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Kinetics of the knife-hand strike used in power breaking in ITF Taekwon-do

Authors' Contribution:

A – Study Design
B – Data Collection
C – Statistical Analysis
D – Manuscript Preparation
E – Funds Collection

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Abstracts. *Description and analysis of a sports technique in terms of its compliance with the principles of biomechanics and with regard to the efficiency of a given technique form the basis for the technical aspect of a training process, which is supposed to result in enhancement of athletes' sports performance level. The study was based on 6 ITF Taekwon-do (International Taekwon-do Federation) athletes (age 16.5±0.7 years; weight 64.1±7.0 kg; height 176.5±4.6 cm). The study relied on an Italian system called Smart-D, manufactured by BTS S.p.A., used for complex movement analyses. The system comprised six cameras reflecting infrared rays, which in real time located the markers fixed to the athlete's body. In the present study the maximum velocity of the sonkal yop tearigi strike reached 13.00 ± 2.35 m/s. The velocity of the traditional fist strike seems to be lower. In this study the average maximum velocity was reached at the length of the arm being equal 92 % of the maximum length value. This length can be taken as the optimum value in this particular technique in order to achieve the maximum dynamics of the strike.*

Keywords: taekwon-do, power test, analysis of movement, kinetics of punch, biomechanics of martial arts

INTRODUCTION

Description and analysis of a sports technique in terms of its compliance with the principles of biomechanics and with regard to the efficiency of a given technique form the basis for the technical aspect of a training process, which is supposed to result in enhancement of athletes' sports performance level. This issue is of particular importance in taekwon-do, in which it is possible for a single strike to reveal the winner. In its Olympic version taekwon-do comprises exclusively sports sparring. However, in the traditional version of taekwon-do (International Taekwon-do Federation) sports competition i.e. a match comprises four events: Sparring, Patterns, Power Breaking and Special Techniques [1,2]. In the power breaking event competitors apply for a particular number of boards which they are supposed to break by using 5 (five) various techniques including hand strikes and kicks. Hand strikes include the forefist and the knife-hand strikes while the kicks comprise the side kick, the roundhouse kick and the spinning kick. Each broken board scores a competitor 2 points. The total of the points scored

decides who the winner is. The knife-hand strike (in taekwon-do terminology - *sonkal yop tearigi*) affects significantly the final result of a given competition. Power breaking requires of a practitioner to have well-prepared striking surfaces, to obtain great breaking force and to master the perfect technique.

The very fact of having included taekwon-do in the Olympic Games has resulted in a growing number of publications on the kicks used in this martial art [3,4,5,6]. However, it seems that the literature available on the subject of taekwon-do includes much fewer publications devoted to the hand strike techniques performed by taekwon-do practitioners.

Using the criteria of sports technique biomechanical analyses [7] and the measurement methods applied in taekwon-do studies, in particular [8], the four movement phases of the knife-hand strike have been specified in the present paper: the starting posture, the backward movement of the hand, the moment of acceleration and stopping i.e. braking.

The following research questions arise:

1. At which moment exactly is the velocity of the wrist the greatest ?
2. What kinematic parameters affect the efficiency of the execution of a strike ?

Providing answers to these questions may help to choose a more efficient method of executing this particular kind of strike in ITF taekwon-do sports competition power breaking test as well as in self-defence.

MATERIAL AND METHOD

Subjects

The study was based on 6 ITF taekwon-do (International Taekwon-do Federation) athletes (age 16.5±0.7 years; weight 64.1±7.0 kg; height 176.5±4.6 cm). The researched group included European Junior Champions, Polish Junior Champions and other athletes who had been practicing taekwon-do for a minimum of 4 years. They trained regularly 3 to 5 times a week. During the study research the athletes used the same starting stance and performed the *sonkal yop tearigi* strike three times each, which gave a total of 18 strikes.

Protocol

For the purpose of the experimental part of the study they were asked to adopt the same starting posture (in taekwon-do terminology called *Niunja So Palmok Degi Maki*) and perform a knife-hand strike three times each. The structure of the movement is presented in figure 1.

The study relied on an Italian system called Smart-D, manufactured by BTS S.p.A., used for complex movement analyses. The system comprised six cameras reflecting infrared rays, which in real time located the markers fixed to the athlete's body. The system made it possible to record the picture of the athlete's moving body and evaluate the kinetic parameters obtained. The movement was recorded with the accuracy of 0.3 – 0.45 mm and the frequency of 120 Hz. The obtained data concerning the movement and speed of the characteristic points on the athlete's body were analyzed, which allowed the author to specify the indicators which define the structure of space and time of the athlete's movement. In the analysis of particular segments of the technique the following factors were taken into consideration: X-, Y-, Z- wrist velocity axes, X-, Y-, Z- elbow velocity axes, and the angle at the elbow joint.

