ISSN 1750-9823 (print)
International Journal of Sports Science and Engineering
Vol. 04 (2010) No. 03, pp. 188-192

Biomechanical Analysis of Jumping Back Kick of Elite Taekwondo Athletes

Chenxiang Qian[+] , Chao Fu, Youguang Fang, Quanhua Li

Dept. of P.E. Teaching, North China Electric Power University, Baoding, P.R.China ,071000

(*Received January 5, 2010, accepted March 21, 2010*)

Abstract. The article analyzes the motion of jumping back kicks by studying four elite athletes of the Chinese national team employing biomechanical three-dimensional DTL method. The jumping back kick is divided into 5 stages and three different movement phases according to time sequence. Combining all stages of body joint angles, velocity and other technical parameters and mechanical theory, the results show as following: The time of run-up stage should be shortened and the knee bending angle should be small. During right foot buffering phase, the right ankle, knee and hip bend in correct order rapidly and the gravity gets lost; swing the arms downward rapidly to increase extension and gravity; tread the land swiftly and strongly and stretching the hip and knee upward with violent force to increase the momentum on the ground and obtain greater reaction and greater initial speed and raise vertical height; make sure to swing the left foot with upper body backward and control the center of gravity well; twist the waist to press the left leg down and keep the right toe hooked tightly to the leg tightly; fold the arms sideward and fix the head to help the body the body swivel; unfold the left arm when the right leg is to tread the ground. In the phase of decline, keep the head down in chest with a view of self-protection; decrease the momentum of outreach through the internal muscular strength. The analysis is expected to provide a helpful reference for the technical teaching and innovation of Taekwondo.

Keywords: Taekwondo, jumping back kick, sport biomechanics

1. Introduction

The main purpose of Taekwondo stunt training is to show the complexity and beauty of that sport which comprises individual and collective actions. Statistics shows that back kick is one of the major methods to score[1]. A late start in practice, however, constrains the athletes from employing the back kick skill results in a lower score rate. In order to improve the taekwondo training level, the author(s) select turning back kick which develops from back kick, which has a certain degree of difficulty and is representative of the kinematic analyses of flight kicking movements. It is expected to provide a theoretical reference which can be applied to the teaching and training Taekwondo.

2. Subjects and methods

2.1. Subjects

Four elite athletes from Taekwondo Demonstration Team of China who won medals at international games. Forty successful motions out of several hundred are selected and analyzed.

2.2. Methods

The Motion Analysis System with 10 high speed cameras (Eagle cameras, Motion Analysis Cororation, Santa Rosa, CA, USA) are used to collect the kinematic data (sampling rate at 120 Hz) through tracking the 32 makers automatically, and then the joint angle for each lower limb obtained in the sequence of time. The literature and data access to a large number of sports biomechanics research results and relevant literature and SPSS 12.0 for statistical analysis are used .

3. Analysis and Results

[+] Corresponding author. Tel.: +86-13463282082.
E-mail address: snowmen@126.com.

The jumping back kick of Taekwondo action diagram is shown as follows:

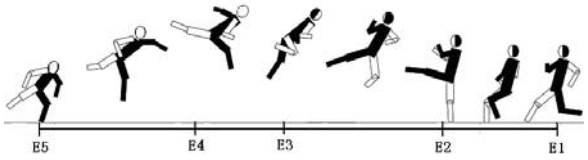

Fig.1.The stick figure of jumping-back process

Take the example for right leg attack: the movement time is calculated from left heel-off to the both-feet ground contact. The motion of jumping back kick (Figure 1) is divided into five stages: first is the instant that the swinging leg leaves the ground (Event 1, E1). Second is while the attacking leg leaves the ground (E2); Third is when the knee of the attacking leg flexes most (E3); Fourth is the instant of impact, and the last is when the swinging leg touches the ground. The duration from E1 to E2 is defined as take-off stage (TS). The duration from E2 to E5 is defined as flight stage (FS). The time after E5 is defined as landing stage (LS)[2].

