KINEMATIC ANALYSIS OF A ROUNDHOUSE KICK ACCORDING TO THE STANCE POSITION

Isaac Estevan[1], Daniel Jandacka[2], Roman Farana[2] and Coral Falco[3]

[1] Department of Management and Applied Sciences in Physical Activity and Sports, Catholic University of Valencia, Valencia, Spain
[2] Human Motion Diagnostic Centre, University of Ostrava, Ostrava, Czech Republic
[3] Department of Physical Activity and Sport Sciences, Catholic University of Valencia, Valencia, Spain

The stance position has been pointed out as an important factor that can potentially affect the kick performance, so the stance position can be seen as a constraint for the execution. The aim of this study was to compare kinematic variables in some main instants during the roundhouse kick in taekwondo according to three stance positions (0º, 45º, 90º). Nine experienced athletes participated in the study. Kinematic analysis was measured by two 3D force plates and an eight-camera motion capture system. Data analyses were processed using Visual 3D software. Signifficant differences in kinematic data were found at the beggining of the kick; these differences disappear at the end of the kick. Athletes are able to adapt their technique even if the stance position is different.

KEY WORDS: kinematic, coordination, taekwondo, execution technique, stance position.

INTRODUCTION: Traditionally, the execution technique has been analyzed in many sports. Kloiber, Baca, Preuschl and Horsak (2009) pointed out that the kick movement is a crucial factor for performing and analyzing the technique in combat sports. Some authors (i.e., Davids, Glazier, Araújo, & Barlett, 2003) stated that motor patterns emerge under different task constraints to achieve stable task outcomes. Concretely, Davids et al. (2003) argued that it is becoming clear that the human motor system is intrinsically noisy and it is seen as functional in allowing individuals to adapt to the multitude of unique constraints on a performance.

The stance position has been pointed out as an important factor that can potentially affect the kick performance (Kim, Kwon, Yenuga & Kwon, 2010; Estevan, Falco & Jandacka, 2011). In taekwondo combats, athletes maintain different stance positions, which have been seen as an example of constraints for the performance. The adoption of the most suitable stance position could be key in a sport performance of taekwondo athletes (Estevan et al., 2011). In a pilot study, Estevan et al. (2011) found the execution and total response time from the lateral stance position (90º) to be longer than forward (0º) and diagonal (45º) stance positions. These authors reported the 45º stance position as the most appropriate position in combats. Thus, it seems necessary to continue to research the kick performance according to the stance position thoroughly, with the objective to clarify it as a constraint.

Moreover, from a technical point of view, Kim et al. (2010) found different relative contributions in hip and knee joints as the kicking leg gradually approaches the target. With all these comments in mind, the aim of this paper was to analyze kinematic variables such as hip and knee angular displacement (β), angular velocity (ω) and linear velocity (V) of the kicking leg in some main instants during the roundhouse kick to the chest in taekwondo according to three stance positions (0º; 45º; 90º).

METHODS: Participants: Nine experienced taekwondo athletes participated in this study (mean age, weight height and experience were 26.62 ±4.6 years, 72.94 ±16.09 kg, 1.76 ±0.09 m, and 14.16 ±5.60 years).

Instrumentation: Participants were standing on two 3D force plates (Kistler 9286AA, Switzerland) (247 Hz), kinematic data during the roundhouse kick were collected at 247 Hz with an eight-camera motion capture system (Qualisys Oqus, Sweden). An LED was placed on the target and all the equipment was synchronized.

Experimental design: After a personal warm-up and during the test, each foot was positioned on the force plates. The kicking leg was the rear foot. Retro reflective markers were attached to the left and right foot, left and right shank, left and right thigh, pelvis and trunk according to the recommendation of the C-motion Company (C-motion, Rockville, MD, USA). Each participant's preferred target distance was used as the execution distance (Kim et al., 2010), and they performed five kicks in each of the stance positions. Each trial started when the LED lit up. The stance position was established by three marks on the ground pointing in different directions: three lines (0º, 45º and 90º) were prepared (Estevan et al., 2011). Trials were randomized.

Analytical methods: Markers data were processed using Visual 3D software (C-motion, Rockville, MD, USA). All extremity segments were modelled as a frustum of right circular cones whilst the torso and pelvis were modelled as a cylinder. During the movement, three main instants were pointed out: the instant in which the kicking leg raised 1% of GRF (1), the instant in which the toe left the force platform (2), and the instant of the impact (3). Variables of this study were analyzed in every of these three main instants in the sagittal plane: hip and knee angular displacement (flex-extension), hip and knee angular velocity and hip and knee linear velocity. In both joints the anatomical stand position was estimated as 0º. The preliminary analysis (Kolmogorov – Smirnov) showed a normal distribution of all the considered variables. A one-way ANOVA with Tukey post hoc test was used to compare kinematic variables according to the stance positions (p <0.05). Cohen's d score was quantified to analyze the effect size. Cohen considered that a d larger than 0.8 signified a large effect, a d between 0.8-0.4 signified a moderate effect, and a d lower than 0.4 signified a small effect (Cohen, 1988).