Statistics

Statistical analyses are reported as mean values and standard deviation (SD). All correlations were evaluated using an MS Excel 2000.

RESULTS

Starting posture – the athlete adopts the L-stance. The heel of the left foot is more or less in line with the toes of the right foot. Both knees are slightly bent. The ratio of the body weight is about 70% on the rear leg and about 30% on the front leg (in taekwon-do terminology referred to as *niunja sogi palmok debi maki* with the right foot moved to the front). The term starting posture provides the information concerning the place where an attempt at power breaking is made as well as the athlete's body posture. The athlete becomes ready to perform the strike. At this time the hand does not really change its position or velocity. The time which the athlete is taking while adopting the L-stance is supposed to help athletes to become focused on the strike and on making an efficient and precise movement.

Backward movement: The athlete moves back the right hand forming a characteristic "cross" with the left hand. The movement is aimed at increasing the distance needed for the acceleration of the right fist. This increases the energy facilitating developing as great velocity as possible, and thus increasing the reaction force generated by the athlete.

Acceleration: The coordinated movement of all his/her body parts facilitates the acceleration of the striking hand. There is a dramatic increase in the velocity of the striking hand, whose climax occurs at reaching the maximum velocity. The change in the velocity of the wrist results not only from the work of the muscles in the arm, but also the technique of delivering the strike.

Stopping : the moment of reaching the maximum velocity is immediately followed by sudden and dramatic braking of the fist, which is supposed to stabilize the upper limb and the rest of the body.

Figure 1. Structure of the knife-hand strike used in power breaking.

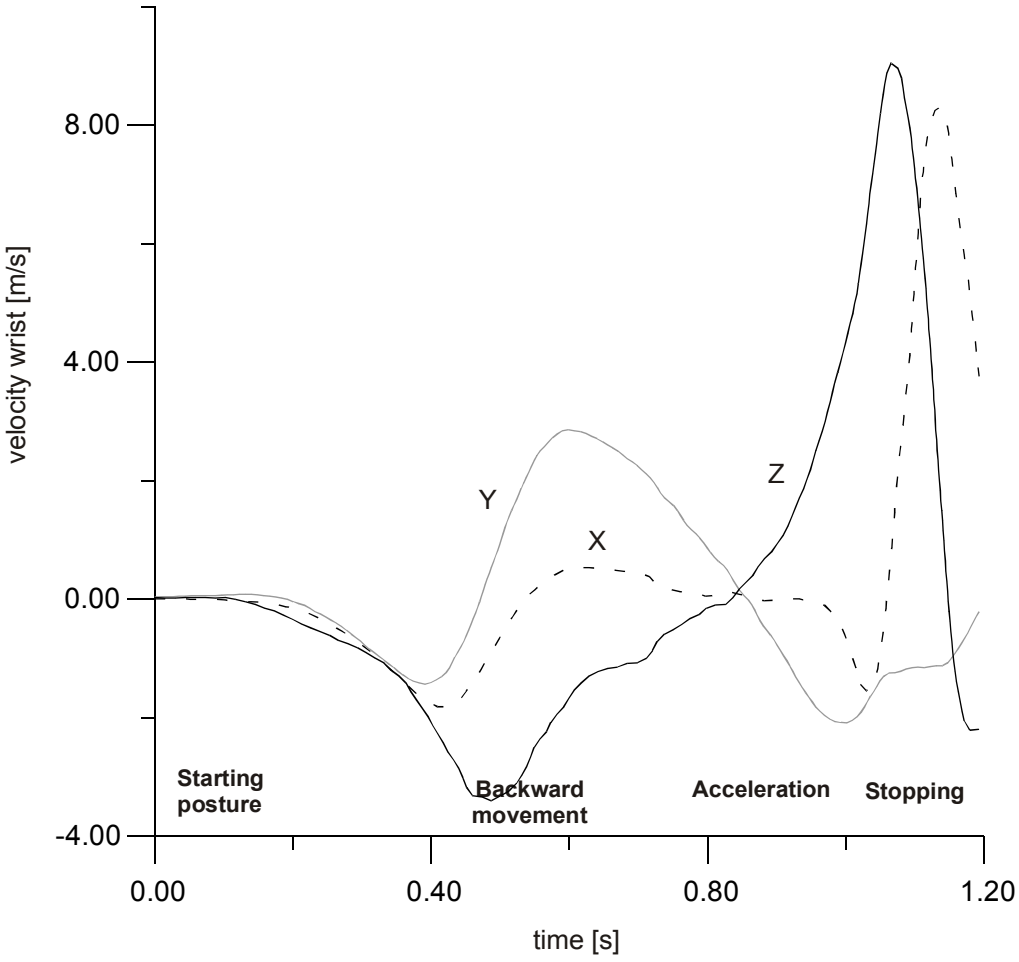

Figure 2. Change in the linear wrist velocity when performing *sonkal yop tearigi* – the knife-hand strike.