3.1. Time characteristics of stages

Research shows that movements from the right foot treading on the ground to both feet landing take a total of 0.90 ± 0.02s. The time of gravity up to the maximum height is more than 0.36 ± 0.02s and the gravity dropping from the maximum height to the right foot touching the ground is 0.24 ± 0.02s.

3.2. Take-off stage

During the take-off stage the trunk angle increases slightly and the shoulder-foot angle changes from -152.2 ± 0.9 ° to 80.6 ± 0.9 ° before the right foot leaves the land, and the extension begins to decrease before the right foot leaves ground. With the intensification of left leg swinging, stunk angle remains stable and the abdomen presses back to raise the gravity.

a. Run-up: Athlete stands in positive, supporting the gravity on his right leg, and the right ankle, knee and hip rapidly bend in turn to get the ground's reaction; the left knee increases force before swing; while the left leg passes vertical, the left leg keeps straight and toe hooked to make the body up to obtain the speed to complete the following actions.

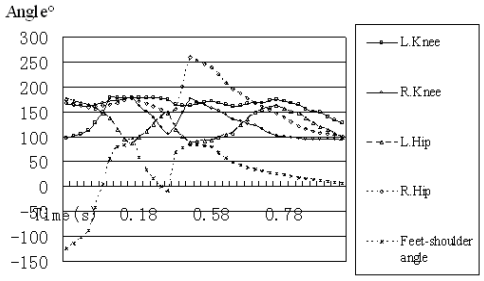

Fig.2. The mean joint angle patterns of legs

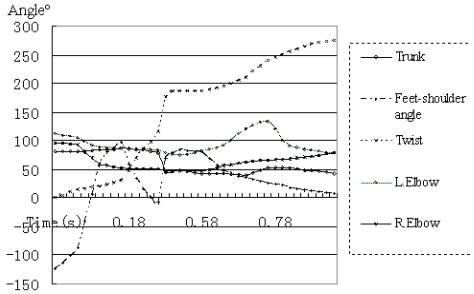

Fig.3.The mean joint angle patterns of trunk

b. Right leg cushion and extension: When the right foot is followed by a transition from heel to full-feet, the center of gravity move forward quickly; the right knee and ankle joints begin to be tense. The right ankle, knee and hip joints are followed by the rapid bending down with the pressure of weight loss. With the decline of gravity in the buffer phase, the right foot changes from the heel over to full-foot support and the joint angle of right ankle increases rapidly. From the momentum theorem:

$$\int_{t_2}^{t_1} \mathrm{F}dt = \int_{p_2}^{p_1} dp = P_2 - P_1 = mv_2 - mv_1$$

It can be learned[3] that the right foot jumps swiftly and with violent force, stretch the hip extensor acutely to increase the momentum on the ground, obtain greater reaction to gain greater initial vertical velocity V_0 and height H. After this phase, the right leg, hip, knee and ankle joint angles gradually increase, in which period the right knee angle accelerates to the highest of 488.4 ± 2.7 ° / s. Trunk angle has a gradually increasing trend, and shoulder-foot angle changes from -154.4 ± 0.8 °when the right foot lands to 81.7 ± 0.9 ° during buffer phase and it increases before the right pedal gets off the ground. As the trunk angle

increases, the gravity grows with the reduced pressure, which is helpful for the abdomen to contract for strength.

3.3. Flight stage

Flight stage includes three phases: swing, extension and decline of legs.

