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# Biomechanics of the Taekwondo Axe Kick: a review

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## ABSTRACT

Mailapalli, D.M., Benton, J., & Woodward, T.W. (2015). Biomechanics of the Taekwondo Axe Kick: A Review. *J. Hum. Sport Exerc., 10*(1), pp.141-149. The axe kick in Taekwondo has been observed to be a highly effective offensive and defensive technique. Its purpose is to attack the opponent's head, collarbone or chest with a powerful downward force. However, few researchers have studied the biomechanics of this kicking technique. The modified competition rules of World Taekwondo Federation (WTF) on the number of points to the head resulted increase in the number of kicks to the head by athletes using the axe kick. Therefore it is important to know the biomechanical principles of the axe kick for executing the kick effectively with minimum injury to the opponent's head, collarbone or chest and for scoring maximum number of points in a competition. The main purpose of this article is to present a general description, variations and biomechanics of the Taekwondo axe kick. **Key words**: TAEKWONDO, AXE KICK, BIOMECHANICS, SAFETY

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## INTRODUCTION

Taekwondo is an ancient art of unarmed combat that includes kicking, punching and way of life. The name 'Taekwondo' is derived from the Korean words, 'Tae' meaning foot, 'kwon' meaning fist, and 'do' meaning the way of. So, literally 'Taekwondo' means 'the way of foot and fist'. The name 'Taekwondo' was coined in 1955 while the arts' Korean roots began in 2,300 BC. The physical training through kicking and punching is what makes Taekwondo unique among other styles of martial arts and the way of life through practicing the tenants of Taekwondo: courtesy, integrity, perseverance, self-control and indomitable spirit. Currently, Taekwondo is widely practiced by 70 million people in 190 countries (Kim, 2009). Martial arts theories tend to be heavily rooted in tradition, and as such have not been biomechanically analyzed to the same degree as more modern sports such as swimming, gymnastics, and cycling (Pieter, 1994). Choi (1988), states that Taekwondo techniques are based on the laws of physics and propose the "theory of power" as a basis for ideal technique. The first attempts made at delivering a scientific biomechanical description of the martial arts techniques began in the 1960s.

Kicks in Taekwondo can be grouped as swing, thrust and combined kicks based on their kinematic characteristics of kicking (Kim & Hinrichs, 2006).The swing kicks (e.g. front kick, axe kick),which attempt to hit the front of an opponent in a straight movement, the thrust kicks (e.g. side kick) are performed by rotating the body towards the side of the opponent (front of the opponent faces side of the attacker) with body rotation directed to the side of the opponent, the combined kicks are performed with both thrust and swing motion(e.g. hook kick). The swing kick is used to maximize the speed of the foot at impact. The thrust kick is used to generate large forces at impact. The combined kick is used to generate both high speed and large forces. Swing kicks have highest speed (13.5 meters/second [m/s]) followed by combined and thrust kicks (Kim & Hinrichs, 2006).

In another study, Bercades & Pieter (2006) grouped the Taekwondo kicks as linear, spinning and circular. The linear kicks are simplest in terms of biomechanical efficiency analysis. Studies on linear kicks have included front snap kick and front pushing kick (Ahn, 1985; Hwang, 1987; Wasik, 2012). The spinning and circular kicks include roundhouse, spinning hook and spinning back kick (Hwang, 1985; Wholin, 1989; Serina and Lieu, 1991; Pieter & Pieter, 1995; Boey & Xie, 2005). The biomechanics of some of the Taekwondo kicks is presented in Table 1.