Figure 2 presents the course of the changes of the wrist velocity in the Cartesian coordinate system when performing strikes with the muscled part of the side of the hand from the wrist to the main knuckle of the little finger. The course of these changes reveals that they all begin at 0 m/s, which refers to the starting posture, in which both hands are stationary. Velocity v_x is the velocity with which the hand is travelling towards its target. The moment the hand starts to move, it actually first moves back so as to generate more energy. This is shown by the negative value of the velocity in relation to X- and Z-axes. Next, there is a clear increase in the maximum velocity value of 8.32 m/s (X-axis) and 9.05 m/s (Z-axis). This phase is followed by the braking phase, when the velocity goes down to the minimum value.

Figure 3 shows the top view of the structure of the knife-hand strike. On the basis of Figures 4 it is possible to notice the changes in the elbow joint angle. The elbow joint is positioned at the angle of 90 degrees because the athlete begins this technique from the *niunja sogi palmok debi maki* starting stance, which requires such position and such angle of the elbow joint. The moment of taking the swing requires the reduction of the angle.

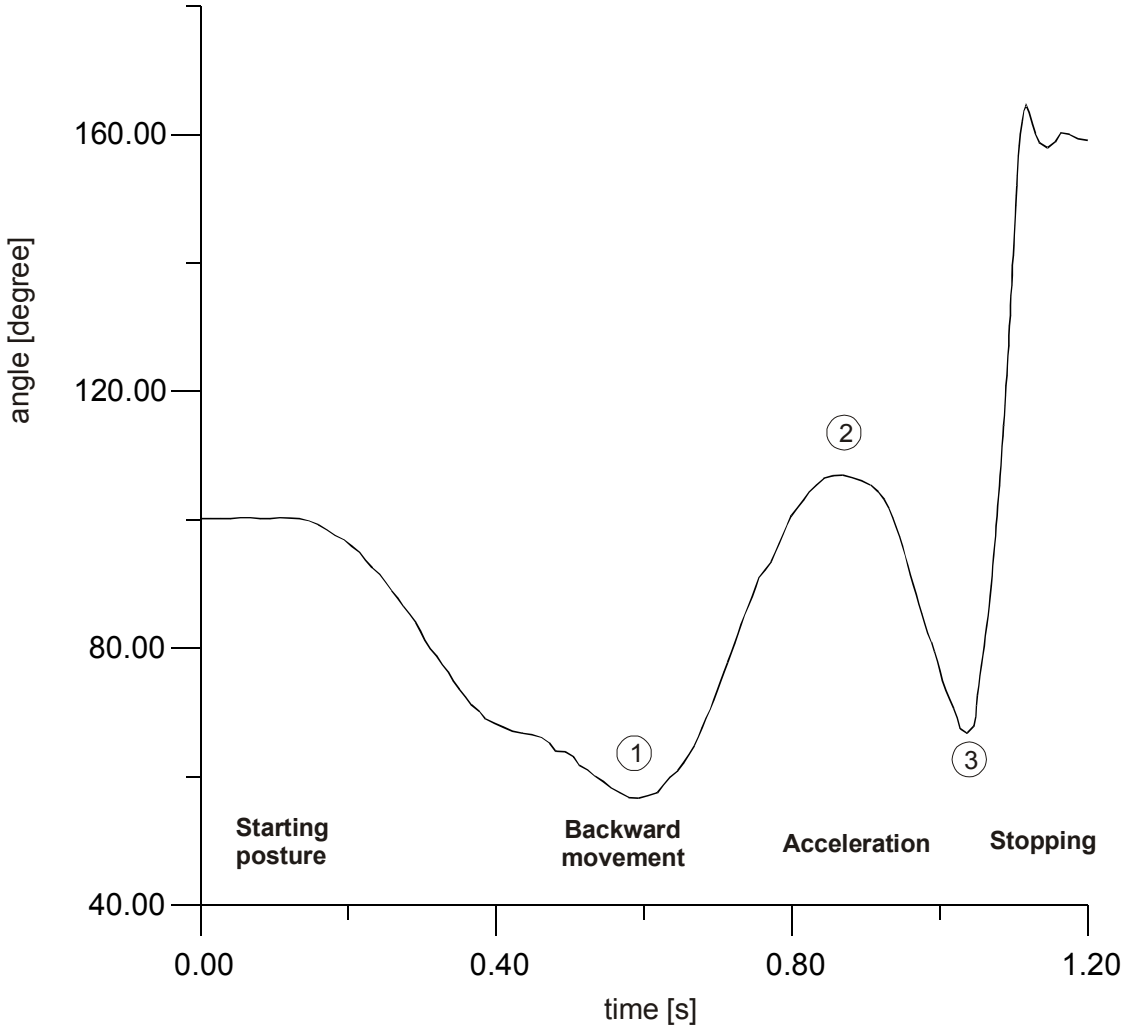

Figure 3. Changes in the elbow joint angle during the performance of the knife-hand strike.

Table 1. Biomechanical factors influencing the efficiency of the strike.

Variables	Average	SD	Range
Maximum wrist velocity – X-axis [m/s]	10.46	2.73	6.57 - 15.25
Maximum wrist velocity – Y-axis [m/s]	2.57	0.79	1.28 - 3.73
Maximum wrist velocity – Z-axis [m/s]	13.00	2.35	9.95 – 16.79
Maximum elbow velocity – X-axis [m/s]	5.40	1.01	3.85 – 7.06
Maximum elbow velocity – Y-axis [m/s]	1.55	0.54	1.04 – 3.12
Maximum elbow velocity – Z-axis [m/s]	6.01	1.67	3.17 – 7.88
Elbow joint angle 1 – α_1 [°]	50.94	4.25	46.67 – 56.57
Elbow joint angle 2– α_2 [°]	95.09	10.19	85.55 – 106.84
Elbow joint angle 3 – α_3 [°]	64.28	1.63	63.16 – 66.66
Duration of the whole movement [s]	1.03	0.21	0.82 – 1.25

Table 2. Correlation coefficient between the parameters influencing the efficiency of the knife-hand strike.

	Maximum wrist velocity Z-axis
Maximum wrist velocity – X-axis [m/s]	0.98
Maximum wrist velocity – Y-axis [m/s]	-0.42
Maximum elbow velocity – X-axis [m/s]	0.81
Maximum elbow velocity – Y-axis [m/s]	0.36
Maximum elbow velocity – Z-axis [m/s]	0.95
