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KINEMATICAL ANALYSIS OF FIVE DIFFERENT KICKS IN TAEKWONDO

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The purpose of this study was to identify those foot techniques in taekwondo to the head with the highest potential for success in competition. We compared five of the most frequently used kicks, the round kick, front leg axe kick, clench axe kick, jump spin back kick and jump spin hook kick. Since the right timing and fast movements vastly determine success, we looked at the reaction time, execution time and total response time. Eight high level athletes participated in the study. Three Casio HD cameras operated on 300 Hz were used to record kinematics parameters. A Hybrid II Crash Dummy head (H2D) and neck were instrumented. The one-way ANOVA showed that there were no differences in reaction time while there were differences in the execution time and, as a consequence, in the total time ($p < .01$) as well.

KEY WORDS: martial arts, performance, reaction time, execution time, total time

INTRODUCTION: Taekwondo is a full contact combat sport wherein the competitors win points by hitting the opponents' chest gear or the head. In 2009, World Taekwondo Federation competition rules changed and kicking the head scores three points (2 before) while a kick to the chest just scores one. Even before the rule change athletes preferred to kick to the opponents' head due to its higher scoring value or sudden win by knock out (Koh et al., 2004). Therefore, training programs and game strategy often focus on attacking the opponents head. Scientific literature (Serina & Lieu, 1991; Sorensen et al., 1996) categorizes two principally different kicking mechanisms to reach the opponent. The swing kicks are kicks performed with body rotation directed to the side of the opponent, and the thrust kicks, which attempt to hit the front in a straight movement. Research on kicks to the chest (Serina & Lieu, 1991) has determined that swing kicks are faster than thrust kicks, with the roundhouse kick being identified as the fastest kicking technique of all (Pieter & Pieter, 1995).
There is a lack of research for kicks to the head level. Little is known about what makes one technique more efficient than the other. The round kick (Estevan et al., 2009) takes 0.286±0.100 seconds to be performed, the front leg axe kick (Tsai et al., 2005) takes 0.327±0.026 seconds, and the jump spin hook kick (Tsai et al., 2007) takes 0.270±0.029 seconds. Of all head techniques successful in scoring, five kicks are dominating combats (Koh et al., 2004): the straight axe kick or front leg axe kick, the outside in axe kick or clench axe kick, the roundhouse kick to the head, the jumping spinning kick or jumping spinning hook kick, and the jumping back kick or jumping back kick. Therefore, it is necessary to study them with regard to reaction time and execution time. Execution time appears to be one of the key elements for victory (Vieten et al., 2007). Therefore, we identify a potentially successful kicking technique by its short total time, the sum of reaction and execution time.

METHODS: Participants: Eight male Taekwondo athletes from the Spanish National Taekwondo team participated in this study. Their mean heights, weights and ages were 1.77±0.07 m, 68.80±3.01 kg and 20.40±2.05 years. Informed consent was obtained from each subject prior to the study.
Experimental design and instruments: Each subjects' foot was marked with reflective markers at the first and second metatarsals. Each participant's preferred target distance was used as the execution distance (Kim et al., 2010). Five different head kicks were performed five times in random order; round kick, front leg axe kick, clench axe kick, jump spin back kick and jump spin hook kick. A kicking action was initiated by switching on the LED on the chest height of the test dummy, this also started the clock time. The variables of this study

were: reaction time (as the time period from LED switched on until the athlete performed the first movement with the foot), execution time (as the period of time from the first movement with the kicking foot until the foot impacted the head of the test dummy), and total time (as the sum of reaction time and execution time). Three Casio HD cameras (300 Hz) were used for recording. A Hybrid II Crash Dummy head (H2D) and neck were instrumented. The H2D was fixed to a height adjustable frame and fitted with a protective TKD helmet (LeCAF - Seoul, South Korea).

Statistical analysis: One way ANOVA was used to compare mechanical variables among the five kicks. Pairwise comparisons were performed using Bonferroni statistics to analyze significant effects of ANOVAs. Cohen's *d* score was used to analyze the effect size. Cohen considered that a *d* larger than 0.8 signified a large effect. The level of significance was set to 0.05.

RESULTS: Statistical descriptions (mean and standard deviation) are shown in Table 1. The one-way ANOVA showed that there were no differences in reaction time ($p = .28$) while there were differences in execution time ($p < .01$) and in total time ($p < .01$). The clench axe kick had the highest execution time, followed by the front leg axe kick and the jump spin hook kick, while there were no differences between the jump spin back kick and the round kick. Lastly, the clench axe kick had the highest total time followed by the front leg axe kick which were also slower than the round kick. No differences were found between the round kick, the jump spin back kick or jump spin hook kick in total time. All effect sizes were above 0.8.

