33rd International Conference on Biomechanics in Sports, Poitiers, France, June 29 - July 3, 2015
Floren Colloud, Mathieu Domalain & Tony Monnet (Editors)
Coaching and Sports Activities

KINEMATIC COMPARISON BETWEEN ATHLETES FROM THE INTERNATIONAL AND THE WORLD TAEKWONDO FEDERATIONS IN THE ROUNDHOUSE KICK

Afonsa J. Silva, Jerusa P. R. Lara, Ricardo M. L. Barros

Laboratory of Instrumentation for Biomechanics, Faculty of Physical Education, University of Campinas, Campinas, Brazil

Taekwondo (TKD) is a combat sport organized by two main federations: International TKD (ITF) and the World TKD (WTF). The present study analyzed the kinematic differences in roundhouse kick performed by ITF and WTF athletes. Seventeen athletes participated in the study (8 ITF; 9 WTF). DVideo system was used to reconstruct the 3D coordinates of sixteen markers. Pelvis and hips angles and angular velocities were used to compare the groups. The results highlight two kick strategies to hit the target. WTF athletes performed the kick with increased pelvis left rotation while ITF used increased pelvis anteversion, hip flexion and abduction on supporting leg. These differences should be considered for adaptation of rules and training.

KEY WORDS: biomechanics, combat sport.

INTRODUCTION: Taekwondo (TKD) is a combat sport organized by two main federations, the International Taekwondo Federation (ITF) and the World Taekwondo Federation (WTF). The sport was developed at Korea 1940 and was improved by a variety of masters from Korean army during the 1950 (Gillis, 2008). Many technical fundamentals, such as kicks and punches are common in the competitions promoted by both federations; however some rules are different. For instance, WTF allows knockout and forbids head punches, whereas ITF forbids knockout and allows punch at head and trunk.

The framework to improve the knowledge about this matter is the possible unification of the sport that has been globally discussed in recent years. The main reasons for that are the common historical origin, the similarity of both styles and the advantages of having TKD as a sport with a stronger global presence. However, after a long period of development apart the same basic striking techniques may have different stylistic techniques between ITF and WTF athletes.

The most used technique in TKD combat and also the most frequently studied one is the Roundhouse kick (Lee, 1998). Many aspects of TKD have been scientifically investigated such as speed of kicking foot and movement time (Estevan, Álvarez, Falco, Molina-Garciá & Castillo, 2011, Falco et al, 2009), impact force of participants of distinct level of expertise (O'Sullivan et al, 2009), among others. Some authors have focused in the kinematics of the lower extremity and pelvis (Lara et al, 2011). This computation requires segmental reference frames defined by landmarks at the respective segment, which results in a more complex analysis that could highlight details of movement pattern in kicks techniques. In this way, Kim M. Kwon, Yeuga and Y. Kwon (2010) analysed the effect of target distance in pivot hip, trunk, pelvis and kicking hip movement and they concluded that the adjustment of the target distances was mainly accomplished through the pivot hip displacements, hip flexion, and pelvis left rotation. This study pointed out the difference on movement pattern of a same kick technique to hit in different target distance.

Thus, the purpose of this study was to perform a biomechanical comparison of Roundhouse kick to the head by ITF and WTF expert athletes. The study of the possible biomechanical differences in the performance between athletes from different federation rules and styles of training could provide insights to help future adaptations towards a unified sport. Moreover, the biomechanical comparison of performance of practitioners of both modalities can provide a better understanding of the characteristics of each one. In this way, no study was found in

the literature about possible technical differences between WTF and ITF practitioners kick execution.