Table 1. Some of the taekwondo kicks and their execution performance

| Taekwondo kick | Peak linear velocity, m/s | Execution time, s | Reference |
|---|---|---|---|
| Front kick | 12 – 14 | 0.25 | Wasik, 2012 |
| Turning(round) kick | 13– 16 | 0.74 | Pearson, 1997<br>Serina & Lieu, 1991<br>Falco et al. 2011 |
| Roundhouse kick | 19-26.3 | 0.30 -0.65 | Kong et al. 2000<br>Pieter & Hiejmans, 2003<br>Hermann et al. 2008 |
| Side kick | 5.2-6.9 | 0.7-0.84 | Pieter & Pieter (1995) |
| Jumping back kick | 9.26 | 0.9 | Qian et al. 2010 |

 

The front kick is characterized by a proximal to distal sequential motion with a fast unloaded movement to maximize kick foot velocity. The peak linear velocity of the foot has been observed within the range of 12-14 m/s and the total execution time for this kick is 0.25 s (Wasik, 2012). The turning (round) kick employs a motor control pattern similar to the front kick, but uses additional body rotations to produce great velocity, with a cost of twice the execution time (Table 1). The roundhouse kick is similar to the turning kick (full turning/round kick) in which the striking surface is the top of the foot. The roundhouse kick constituted 50% of all kicks and contributed 89% of all points in competition (Lee, 1998). This could be due to its greater peak linear velocity and lower execution time compared to turning kick. Side kick generates a peak velocity (5.65 m/s) at the length of the leg equal to 82% of the maximum length of the fully extended leg (Wasik, 2011a, b). These kicks are more frequently used by the athletes during the tournaments. In order to make Taekwondo sports fairer and more interesting to watch World Taekwondo Federation (WTF) has modified competition rules and increased the number of points to the head to three (Han, 2012). This resulted increase in the number of kicks to the head using the head kicks such as axe kick.

Taekwondo axe kick has not been biomechanically studied by many researchers. The axe kick can be characterized as a whip-like kicking movement during leg lift and an axe-like movement during the downward drive of the heel or the ball of the foot. The axe kick is most useful when an opponent is open in the upper body region. Koh & Watkinson (1999) concluded that about 51.4% head blows were by the axe kick followed by roundhouse kick (25.7%).The challenge in studying the axe kick is that there is readily available technology to study other kicks, and devising tools to measure axe kick efficiency is more difficult (Bercades & Pieter, 2006; Yu et al., 2012).

## TAEKWONDO AXE KICK

To execute the axe kick, the fighter brings up his/her kicking leg in a linear/circular motion, and at the peak height, brings the heel or ball of the foot straight down (like a downward movement of an axe) (Figure 1) upon the opponent's head, shoulder or chest. Another use for the axe kick is to stop an incoming attack. The fighter can target an axe kick against the supporting thigh of an opponent in the initial stages of a kick.

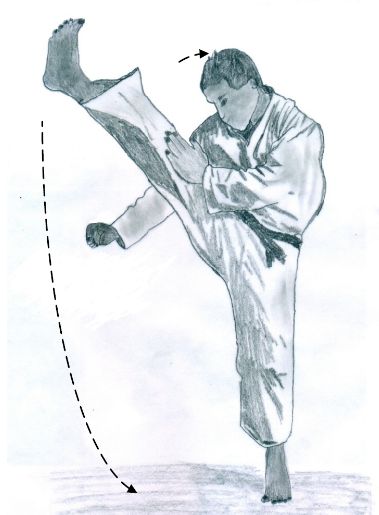

Figure 1. Axe kick execution during power load

The axe kick is executed in four stages and Yu et al., (2012) demonstrated graphically as shown in Figure 2. Stage one, the Decoy, is optional and meant only to confuse the opponent with regards to which leg is the kicking leg and, in turn, create an opening to target. The fighter executes a rapid stance change, followed immediately by the next stage: The Power Load. In this second stage, the fighter raises the kicking leg in a slight medial circular motion, building power for the ensuing kick by pre-lengthening the kicking muscles. The velocity of the upward motion, as well as the height of the kicking heel will determine the force of stage three: The Drive. Here, the fighter positions the heel of the kicking foot directly above the target area as the heel reaches peak height. The circular motion is stopped and all the energy derived from the Power Load is transferred to the Drive downward into the opponent. Finally, stage four, the Landing and Stabilization, returns the fighter to a stable stance so further techniques can be performed.