a. Left leg swing: The body is only influenced by gravity without the role of external torque at the instance of right foot leaving ground, so $\int_{t_1}^{t_2} Mdt = \mathrm{I}_1\omega_1 - \mathrm{I}_2\omega_2 =$ Constant and conservation of angular momentum[4]. The body swivels at the moment the right leg jumps off the ground, the head first and then the body, to get acceleration which stimulates the vestibular analyzer to get the sense of direction and regulate body organs to complete the swivel. Myotactic reflection caused by the swivel of head is conducive to the completion of twist. In order to be able to complete swivel in a relatively short time, the body should be fully stretched when the upper body twists, two shoulders outreach and the arms rotate round the body axis; reduce the distance between the arm and the vertical axis and keep the hip fixed. With the upper body rotation the left leg swings to the highest point, driving the right leg positively swarmed with the transfer of angular momentum. Both the left leg under pressure and upper body moment of inertia of the trunk are combined together to keep the right leg rotary around the human frontal axis. According to law of conservation of angular momentum, when the right foot gets off the ground, the body is in flight state and the body axis in the frontal external distance is free from the conservation angular momentum. When one part of the body rotates in a certain momentum in one direction around the axis of rotation, the other part of the body will move in an opposite direction around the same shaft with the same momentum[5]. Therefore, when the left leg presses down the angular momentum of the right leg rises and so does speed.

b. Right leg swing and stretch: Swinging of left foot drives right leg to swarm positively. The right knee angle is rapidly folded in 0.24s and angular velocity rises up to 620 ± 1.2 ° / s, the right hip angle decreases gradually from maximum angle and right ankle angle is unchanged during over-stretch tread. 0.36±0.02s after flight, the right foot hits the highest point at which moment the right leg extends completely. The speed of toe-line rises up to 9.26 ± 0.84m / s . When the body continues to rotate around the vertical axis, angular momentum transfers from the trunk, left arm and leg to the right leg; the knee bends backward, the angle of right hip and knee reduces gradually and the ankle joint maintains appropriately tense when the right leg passes the highest point.

c. Trunk angle: The trunk angle is almost unchanged during the course of left leg swinging to bring gravity up. When the left leg reaches the highest point, it brakes internal rotation and the trunk angle decreases gradually to meet the body's rotation[6].When gravity rises up to the highest point, that is, when the upper body swivels 180 ° and the right leg extends completely, the trunk angle increases again. After the right leg passes the highest point, the trunk angle decreases.

d. Foot-shoulder angle: Foot-shoulder angle achieves the maximum at the moment when the right leg gets off the ground. As the arms and left leg swing upward, the left leg and arms brake together when the left leg swings to a plane level; the right leg actively pedals up. With left leg braking the foot-shoulder angle decreases rapidly to 42.6 ± 0.7 ° negatively. When the upper body completes the swivel, with the attack extension of right leg, the foot-shoulder angle increases again before it gradually decreases after the pedal extends completely.

e. Twist angle: The moment when the right leg treads on the ground, the head twists backwards first along the axis of rotation. When the waist strengthens to rotate, two arms are folded beside the intercostal and the trunk begins to rotate around the longitudinal axis. With the shoulder foot angle decreasing the torso twist angular velocity increases and make the sight return to the target and then the attack is completed. Practice shows the reason why many athletes can not hit the target after the completion of flight is because their sight can not return to the target in time after they finish the back kick[7]. Therefore the head should also turn actively around the vertical axis to facilitate the early return of sight.

f. Elbow angle: Fold the two arms in order to reduce inertia and avoid being attacked during the twist. From Figure 3 it can be learned that the right elbow angle maintains around 60 ° stably. While the left elbow angle keeps unchanged at the moment the right leg stretches, the right elbow stretches rapidly to stabilize the stunk angle effectively. Meanwhile, the extension of the left arm also leads to improvement of the hit results and be conducive to the energy transfer of right leg extension. In the process of swivel, the upper body brakes actively, the left arm stretches in the opposite direction of rotation axis to balance the body rotating

inertia, which will help the upper body brake. The fixed head and rightward turning are conducive to the right leg brake.

g. Ankle angle: After actively extending the leg, the upper body swarms positively and keeps hook-pin during the leg extension moment. After the complete brake of back extension, the leg completely stretches and keeps the hip and knees fixed. Figure 1 shows that thigh and crus stretching together keeps the foot attack in straight line, which is the most economical route, so that it helps to accelerate movement and improve attack efficiency. The leg hook pin is steady in the stretch and the ankle is fixed so that, one, it reduces the buffer to avoid weakening the force of role; two, according to the speed leverage theory, hooked feet can stimulate the calf muscles to contract strongly to increase the crus muscle torque. But we can't hook the feet early before the calf stretches completely to avoid the premature tension of calf muscles. And the last, it can keep ankle muscles and ligaments tense to avoid injuring the feet.