METHODS: Seventeen black belt male athletes of TKD were divided in two groups according to their federation affiliation: eight ITF with age 25 (10.5) years, height 1.74 (0.09) m, mass 70.8 (11.63) kg, 1.88 (1.13) Dan and 12 (7.3) years of experience, and nine WTF with age 26 (5) years, height 1.77 (0.08) m, mass 74 (8.94) kg, 1.50 (0.76) Dan and 11 (4) years of experience, voluntarily participated in the study. All of them gave their written informed consent and the protocol was approved by the University Ethics Committee.
The DVideo kinematic analysis system was used to obtain the three dimensional coordinates of 16 markers (Figueroa, Leite & Barros, 2003). An extra marker was located at the sparring doll head. The system consisted of five Basler cameras (A602fc) working at 100 Hz. The data were filtered with a low pass filter, Butterworth 4th orders with a cut-off frequency of 10 Hz. Sixteen anatomical markers were tracked, modelling the athlete's body with five segments: pelvis, thighs and shanks (right and left). The software Visual 3D (v5 professional) was used to model the athlete's segments and to compute the variables. The pelvis and hip joints were represented by three joint angles. Pelvis orientation angles were computed relative to the global reference system and hip orientation angles were relative to the pelvis reference system using a XYZ Cardan sequence. The athletes performed three repetitions of the roundhouse kick to the head with the preferred limb. As a target was used a sparring doll levelled to the subject's head, positioned in front of the athlete at the preferred target distance of the athletes. The comparisons between groups were performed at two movement conditions: 1) the initial condition - start and 2) the final condition - impact. The initial condition - start, was assumed as the previous instant to the first detectable malleolus movement towards the target. The final condition - impact, was defined as the instant of the first detectable movement of the doll's head marker. The angles and angular velocities of the pelvis and hips (left and right), at the selected conditions, were extracted. The Anderson-Dailing test was used to test data normal distributions and did not show normal distribution. The reliability was determined in a previous study (Silva, Lara & Barros 2015). Only variables with satisfactory or excellent reliability were used in comparison. For pelvis and hip (left and right) angles was observed ICC over than 0.82 and for pelvis and hip (left and right) angular velocities over than 0.43. One-way repeated measures Friedman test was performed to compare variables between groups *(p*<0.05). A simple sequentially rejective multiple test procedure was applied to strongly controls the family-wise error rate at significant level, the Holm correction (Holm, 1979). The corrected p-values (*p_cor<0.05*) were used to test statistical differences.

RESULTS: The compared results of Roundhouse kick to the head executed by ITF and WTF expert athletes are evidenced in Table 1. The median, 25th percentile and 75th percentile of the variables with significant difference between groups at both conditions (start and impact) are presented.
The analysis of the variables emphasized different attitude of pelvis and hips of supporting leg for the groups.
In terms of pelvis motion, ITF group presented higher values of anteversion and left obliquity at start condition, whereas showed lower values of left rotation than WTF. No significant statistical differences for these variables were found at impact condition.
Concerning the hip of supporting leg was observed higher values of flexion angle for ITF than WTF at start and impact conditions. Likewise, ITF presented higher values of abduction angle than WTF at impact condition.

Table 1 Median, 25th percentil and 75 percentil of the variables with significant difference. Angles of pelvis and hip of supporting leg at the start and impact conditions of Roundhouse kick to the head executed by ITF and WTF athletes.

	PELVIS		
	Start Condition		
	Ant/Ret (º)	**Obliquity** (º)	**Rotation** (º)
ITF	5.4* (3.5; 11.2)	14.0* (10.0; 18.3)	-135.2* (-143.4; -124.8)
WTF	0.8 (-4.1; 5.7)	3.7 (-3.1; 5.5)	-136.7 (-141.2; -41.7)
p_cor	0.0310	*0.0000*	*0.0000*
	HIP		
	Start Condition	Impact Condition	
	Flex/Ext (º)	**Flex/Ext** (º)	**Add/Abd** (º)
ITF	44.5* (41.2; 46.9)	26.7* (15.3; 40.7)	-51.8* (-55.3; -49.9)
WTF	32.7 (27.8; 38.7)	4.8 (-3.1; 21.6)	-49.0 (-52.1;-46.4)
p_cor	*0.0009*	*0.0017*	*0.0057*

Legend: Ant/Ret - Anteversion/Retroversion; Flex/Ext - Flexion/Extension; Add/Abd - Adduction/Abduction. Median (25th percentile; 75th percentile). Friedman test. Holm correction, *p_cor<0.05.

DISCUSSION: Previous study observed difference between ITF and WTF groups on muscle torque under static conditions for lower extremity (WTF > ITF) (Pedzich, Mastalerz & Sadowski, 2012). Regarding kinematic of pelvis and hips during the execution of kicks techniques no studies comparing ITF and WTF athletes were found.
The ITF and WTF athletes adopted different strategies to hit the target during the execution of Roundhouse kick to the head for the same execution situation.
WTF athletes start the kick with increased pelvis left rotation while ITF used increased pelvis anteversion and left obliquity and hip flexion of supporting leg. In the other hand ITF athletes hit the target with increased hip flexion and abduction of supporting leg.
The WTF position on start condition demonstrates more frontal position of pelvis at the kick begins. ITF groups adopted a less frontal position.
The strategy adopted by ITF at start, with less frontal position, an anteversion position of pelvis and a more flexed position of hip of supporting leg, could be an effect of a tactics to escape from possible opponent's punch attack, as indicate for coaches in ITF.
The analyse of impact conditions showed that ITF keeps a more flexed position of hip and increased the abduction of supporting leg . This strategy is used to increase the distance for an effective opponent's punch attack, while provide a perfect contact between kicking foot and target.
Although a very conservative statistical method has been applied to test the results, significant differences were observed between groups. In order to avoid the possible inflation of type I error due to the number of variables tested, the sequentially rejective multiple test

procedure (Holm, 1979) was applied at the Friedman test results. Nevertheless future studies should consider that these procedures could inflate the type II error concealing differences on the sample (Cabin & Mitchell, 2000; Nakagawa, 2004).
In view of these differences, it is suggested to author explicitly inform the athlete's affiliation in their study, in order to facilitate future comparisons.
The findings of the study provide several important implications for the unification of TKD federation. For a successful unification, the managers should observe the effects of possible kinematics difference on kicks techniques between groups to developed better adaptations on rules and training.