RESULTS: Statistical descriptions (mean and standard deviation) are shown in Table 1.

Table 1: Comparative analysis among three different stance positions in kinematic variables.

	1% of GRF		
	0º stance position	*45º stance position*	*90º stance position*
	Mean ±SD	*Mean ±SD*	*Mean ±SD*
Hip β (º)	3.71 ±11.42^{a}	8.67 ±14.63^{b}	28.20 ±17.18^{ab}
Hip ω (º·s^{-1})	6.60 ±22.71	-1.34 ±18.27^{a}	22.49 ±38.85^{a}
Hip V (m·s^{-1})	-0.001 ±0.04	0.001 ±0.05	0.02 ±0.08
Knee β (º)	-30.00 ±12.33^{a}	-30.99 ±13.56^{b}	-52.07 ±13.25^{ab}
Knee ω (º·s^{-1})	-3.32 ±33.32^{a}	-3.32 ±33.32	-8.01 ±44.00^{a}
Knee V (m·s^{-1})	-0.01 ±0.07^{a}	0.05 ±0.10	0.12 ±0.25^{a}
	Toe off		
	Mean ±SD	*Mean ±SD*	*Mean ±SD*
Hip β (º)	0.23 ±10.15	-0.09 ±9.05	-2.65 ±9.50
Hip ω (º·s^{-1})	92.78 ±87.38^{a}	35.76 ±106.29^{b}	-72.42 ±115.23^{ab}
Hip V (m·s^{-1})	-0.90 ±0.26	-0.94 ±0.33	-0.76 ±0.40
Knee β (º)	-49.57 ±5.87	-48.58 ±6.25	-46.57 ±6.91
Knee ω (º·s^{-1})	-529.12 ±224.92^{a}	-560.22 ±175.05^{b}	-337.35 ±163.79^{ab}
Knee V (m·s^{-1})	-2.88 ±0.98^{a}	-2.78 ±0.84^{b}	-2.12 ±0.69^{ab}
	Impact		
	Mean ±SD	*Mean ±SD*	*Mean ±SD*
Hip β (º)	43.68 ±20.30	45.89 ±18.74	42.28 ±20.59
Hip ω (º·s^{-1})	102.63 ±233.33	49.22 ±204.64	34.09 ±305.93
Hip V (m·s^{-1})	0.38 ±0.20	0.19 ±0.60	0.35 ±0.26
Knee β (º)	-41.88 ±13.56	-38.62 ±19.61	-35.47 ±14.35
Knee ω (º·s^{-1})	1302.07 ±152.48	1182.24 ±451.41	1297.58 ±170.14
Knee V (m·s^{-1})	0.31 ±0.31	-0.06 ±1.29	0.26 ±0.38

Note: β = angular displacement. ω = angular velocity. V = linear velocity. Similar letters to the right of the mean and *SD* value mean significant differences (p <0.05).

The one-way ANOVA showed that, when taekwondo athletes get the 1% of GRF, they reach a higher hip β and knee β in the 90º stance position than in the 45º (p<0.01) and 0º stances (p<0.01). At this instant, athletes also get higher hip ω in the 90º stance position than in the

45° stance ($p<0.01$). Finally, they get higher knee V in the 90° stance position than in the 0° stance ($p<0.01$). Moreover, when their kicking foot left the force platform, taekwondo athletes get higher hip ω and knee ω in the 90° stance position than in the 45° and 0° stances ($p<0.01$). Finally, they get higher knee V in the 90° stance position than in the 45° and 0° stances ($p<0.01$). No differences were found when kick impacts the target.

According to the Cohen's *d* score (Cohen, 1988), most of the differences we found when comparing kinematic variables can be estimated as large differences; only, in the instant when athletes reach the 1% of GRF comparing knee V and ω between 90° and 0° stance positions the differences were moderate and small, respectively. Figure 1 shows the kinematic variables in each of the three different stance positions.