Elbow joint angle 1 – α_1 [°]	0.95
Elbow joint angle 2 – α_2 [°]	0.74
Elbow joint angle 3 – α_3 [°]	0.94
Duration of the whole movement [s]	0.93

r – correlation coefficient

DISCUSSION

In the studies conducted by Wilk et. al. [9] the knife-hand strike performed by karate practitioners (no particular style of karate was indicated) had the velocity of between 10 and 14 m/s. In the present study the maximum velocity of the *sonkal yop tearigi* strike reached 13.00 ± 2.35 m/s. The velocity of the traditional fist strike seems to be lower. According to other researchers the velocity obtained by karate practitioners is 5.7-9.8 m/s [9] and 8.41 - 11.38 m/s [10] by taekwon-do practitioners. The side kick reaches the velocity of 5.65 m/s [6], the turning kick - 9.75 m/s [11], and the downward kick - 8.89 m/s [12]. Hence, it can be said that the traditional knife-hand strike develops high velocity. Taking into account its limited striking surface it can be assumed that this strike can put great pressure on the target of the impact.

Using the kinetics of the strike to the full is possible only when the attacked object is situated at the optimum distance [13]. In this study the average maximum velocity was reached at the length of the arm being equal 92 % of the maximum length value. This length can be taken as the optimum value in this particular technique in order to achieve the maximum dynamics of the strike. An error of 5-10 % in calculating the distance in relation to the object being attacked clearly reduces the force of the strike [14]. Hence, both factors, i.e. the precision in assessing the distance and the moment of impact are of great importance for athletes, especially in taekwon-do power breaking tests, where a fixed board is the target of the intended strike. The maximum wrist velocity depends on the velocity of the elbow, elbow joint angles and the total duration of the strike (Table 3).

The presented method of an analysis of taekwon-do techniques (and other Eastern martial arts based sports) enables researchers to obtain precise information and data on the course of movements. This case study presents only a limited part of a much greater research issue.

The results and considerations presented herein can be used as an introductory material for comparisons made by other researchers and a springboard for further research for the author himself.

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