CONCLUSION: Regarding the motion of pelvis and hip of supporting leg, the ITF and WTF athletes adopted different strategies to hit the target in execution of Roundhouse kick to the head. ITF used increased pelvis anteversion, left obliquity and hip flexion of supporting leg at start condition. Likewise, at impact condition, ITF used increased hip flexion and abduction on supporting leg. These differences should be considered by the organizers for adaptation of rules and training in order to an effective unification.

REFERENCES:

Cabin, R. J., Mitchell, R. J. (2000). To Bonferroni or Not to Bonferroni: When and How Are the Questions *Bulletin of the Ecological Society of America*, 81, 3, 246-248. Retrieved from: http://www.jstor.org/stable/20168454.
Estevan, I., Álvarez, O., Coral, F., Molina-García, & Castillo, I. (2011). Impact force and time analysis influenced by execution distance in a Roundhouse kick to the head in taekwondo. *Journal of Strength and Conditioning Research*, 25, 10, 2851–2856. Retrieved from: http://www.nsca-jscr.org.
Falco, C., Aalvarez, O., Castillo, I., Estevan, I., Martos, J., Mugarra, F. & Iradi, A. (2009). Influence of the distance in a Roundhouse kick's execution time and impact force in Taekwondo. *Journal of Biomechanics*, 42, 242–248. doi:10.1016/j.jbiomech.2008.10.041.
Figueroa, P,J.,Leite,N.J., Barros, R.M.L. (2003). A flexible software for tracking of markers used inhuman motion analysis. *Computer Methods and Programs in Biomedicine*, 72, 155-65. Retrieved from: http://www.elsevier.com/locate/cmpb.
Gillis, A.A. (2008). *Killing art: the untold history of tae kwon do*. ECW Press: Toronto.
Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics*, 6, 65-70. Retrieved from: http://www.jstor.org/stable/4615733
Kim, J-W, Kwon, M-S., Yenuga, SS; Kwon, Y-H. (2010). The effects of target distance on pivot hip, trunk, pelvis, and kicking leg kinematics in Taekwondo roundhouse kicks. *Sports biomechanics*, 9 (2), 98-114. doi: 10.1080/14763141003799459.
Lara, J.P.R., Silva, A. J., Misuta, M. S., Silvatti, A. P., Mercadante, L. A., & Barros, R. M. L. (2011) Kinematical analysis of bandal and dolyo Taekwondo kicks of a high level female athlete. *Portuguese Journal of Sport Sciences*, 11, 303-305. Retrieved from: http://www.scielo.mec.pt/revistas/rpcd/paboutj.htm.
Lee, J.B. (1998). *A study of kicking techniques of advanced Korea Taekwondo players*. Coach Field Reports. Seoul, Korea: Korea Sports Research Institutes.
Nakagawa, S. (2004). A farewell to Bonferroni: the problems of low statistical power and publication bias. *Behavioral Ecolog,* 15, (6), 1044–1045. doi:10.1093/beheco/arh107.
O'Sullivan, D., Chung, C., Lee, K., Kim, E., Kang, S., Kim, T., & Shin, I. (2009). Measurement and comparison of Taekwondo and Yongmudo turning kick impact force for two target heights. *Journal of Sports Science and Medicine,* 8(CSSI III), 13-16. Retrieved from: http://www.jssm.org.
Pedzich, W., Mastalerz A., & Sadowski, J. (2012). Estimation of muscle torque in various combat sports. *Acta of bioengineering and biomechanics*, 14 (4). doi: 10.5277/abb120412.
Silva, J., Lara, J, & Barros, R.M.L. (2015, July). *Reliability of Dolyo chagui kick In Taekwondo described by hip and knee joint angles*. Poster session presented at the meeting of XXV Congress of the International Society of Biomechanics, Glasgow-UK.

Acknowledgement
Research supported by FAPESP (05/53262-6, 00/01293-1, 2006/02403-1, 2012/07757-7), CAPES (478120/2011-7) and CNPq (130505/2008-0, 304975/2009-5, 473729/2008-3).