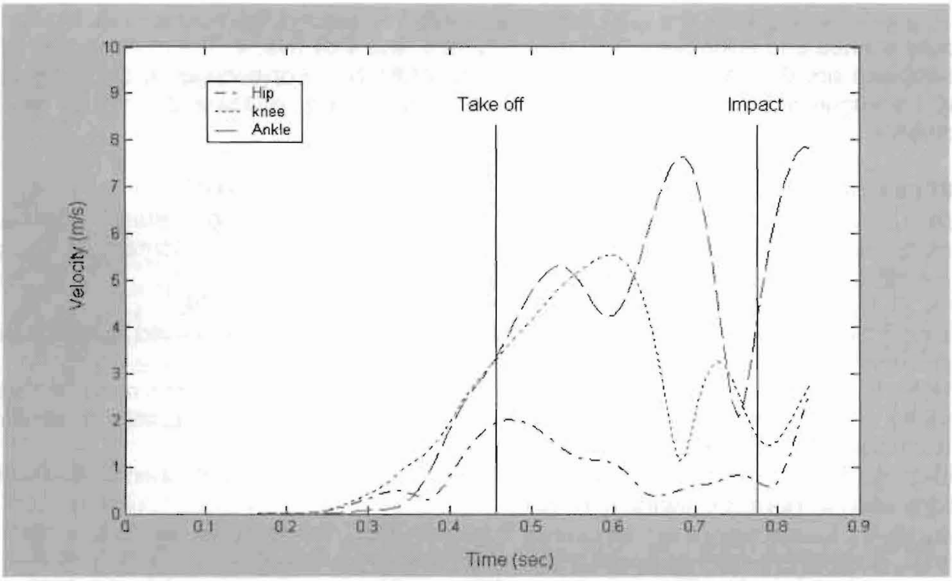

Figure 2 Linear velocities of hip, knee and ankle points from a selected subject.

Table 4 showed the peak vertical GRF and impulse in the movement phase. The peak vertical GRF was normalized by body weight of individual subject. Tsai (2002) showed that the peak vertical GRF and impulse of kicking leg were 1.46 BW and 225.8N-s in back-leg axe-kicking. This maybe due to the longer swing distance in back-leg axe-kicking, and the greater GRF could be produced. Base on the Newton's Second Law of motion: Impulse equal to the change of momentum (I=mV2-mV1), the total impulse will influence the velocity of push off, and then influenced the motion time. Therefore, the front-leg axe-kicking with shorter swing distance need more power and flexibility in lower extremities.

Table 4 The vertical GRF and impulse of Kicking Leg.

Variables (N=8)	Mean	S.D.	Max.	Min.
Fy_{max} (BW)	0.96	0.23	1.28	0.68
Impulse(N-s)	77.57	23.87	108.20	36.02

Table 5 Time of the two propulsive phases. Unit: sec.

Variables (N=8)	Mean	Max.	Min.
Total time	0.245 ±0.041	0.300	0.260
Time to Fy_{max}	0.143 ±0.042	0.220	0.110
Percentage	58%	73%	42%

The propulsive phase was defined as the duration from attack leg starting to push to take off. Table 5 showed that the time of propulsive phase was 0.245 ± 0.041 s and, the peak vertical GRF occurred at the 0.143± 0.042 s after leg pushed. According to the definition of propulsive rate (Fy max / Δ t), if the GRF of push is greater and the time to the peak is lesser, the propulsive rate will be greater. This could be benefit to the leg lifting ground faster.

CONCLUSION: The conclusions were as follows: 1. The average reaction time and movement time were 0.423 s and 0.327 s, which were about 56% and 44% of attack time. 2. The average minimum joint angles of knee and ankle during motion were 83.69 degree and 106.13 degree, and while the kicking leg touched the target, the joint angles of knee and ankle were171.26 degree and161.44 degree. 3. The maximum velocity of hip, knee and ankle are 1.74 m/s, 5.25 m/s and 7.43 m/s ; while the kicking leg touched the target, the velocity of knee and ankle were 0.78 m/s, 1.72 m/s, and 4.64 m/s. 4. The peak vertical GRF and impulse are 0.96 times of body weight and 77.57 N-s. For decreasing the movement time, it's suggested that increasing the power and flexibility of lower extremities will be necessary.

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