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BIOMECHANICAL ANALYSIS OF BACK-SOMERSAULT KICKS IN TAEKWONDO

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This study was purposed to investigate biomechanical differences between best and worst trials in performing back-somersault kicks in Taekwondo. Six elite members of college Taekwondo demonstration team participated in this study and executed each ten trials of single back-somersault kick and double back-somersault kick, respectively. High speed motion capturing system collected positions of 21 markers on major anatomical locations to obtain motion data of full body segments. After post-processing procedure, results showed that the best trial of back-somersault kicks indicated longer preparation time (countermovement), larger range of motions of hip joint, and higher peak angular velocities of knee and hip joints prior to take-off than those of the worst trial. We concluded that athletes should avoid a quick countermovement before take-off, which induces insufficient strain energy of lower extremities and ground reaction impulse. Therefore, a sufficient time for muscle contractions are required to develop high power.

KEY WORDS: Taekwondo, back-somersault kick, jump.

INTRODUCTION: Taekwondo is represented by Olympic style competition (i.e., sparring between two athletes). Recently the demonstration of breaking skills has gained the popularity so that demonstration became a type of Taekwondo competition. Due to necessity of high scores in competitions, athletes in demonstration tend to perform advanced back-somersault kicks. However, no biomechanical research on the demonstration jumping kicks in Taekwondo has been studied. Even though the preparation of back-somersault kick was similar to gymnastic back-somersault (Kwon, 2011), there was an unique kicking process on target(s) during airborne time. In gymnastic technique, athletes tend to tuck body segments in during airborne time in attempt to get smallest moment of inertia (MOI). However, athletes in Taekwondo have to extend leg segment to hit a target (disadvantage from the perspective of MOI) and then flex knees immediately to land on ground.

The purpose of this study was to execute biomechanical analysis of back-somersault kicks in Taekwondo. Especially we wanted to find biomechanical differences between the best and worst trials (with-subject trials) in order to provide coaches and athletes with biomechanical clues for successful kicks. We investigated both single back-somersault kick (SBS) indicting one leg hitting a target and double back-somersault kick (DBS) showing two legs hitting targets together. SBS is usually used for hitting an apple on the sword and DBS is normally used for breaking two wooden boards in the air.

METHODS: Six Taekwondo athletes (height of 1.72±0.07 m and weight of 65.3±3.7 kg) working at college Taekwondo demonstration team participated in this study. All of them could perform both SBS and DBS freely and had no neurological problem in performing back-somersault kicks. They signed consent forms prior to experiment.

Motion capturing system consisted of eight high speed cameras (Eagle®, Motion Analysis, Santa Rosa, CA, USA) with a sampling rate of 200 Hz and two forceplates (Type 9281E, Kistler, Winterthur, Swiss) with a sampling rate of 2,000 Hz. Twenty-one reflective markers were attached on major anatomical positions of a participant. Targets were a kicking pad for SBS and two practice flexible boards for DBS. A reflective marker was attached on each target in order to provide the instant of impact of kicking.

Each subject performed ten trials of SBS and DBS, respectively, after a 15-min warm-up sessions. The best trial was selected as a trial showing the best jumping height, flawless kicking on target(s), and safe landing among ten trials. The worst trial was selected as a trial showing improper or missing kicking on target(s) and/or improper landing.

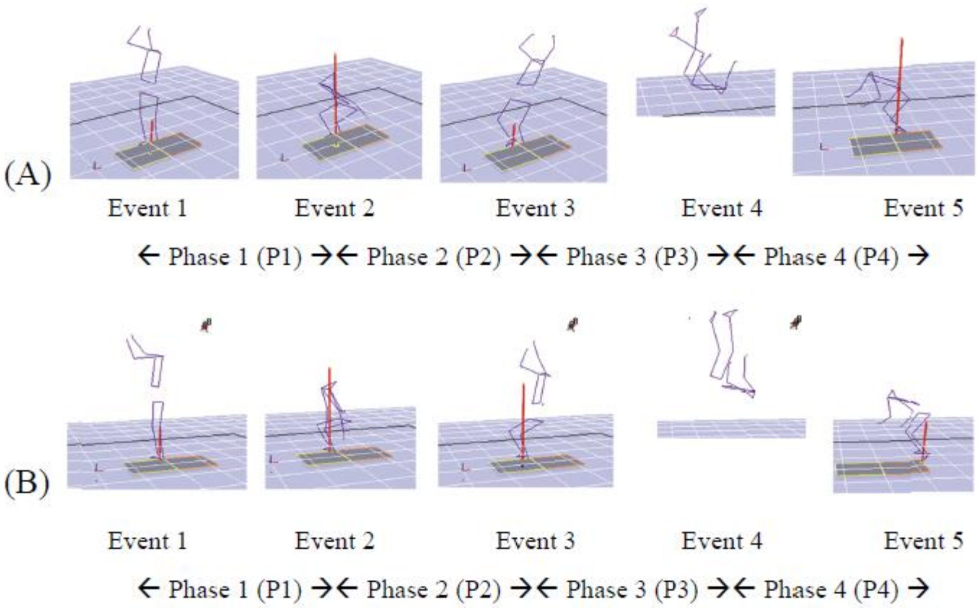

Figure 1: Definitions of event and phase during single back-somersault kick (A) and double back-somersault kick (B).