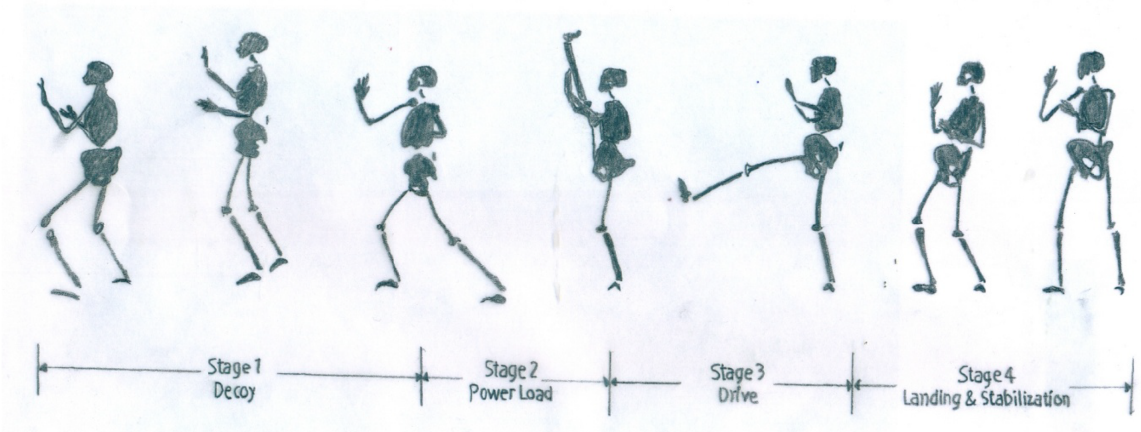


Figure 2. Different stages in the axe kick

## VARIATIONS IN THE AXE KICK

The sequential movements during the axe kick include the knee-raising in an upward in-to-out or out-to-in arc motion. Another variation to this kick involves the simple raising of the leg straight up and down in front of the body (Figure 3), where the leg is extended above the target and pulled down onto the target. Because the axe kick motion requires the kicking foot to be raised higher than the intended target, the angle created at the hip joint is found to require a substantially large range of motion, and the action can generate more power.

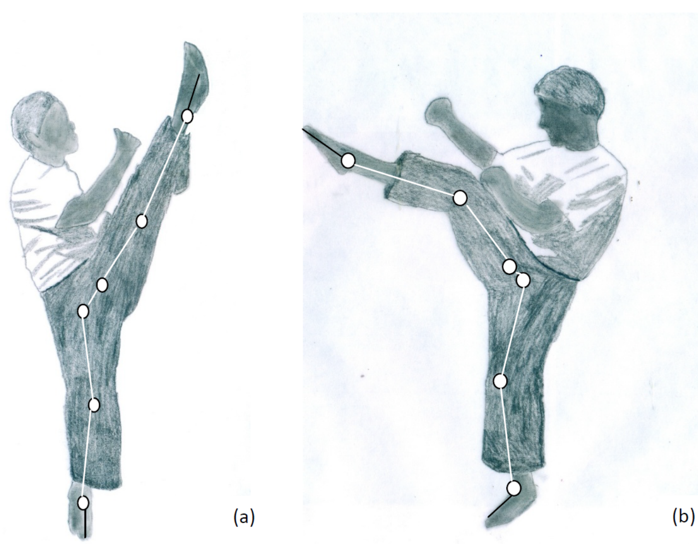


Figure 3. Demonstration of Taekwondo axe kick; a) Classical axe kick and b) Modified axe kick

The modified version would entail the consecutive segmental extension of the hip and flexion of the knee on the downward phase of the axe kick (see figure 3b) instead of simply lowering the extended leg as is done in the classical version of the kick. The chamber for the modified axe kick is same as a front kick in the beginning and then it snaps like a whip. The bent-leg start in modified axe kick is important in competition as it prevents the opponent from being able to read what kind of kick is thrown at him until it whips. It would also be recommended to minimize injuries in competition and at the same time score points (Bercades & Pieter, 2006).

## BIOMECHANICS OF THE AXE KICK

Biomechanics is one of the sub disciplines of kinesiology and by definition it is the study of the application of mechanics to biological systems such as human systems. The Biomechanics performance-related areas include measurement and motor control of human locomotion, sports, clinics and rehabilitation, orthopedics, among others.