Table 1
Comparative analysis among five different kicks in time variables.

	round kick	front leg axe kick	clench axe kick	jump spin back kick	jump spin hook kick
	Mean ± *SD*	*Mean* ± *SD*	*Mean* ± *SD*	*Mean* ± *SD*	*Mean* ± *SD*
reaction time [s]	0.281±0.061	0.264 ± 0.076	0.272 ± 0.102	0.299 ± 0.065	0.274 ± 0.055
execution time [s]	0.460±0.095[abc]	0.608 ± 0.100 [adfg]	0.839 ± 0.121 [befh]	0.509 ± 0.063 [gh]	0.540 ± 0.081 [cde]
total time [s]	0.740±0.086[ab]	0.872 ± 0.088 [ac]	1.119 ± 0.122 [bcde]	0.808 ± 0.092 [d]	0.809 ± 0.186 [e]

Note: Similar letters to the right of the mean and *SD* value mean significant differences ($p < 0.05$).

DISCUSSION: In taekwondo, fast reactions are essential for success in competitions (Vieten et al., 2007). The quicker the athletes react, the more time they have to accomplish their strategy (Tsai et al., 2004). Therefore, taekwondo athletes should not only use those techniques that allow them to react fast but also the techniques where they need least time to reach the opponent (Estevan et al., 2009). However, to our knowledge the presented study is the first to compare time variables for the techniques to the head most often used in competition (Koh et al., 2004).

In spite of the fact, that athletes were instructed to perform kicks in pre-selected order, no significant differences in reaction time were observed. This indicates that the subjects mind set does not influence their ability to react. Thus, it seems athletes are not in a specific "mode" when prepared to perform a kick. However, our results are in contrast to Chou (1996, cited by Tsai et al., 2004) who studied four different kick actions and found that the axe-kick and the round kick had lower reaction time than the other kicks. This might be due to the differences in the definition of the reaction time variable. Therefore, future research should study the time needed for the foot to leave the floor when comparing these techniques.

In line with previous research (Serina & Lieu, 1991), the results of our study shown that swing kicks (round kick and jump spin hook kick) were faster than thrust kicks (front leg axe kick and clench axe kick). Even the jump spin back kick can be considered a thrust kick, there were no differences when comparing this kick with the swing kicks (round kick and jump spin hook kick). It might be, as literature suggests, that the addition of the initial spin prior to kick execution generates a greater kick velocity (Serina & Lieu, 1991). The sequence of kicks from short to longer execution time can be described as follows: round kick, the jump

spin back kick, the jump spin hook kick, the front leg axe kick and the clench axe kick. We emphasize there were no statistically significant execution time differences between the round and the jump spin back kick, as well as between the jump spin back kick and to the jump spin hook kick. Our study shows that execution time can explain the kicking and scoring rate found by previous studies (round-kick, back-kick, axe-kick, back round-kick and front-kick) (Chian, 1991; Lee, 1992; Tsia et al., 1998; cited by Lan et al., 2000). The only exception is the axe-kick that our taekwondo players performed making a previous back-step which increased the execution time.

In line with Pieter and Pieter (1995), the round kick was the fastest kick among both the swing and thrust kicks. It might be the reason why the round kick is the most often used technique in training and competition. It is necessary to identify if the round kick has an intrinsic mechanism that makes it faster than other techniques. Or, is it due to a more frequent use, both during training and competition and therefore athletes being more experienced in performing this technique? Since the jump spin back kick has a spin prior to the kick, we can not describe it either as swing or as a thrust kick. It is needed to study this technique further in order to know the purpose of this initial movement. In agreement with Lan et al. (2000), we did not find differences in execution time when comparing the round kick and the jump spin back kick. In this sense, we do not find a plausible explanation for the less utilization of this technique during a competition (Kohn et al., 2004).

The results also showed that the clench axe kick had the highest execution time. Moreover, this technique also had the highest total time followed by the front leg axe kick. It can be related with the back-step performed by the athletes, previous to the kicking movement. Interestingly, the axe kick causes the second highest concussion rate (Koh et al., 2004). It seems that if the taekwondo player has a lot of time to perform a technique, he/she can adjust it to an optimal performance and thereby optimize the energy exchange. No differences have been found when comparing the round kick, the jump spin back kick and the jump spin hook kick. Those techniques with a previous spin are mainly used during a counter attack. More research is needed to focus on the intrinsic mechanisms of these techniques. The analysis might uncover the reasons that motivate the athletes to perform those techniques in each specific situation during competition. Lastly, future studies should attempt to find out what happens between the first movement till the foot leaves the floor, and between the time the foot leaves the floor and hitting the target (Lan et al., 2000; Estevan et al., 2009). Studying those time variables will give a better understanding of the use of these techniques during competition. One limitation of the study is that we tested one weight category of taekwondo athletes only. In this sense, it will be important to apply the same research to other weight categories as well as to female athletes.

CONCLUSION: We did not find differences in reaction time among the five kicks. Hence, this phase within a combat's action does not select a technique to having a higher scoring probability. Execution time however, is different between the kicks. Swing kicks (round kick, jump spin back kick and jump spin hook kick) are faster than thrust kicks (clench axe kick and front leg axe kick). Interestingly, there are no statistically significant action time differences comparing round kick and kicks with a previous spin. The new competition rules reward kicks initiated by a spinning motion with one additional point. The probability executing a successful technique (same action time) is alike for round kick and kicks with a previous spin. Spin kicks do score higher, and consequently it is well advisable to use more techniques with a prior spin during competition.

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