Each kicking motion was divided into four phases with five events in order to investigate the temporal variables and kinematic variables. Event 1 was a starting point, Event 2 was indicating the lowest position of the body center of mass, Event 3 was the instant of take-off, Event 4 was the moment of kicking, and Event 5 was the moment of the landing (see Figure 1).

After collecting motion capture, marker position data passed through Butterworth 2nd order filter (8 Hz of cutoff frequency) and used for joint angle calculation. Ground reaction force data were used for calculating peak ground reaction force, positive impulse, negative impulse, and net impulse prior to take-off.

In interpreting joint kinematics, symmetric motion was assumed in DBS and right joint kinematics was represented in statistical analysis. In SBS, all subjects used right leg as a kicking leg.

A paired t-test on each variable was performed. Test-wise significance level was set as 0.025 due to two kicks comparison.

RESULTS: Table 1and Table 2 demonstrated biomechanical differences between the best trial and the worst trial (within-subject trials) across six participants. Overall phase times of the best trials were significantly longer than those of the worst trials. As well, the vertical jumping height of the best trials was significantly higher than that of the worst trials.

Regarding joint kinematics, the hip range of motion and peak angular velocities of hip and knee for the best trials were significantly larger than the worst trials.

Table 1: Biomechanical comparison between the best and the worst trials in single back-somersault kick.

Single Back-Somersault Kick (SBS)				
	Best	Worst	t	*p*
Phase time (s)				
P1	1.06±0.11	0.82±0.05	5.47	<0.01*
P2	0.82±0.31	0.59±0.02	1.69	0.17
P3	0.51±0.04	0.44±0.04	11.2	<0.01*
P4	0.57±0.05	0.52±0.04	3.52	0.024*
Jumping Height (m)	0.31±0.04	0.24±0.03	13.5	<0.01*
Peak angular velocity (°/s)				
Hip	645.2±71.5	543.3±71.6	5.32	<0.01*
Knee	610.7±129.9	514.3±119.6	4.18	0.014*
Range of motion (°)				
Hip	93.4±12.6	83.8±8.8	4.03	0.019*
Knee	84.9±14.9	73.1±10.8	3.27	0.03
Ground net impulse (N·s)	371.2±150.4	103.8±80.3	3.42	0.027

* indicates significant difference statistically (p<0.025).

Table 2: Biomechanical comparison between the best and the worst trials in double back-somersault kick.

Double Back-Somersault Kick (DBS)				
	Best	Worst	t	*p*
Phase time (s)				
P1	1.05±0.13	0.80±0.11	3.57	0.023*
P2	0.67±0.02	0.60±0.02	5.80	<0.01*
P3	0.50±0.03	0.45±0.04	6.33	<0.01*
P4	0.55±0.05	0.50±0.05	7.21	<0.01*
Jumping Height (m)	0.30±0.02	0.26±0.05	2.28	0.07
Peak angular velocity (°/s)				
Hip	651.5±59.2	565.4±46.8	12.4	<0.01*
Knee	611.8±157.3	517±133.6	8.72	<0.01*
Range of motion (°)				
Hip	98.1±11.2	88.3±12.0	3.80	0.022*
Knee	84.0±17.5	75.3±16.5	3.01	0.034
Ground net impulse (N·s)	350.7±161.9	137.2±64.3	2.84	0.047

* indicates significant difference statistically (p<0.025).

DISCUSSION: This study performed the biomechanical analysis of back-somersault kicking including SBS and DBS. Since the advanced jumping kicks are necessary to get high scores in competitions of demonstration skills, athletes tend to perform back-somersault kicks within their demonstration program. This study illustrated that the best trial and the worst trial had some biomechanical differences. The major key point of performing back-somersault kicks was the preparation process. Especially the sufficient countermovement was the core among the whole process. The longer preparation time (P1 plus P2 time) might result from larger range of hip motion. This time also could be associated with the longer muscle contraction time of contractile muscles in an attempt to utilize force-velocity relationship efficiently since the longer concentric contraction time is the larger force production of contractile muscles

(Bosco, Viitasalo, Komi, & Luhtanen, 1982; Jung, 2007). Consequently, longer airborne phases (P3 plus P4) were obtained.

CONCLUSION: The successful back-somersault kicks including both SBS and DBS required sufficient countermovement prior to take-off. This process was the core determining successful kicks. From the coaching perspective, athletes should utilize large hip joint range of motion with enough countermovement time to produce higher ground reaction impulse. This enables an athlete to jump higher and sufficient airborne time to finish a clean kicking.

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