The biomechanical factors instrumental to the success and effectiveness of an axe kick are based on the three aspects of the kick: 1) the maximum target height, 2) the inertia of the kicking leg and 3) the speed of the kicking foot. The height at which an athlete can make an attack is determined by the anthropometry of the fighter (e.g. body height and leg length) and the flexibility of the fighter. For an axe kick to be effective, all movements of the kicking leg need to have minimal execution time. Thus the dynamic posture / kinematics of the kick should minimize the moment of inertia of the kicking leg during the power load phase. The power of the axe kick is directly determined by the speed of the kicking foot, as it drives downward toward its target. Thus the degree of extension of the kicking leg and its angular velocity should maximize the speed of the kicking foot.

Based on these aspects, Woo et al. (2012) reported that front axe kick has maximum kicking height compared to other variations of the kick (Table 2). Yu et al (2012) measured total action time as 0.66 sec for the front axis kick (Table 3). Tables 2 and 3 also present the other parameters in the biomechanics of the axe kick.

Table 2. Features of an axe kick without wearing a chest gear (Woo et al., 2012)

| Type of axe kick | Height (m) | Foot speed(m/s) | Shoulder speed (m/s) | Hip flexion (°) | Shoulder range of motion (°) |
|---|---|---|---|---|---|
| Front axe kick | 1.76 | 7.91 | 2.7 | 146.96 | 71.83 |
| In-out axe kick | 1.74 | 7.72 | 3.0 | 150.95 | 71.45 |
| Out-in axe kick | 1.72 | 7.41 | 2.93 | 145.55 | 68.93 |

Table 3. Biomechanical parameters in the axe kick performed by the professional (Yu et al., 2012)

| | Parameter | Measurement |
|---|---|---|
| Flexibility | Maximum kick height (% of body height) | 137.1% |
| | Angle between the thighs (°) | 173.5 |
| Kinematics of the power load | Range of motion of the hip (°) | 206.1 |
| | Range of motion of the knee (°) | 99.6 |
| | Duration of power load (s) | 0.35 |
| | Maximum speed of ankle (m/s) | 11.4 |

| | | |
|---|---|---|
| Kinematics of the drive | Range of motion of the hip (º) | 139.1 |
| | Duration of the drive (s) | 0.31 |
| | Maximum speed of ankle (m/s) | 10.9 |
| Action | Total time (s) | 0.66 |

The key in this kicking technique involves hip flexibility, muscle power and whip-like movement. These components account for differences between professional and advanced (about 5 years of experience) fighters. Researchers have shown a 15% difference observed in action time, 12% in maximal kick height and 20% in maximal drive ankle speed (Yu et al., 2012). The power of the axe kick is directly determined by the speed of the kicking foot, as it drives downward toward its target. Thus the degree of extension of the kicking leg (greater the angle of hip flexion) and its angular velocity should maximize the speed of the kicking foot.

Sung (1987) found maximal foot velocities of 11.3 m/s and 10.4 m/s for back leg (classical) and jumping front leg axe kicks, respectively. The flex-stretching axe kick (modified) had a faster attacking time than the straight (classical) axe kick (0.37 vs. 0.42 s), while it also reached a higher velocity (5.55 vs. 4.70 m/s) (Tsai and Huang, 2006). However, the impact velocity on target was 7.74 m/s for classical axe kick compared to 5.97 m/s for the modified version. Tsai et al., (2004) investigated a modified axe kick in high school male and female students. The modified axe kick was executed with the back leg. In the upswing phase, the leg was bent at the knee joint during hip flexion, while it was straight in the downswing phase. The authors reported reaction times of 0.523 s and 0.493 s with movement times of 0.367 s and 0.392 s for boys and girls, respectively.

In a follow-up study, Tsai et al., (2005) analyzed the front leg axe kick in adult male Taekwondo practitioner. Reaction time and movement time contributed 56% and 44% to performance time (reaction plus movement time), respectively. As expected, the front leg axe kick (0.750s) recorded a faster performance time than the back leg version (0.886s). The upswing and downswing phases of the kick were the same as in their previous investigation.