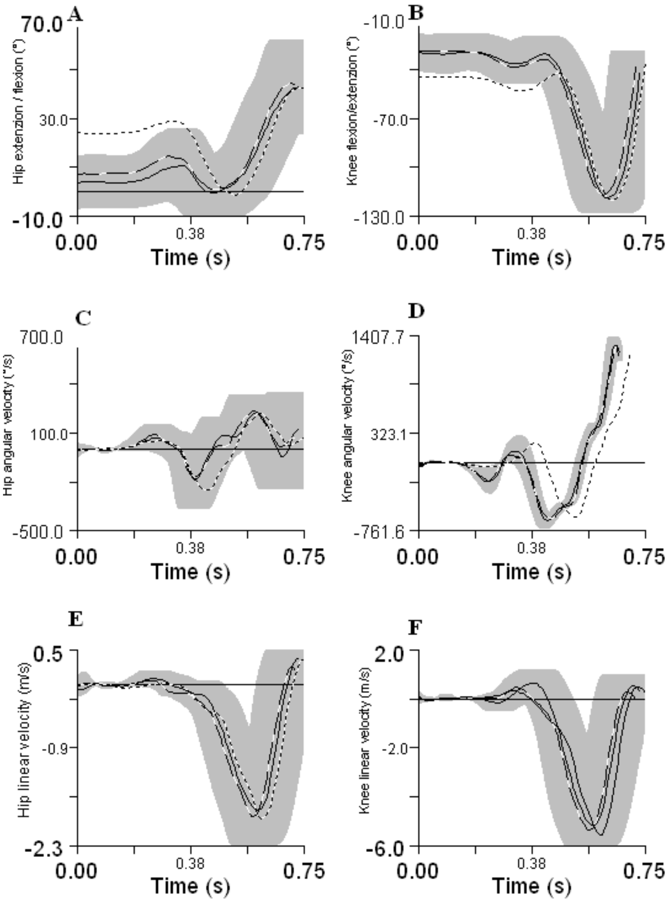

Figure 1: Mean and standard deviation of kicking foot kinematic variables in the three (0°, 45° and 90°) stance positions (n = 9). A) represents hip β, B) represents knee β, C) represents hip ω, D) represents knee ω, E) represents hip V, and F) represents knee V. Solid line represents mean of kinematic data during 0°, dash line during 45° and dot line during 90° stance positions. Solid area represents standard deviation of kinematic data during 0°.

DISCUSSION: The purpose of this study was to compare kinematic variables in some main instants during the execution of the roundhouse kick in taekwondo among the three stance positions. The results show differences at the beginning of the kick but no differences in kinematic variables were found in the impact. Taking into account that Estevan et al. (2011) reported the 45° stance position as the most appropriate position in combats, we also could suggest that taekwondo athletes use this position preferably because they react faster than in the 90° stance position (Estevan et al., 2011) and the execution technique is similar. So in the 45° stance position the performance and execution could be more favorable than in the 0° and 90° stance positions.

Kim et al. (2010) argued that in case of the roundhouse kick the velocity of the kicking foot is a combined effect of linear motion of the pivot hip, angular motion of the pelvis about the pivot hip, and angular motions of the kicking leg joints. Although in our study velocity of the kicking foot has not been analyzed, it seems that our results support this statement. Since athletes kick from different stance positions and differences in kinematic data are found at the beginning of the kick but at the end of the kick these differences disappear. That is, during the kick movement the initial differences disappear as the kicking approaches the target.

On the other hand, Kim et al. (2010) found a higher relative contribution of the hip displacement in the initial phases than in the last ones. Moreover, Davids et al. (2003) stated that constraints, such as different stance positions, should be studied as an inherent part of a performance that affects the motor system output. The results of this study show differences in the execution technique at the beginning of the kick due to the different stance positions. That is, the stance position affects the execution technique. However, these differences disappear at the end of the kick, which makes us side with Davids et al. (2003) who stated that athletes adapt to constraints and their performance becomes similar in the end part of the execution. Results of this study suggest that taekwondo athletes are able to adapt their execution technique even if the stance position is different.

Future studies should analyze specifically the variability of the execution during the technique overall in the first half (i.e., the instant of 1% of GRF of the rear foot and the instant when the toe leaves the force platform) and in the second half (i.e., the instant when the knee achieves the maximum flexion), and the instant of impact (Kim et al., 2010) in order to study the execution technique in taekwondo thoroughly from a functional point of view. Moreover, these future studies should analyze the relationship between the execution technique and the performance so that reporting practical applications based on empirical data.

CONCLUSION: According to the results of this report, experienced athletes are able to adapt their execution thus getting similar output at the end of the kick, that is, when the kicking leg impacts the target. Therefore, the stance position is a factor that affects the execution technique of taekwondo athletes' kicks so the stance position must be seen as a constraint to which athletes must adapt.

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