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KINEMATICAL ANALYSIS OF BANDAL AND DOLYO TAEKWONDO KICKS OF A HIGH LEVEL FEMALE ATHLETE

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The purpose of this study was to analyze the kinematics of two Taekwondo kicks performed by a high level female athlete. The kicks were compared according to three main factors: a) type of kick (Bandal or Dolyo), b) foot of kick (right or left foot); c) kick starting with the kicking foot in front of the support limb or behind (front or back foot).The DVideo kinematical analysis system was used to reconstruct the 3D coordinates of twelve landmarks. The study was able to identify the main differences between the two most frequently used Taekwondo kicks, showed that the initial condition should be considered when comparing kicks and revealed differences between kicks accomplished with right or left foot of this high level athlete.

KEY WORDS: biomechanics, sport, turning kick.

INTRODUCTION: Taekwondo (TKD) is an Olympic sport since 2000 and its practice has increased in many countries. More recently, TKD has also become an object of scientific investigation (Pearson, 1997; Kong, 200; Kim, 2002; P_Dzich, Mastalerz & Urbanik, 2006; Falco et al, 2008; Kim et AL, 2010). However, just a few biomechanical studies were published in the scientific literature analyzing the kick kinematics of high level athletes.
Bandal and Dolyo are the most frequently used kicks in training and competition. Lee (1998) found a frequency of use for men equal to 50% and Kim & Kim (1997) found 79% for women. The technique starts with the kicking leg travelling in an arc towards the front with the knee in a flexion and extension motion, simultaneously that occurs a rotating of the trunk and a flexion and extension motion of the hip. The movement finishes when the instep hits the target.
The purpose of this study was to compare kicks of one high level athlete according to three experimental conditions aiming to identify possible effects on performance due to those conditions.

METHODS: A female TKD athlete ranked in the top ten, according to World Taekwondo Federations (WTF), was a volunteer to the study. The athlete was evaluated at the end of the 2009 season during its transition phase from training period to rest.
After a warm up, the athlete was asked to use the instep of her foot to kick one second volunteer, appropriately dressed with protective clothing, statically positioned in front of the athlete. The athlete was instructed to perform three consecutive repetitions of each kick for each condition.
The DVideo kinematical analysis system (Barros et al, 1999, 2006, Figueroa, 2003) was used to obtain three-dimensional coordinates of the markers on the images captured by six gen-locked Basler digital video cameras (model A602FC) with frequency of acquisition of 120 Hz, positioned around the athlete. Twelve landmarks were tracked, modeling the athlete's body with the follow 11 segments: trunk, arms, forearms, thighs, calves and feet. These 3D data were smoothed with a zero-phase forward and reverse Butterworth digital filter of 3th order with a 6 Hz cut-off frequency.
The kicks were compared according to three main factors: a) type of kick (Bandal or Dolyo), b) foot of kick (right or left foot); c) kick starting with the kicking foot in front of the support limb or behind (front or back foot). From the set of collected data, the linear kinematics of the

kick foot (malleolus marker) and the angular knee kinematics were selected and presented in this study.
Six dependent variables were analyzed in the study: Foot maximal height (FH), velocity (FV) and acceleration (FA); and knee maximal flexion angle (KF), knee maximal extension velocity (KV) and acceleration (KA).
The mean values and standard deviation of three replicates of each type of kick, for each one of the conditions, were described and used in comparisons. Three-way analysis of variance (ANOVA) was used to compare the means of different variables according to three factors: type of kick, initial condition and kick with right or left foot. Initially a full model was used to test all interactions. Non-significant interactions were removed from this model and the ANOVA was recalculated. Where a significant effect was detected, Tukey's honestly significant difference criterion ($p < 0.05$) was performed. The data were analyzed using Matlab®.

RESULTS AND DISCUSSION: Table 1 shows the results of kicking foot linear kinematics and knee angular kinematics for both kicks.

Table1
Linear and angular variables of the Bandal and Dolyo kicks

Kick	Start	FH(m)	FV(m/s)	FA(m/s^2)	KF (rad)	KV(rad/s)	KA (rad/s^2)
Bandal	RFF	1.24±0.02	8.39±0.66	100.78±4.46	1.7±0.1	16.3±0.5	285.4±8.7
	LFF	1.26±0.01	9.11±0.29	116.77±3.83	1.6±0.0	13.9±0.4	547.5±204.8
	RFB	1.22±0.01	11.29±0.11	154.66±2.01	1.8±0.0	11.7±0.5	432.4±79.5
	LFB	1.25±0.01	11.64±0.13	138.38±4.20	1.8±0.0	12.0±0.0	418.7±30.6
Dolyo	RFF	1.62±0.02	7.93±0.27	102.98±8.09	1.7±0.2	18.3±0.0	1212.9±0.0
	LFF	1.57±0.01	8.12±0.23	115.49±12.51	1.6±0.1	15.2±0.0	374.0±37.0
	RFB	1.67±0.03	11.73±0.54	129.70±10.56	1.7±0.0	15.9±0.0	569.4±37.1
	LFB	1.66±0.02	10.92±0.48	121.55±7.62	1.8±0.0	15.8±0.0	478.7±26.0

Start condition: Right Foot Forward (RFF), Left Foot Forward (LFF), Right Foot Back (RFB) and Left Foot Back (LFB). Variables: Foot maximal height (FH), velocity (FV) and acceleration (FA); and knee maximal flexion angle (KF), knee maximal extension velocity (KV) and acceleration (KA).

Three-way analysis of variance (ANOVA) revealed statistical differences in the three main factors ($P<0.05$). Bandau and Dolyo were different in all dependent variables, except for (KF). The mean (± SD) found for Foot maximal height (FH) were 1.24±0.02m (Bandal) and 1.63±0.04m (Dolyo). This fact was expected since the Dolyo kick aims to hit the opponent's head and the Bandal aims the trunk.
Bandal showed means velocity and acceleration (FV=10.11±1.48m/s e FA= 127.65±21.67m/s^2) higher than Dolyo (FV=9.67±1.78m/s e FA=117.43±13.23 m/s^2), but the mean maximal knee extension velocity (KV) and acceleration (KA) were lower. (Bandal: KV= 13.46±1.97rad/s KA=421.00±135.54rad/s^2; Dolyo: KV=16.29±1.24rad/s KA=658.76±342.75 rad/s^2). Right and left foot presented differences in terms of knee maximal angular velocity (KV) and acceleration (KA). The mean maximal knee angular velocities for right and left foot were: 15.54±2.54rad/s and 14.22±1.03rad/s, respectively and for accelerations (KA) were: 625.02±371.58 rad/s^2 and 454.75±113.14 rad/s^2 respectively.
The initial conditions were different for all dependent variables. The mean (±SD) values (front and back foot) for the variables were: 1.42±0.18m and 1.45±0.23m for foot maximal height (FH); 8.39±0.58m/s and 11.40±0.46m/s for velocity (FV), 109.01±10.15m/s^2 and 136.07±14.11 m/s^2 for acceleration (FA); 1.65±0.1rad and 1.75±0.1rad.for knee maximal flexion angle (KF); 15.93±1.71rad/s and 13.83±2.10rad/s for knee maximal extension velocity (KV); and 604.95±389.82rad/s^2 and 454.75±113.14rad/s^2 for acceleration (KA).

CONCLUSION: The study was able to identify the main differences between the two most frequently used Taekwondo kicks, showed that the initial condition should be considered when comparing kicks and revealed differences between kicks accomplished with right or left foot of this high level athlete.

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