h. Decline phase: The body should prepare for landing when the right leg stretches completely. Body posture is directly related to the stability and security of landing. Upon completion of the right leg stretching movements, the muscle contracts, and, head down on chest, the body is in the posture of self-protection, reducing the momentum of outreach through the work of internal muscular forces.

3.4. Landing stage

During landing stage, the left foot lands ground transiting gravity from sharp to sole, and left knee, followed by right foot and right knee, bends actively to buffer gravity and to increase support and stability in landing. According to the law of impulse $Ft = \triangle mv$, so $F = \triangle mv / t$, in landing, buffering by extending time reduces the external force from ground to body. The left ankle angle maintains moderately tense about 90 ° when the left foot lands, and the trunk angle decreases further and right knee bends further backward to reduce the speed of falling gravity.

4. Conclusions and recommendations

a. The right foot should transit from heel point to whole feet in the run-up stage, shortening the treading time, and the knee bending angle should be small to reduce energy loss and facilitate the completion of flight action. During right foot buffering phase, when the right ankle, knee and hip bend in correct order rapidly and the gravity gets lost, put down the arms rapidly to increase the extension and loss of gravity; tread swiftly and strongly and stretch the hip extensor with violent force are acute in some way to increase the momentum on the ground and obtain greater reaction and greater initial speed and improve the vertical height. Make sure to swing the left foot with upper body backwards and control the center of gravity well.

b. Keep the attention to the waist twist; press the left leg down and keep the right toe hooked tightly to the leg tightly; fold the arms and fix the head to drive stunk rotation. Be careful to extend the left arm when the right leg treads and stretches. In the phase of decline, keep the head down on chest to in the posture of self-protection, reducing the momentum of outreach through the work of internal muscular forces.

c. Improves muscular power through jumping and lowering limbs training to meet the needs of difficult practicing moves. Do more basic movement exercises to establish the correct ground movements, and more practices of raising one knee swivel kick on the ground to establish the correct body posture. Do more auxiliary exercises of right leg swinging down and stretching upward which require calf relaxation and foot hook tightness.

5. References

[1] Hui Zhu, xin-xuan Xue. A comparison of application of leg techniques of male Taekwondo athletes both in China and abroad. *Journal of Wuhan Institute of Physical Education*. 2002, **36**(6): 149-150.

[2] Y. J, Tsai, C. F, Huang and G. H, Gu. *The kinematic Analysis of Spin-Whip Kick of Taekwondo in Elite Athletes.Journal of Biomechanics 40(S2).* XXI ISB Congress, Poster Sessions. 2007, S615.

[3] Feng Yang. Analysis of the kinematics of difficult movement with 0.9 score in jumping and spring of group C in competitive aerobics. *Journal of Shandong Institute of Physical Education and Sports*. 2006, **22**(3): 85-89.

[4] Chao Fu, Chenxiang Qian. A Biomechanical Analysis of 360°Turning Kick in Taekwondo Stunt. *Journal of Shandong Institute of Physical Education and Sports*. 2009, **25**(1): 68-71.

[5] Yugang LI. Rotating mechanical analysis of Taekwondo Yeop-Jireugi. *Journal of Wuhan Institute of Physical Education*. 2003, **37**(3):55-58.

[6] Zongxiang Hu, Xuezhen Liu. The Biomechanics Analysis on Trunk Sport at Horizonta1-Kicking of Taekwondo. *Journal of Beijing Sport University*. 2008, **31**(1): 64-81.

[7] Junfa Wang, Jianguo Liu. Research on Phenomenon of Taekwondo Elite's Instantaneous Loss of Attention. *Journal of Shanghai University of Sport*. 2006, **30**(1):71-74.