## SAFETY CONCERNS REGARDING AXE KICK

An efficient axe kick could cause terrible injury to the opponent’s head/color bone, and an inefficient kick can also be dangerous to the person executing the kick. Head injury estimates in Taekwondo sports range from 5.5 to 50.2 per 1000 athletes in a competition (Pieter & Zemper, 1998; Koh & Cassidy, 2004), which may be attributed to difference in methodology (medical examination versus video analysis) and this rate is up to four times higher than in other sports such as American football (Pieter, 2009). Recently, a medical case study (Cohen et al., 2010) reported that axe-type offensive kick to cause a massive brain haemorrhage, although it was found to be one of the lower-magnitude (head injury) techniques examined by Fife et al., 2012.Koh and Watkinson (2002) reported that lack of blocking skills or evasive manoeuvres (e.g. ducking as used in boxing) were involved in 99% of head injury cases. A possible reason for lack of blocking skills is believed to be related to the competition rules, which favor offensive skills as they offer no points for defensive techniques.

On the defense side, the axe kick also requires an ergonomically designed chest protector to protect the kicker from injury and to execute a full power kick. Because the axe kick motion requires the kicking foot to be raised higher than the intended target, the angle created at the hip joint is found to require a substantially large range of motion. At the 2011 Gyungju World Taekwondo Competition, Woo et al. (2012)

 

surveyed 56 Korean professional players (age: 21.8 ± 2.21 years) using the provided satisfaction survey of the chest protector and observed over 91% athletes indicated that the current chest protector interferes with head high axe kicks. They developed a novel chest protector based on the biomechanical observations of the axe kick and found that the novel chest protector enables a player to have more natural axe kicking motion.

## DISCUSSION AND CONCLUSIONS

In Taekwondo, like any martial arts, fast reactions are essential for success in competitions. The quicker athletes react, the more time they have to accomplish their strategy. Therefore, Taekwondo athletes should not only use those techniques that allow them to react fast but also the techniques where they need the least time to reach the opponent. From the literature reviewed in this paper, the axe kick generally has an execution time ranging from 0.37 to 0.88 S with a peak linear velocity ranging from 5.5 to 7.91 m/s. The action time of the axe kick can be comparable to the roundhouse, turning, side and back kicks but not with the front kick, which is relatively quick. Furthermore, the peak velocity of the axe kick is lower than the front, round, roundhouse and back kicks but comparable to the side kick. Fernandes et al. (2011) reviewed biomechanical methods applied to martial arts techniques and suggested that depending on the parameters studied e.g.: reaction time, speed, strength, power, among others, there is the need to apply one or more methods since there are situations in which only one biomechanical method will not be enough to answer the pointed question. The character of a descriptive examination of the Taekwondo kicks from the biomechanical studies, not directly applied to the development of Taekwondo techniques used on different modalities. This is where future research should focus.

Maximum velocity at the moment of impact is usually achieved at the cost of attack duration. In case of board breaking, athlete requires maximum velocity at the moment of impact (faster attack) at the cost of lower attack duration. For obtaining points in sports competition, athletes should focus on reducing the duration of the kick and increasing mean kick velocity. The Taekwondo axe kick may be performed to generate maximum momentum on impact, but this may not be advisable in terms of safety to the one be in ghit. The axe kick is easy to get tangled up and jammed by the opponent, which could result in the attacker falling. With the new rules, falling is more heavily penalized. The axe kick, when caught at full extension is also very hard on the supporting knee and there could be a high risk of ACL (Anterior Cruciate Ligament) injury. Executing a modified axe kick (Bercades & Pieter 2006), may be one way to combine optimal performance of the skill relative to biomechanical principles and minimize injury from the kick. More studies should be conducted to quantify the differences among various versions of the axe kick and striking surfaces (heel, ball or side of the foot-crescent kick targeting the temple) to determine the best way to perform the skill based on biomechanical principles and with the goal of injury prevention.

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