

The comparison of the dynamics of selected leg strokes in taekwondo WTF

WIOLETTA PĒDZICH, ANDRZEJ MASTALERZ, CZESŁAW URBANIK

Chair of Anatomy and Biomechanics, Department of Biomechanics, Józef Piłsudski Academy of Physical Education, 01-813 Warszawa, ul. Marymoncka 34. E-mail: andrzej.mastalerz@awf.edu.pl, mika57@wp.pl

The aim of the study was to compare a dynamics of selected leg strokes in taekwondo WTF (World Taekwondo Federation). Investigations were carried out in the group of 5 competitors with mastery class of taekwondo WTF. Indicators which described two maximal trials of each limb of the body for the side-kick (yop-chagi) and spinning back kick (dwit-chagi) were analyzed. The athletes executed strokes against vertically mounted force plate equipped with an appropriate absorption layer which minimized the risk of injuries. The signal of force was sampled with the frequency of 800 Hz. Signals were filtered by Bessel's filter at a limit frequency of 75 Hz. The following indicators were analyzed: maximal and average values of stroke force, impulse of stroke, time of gaining maximal force, average velocity of increasing stroke force. The results show that taekwondo athletes recorded similar values of the strokes investigated. The differences in maximal stroke force were 6% and in average stroke force – 3% and they were also related to athlete's weight. The results confirm athlete's ability to use the total body mass to increase the stroke force. No significant relations were found between time of gaining maximal force and the value of stroke force. This proves that the technique of stroke, different size and kind of striking surfaces influence the value of stroke force.

Key words: biomechanics, taekwondo WTF, force of stroke, impulse of stroke

1. Introduction

The kinematics and dynamics of strokes in martial arts were the subject of investigations conducted by many biomechanists. They usually estimated relation between stroke velocity and dynamic parameters [1], [3]–[7], [11], [15], [16]. The way of getting high-stroke force in the punches and kicks executed by karate and kick-boxing athletes was different. Relatively high velocity in punching and great athlete's weight engaged in kicking were significant. FIDELUS et al. [7] examined taekwondo athletes and found no significant correlation between stroke velocity and stroke impulse. This

testified to different athlete's weight being engaged in stroke. In KARPIŁOWSKI'S study [9], [10], stroke velocity and stroke force in hand strokes (in boxing gloves) were not related. There were two ways allowing the stroke force to be increased: by an increase in its velocity or by engaging more athlete's weight. Both elements were connected with the sport level of athletes. More significant relations were found between stroke energy, stroke force and stroke impulse. Correlations between stroke impulse and stroke force of hand strokes executed by boxer into boxing trainer are best described by the logarithmic curve. Stroke effectiveness depends on the accuracy of stroke, taking the opponent by surprise and gaining strong stroke impulse which is connected with impulse and stiffen the stroking body part (stroke force). The results showed that both synergic and antagonistic muscles should be trained [8]. The results of the study confirm the influence of specific sports technique on stroke force and stroke impulse values. Due to the lack of articles about taekwondo WTF the aim of the study was to compare the dynamics of different stroke techniques of this sport discipline.

2. Material and methods

Five taekwondo WTF athletes at the age of 25 ± 3.74 years joined the study. All competitors had mastery class (minimal degree was the third kup, maximal degree was the first dan). They belonged to different weight classes (body mass: 79 ± 15.9 kg, body height: 1.81 ± 0.1 m). The practise required was at least 5–7 years.

Stroke force was measured with vertically mounted Impact Force Plate (stroke surface was parallel to wall) which was connected to Spider 8 amplifier (Hottinger Baldwin Messtechnik GmbH). The signal of force was registered with the frequency of 800 Hz. Signals were filtered by Bessel's filter at a limit frequency of 75 Hz. Every athlete performed two maximal trials of each limb of the body for the side kick (yop-chagi) and spinning back kick (dwit-chagi). Yop-chagi was executed by front leg after one step forward. During execution of yop-chagi athletes raised the knee of kicking leg. The hips were shifted slightly as the foot was raised. Finally, the leg was straightened toward the target throughout sagittal plane. The heel and the outside of foot were the striking surfaces. To execute dwit-chagi the athlete should turn through an angle of 180 degrees on the ball of the standing front leg, raise the knee of rear leg (which is provided near standing front leg). Next the athlete turned the body slightly toward the target and strikes it with the heel and the sole of the foot.

The indicators describing the best stroke were analyzed:

- maximal stroke force F_{\max} [N],
- time of getting maximal stroke force $t_{F_{\max}}$ [s],
- average value of stroke force F_a

$$F_a = \frac{I}{t_{F_{\max}} - t_0},$$

where t_0 is an initial stroke time,

- stroke impulse I [N s]

$$I = \int_{t_0}^{t_{F_{\max}}} F(t) dt,$$

- average velocity of the increasing force G [N/s]

$$G = \frac{F_{\max}}{t_{F_{\max}} - t_0}.$$

3. Statistical analysis

Data were expressed as means \pm standard deviation (mean \pm SD). The hypotheses about the differences between strokes were tested for significance using Student's t -test for matched pairs (two-tailed $p < 0.05$). All correlations were evaluated using a Pearson's product moment correlation coefficient and regression analysis.

4. Results

Stroke indicators of maximum value of stroke impulse and maximal stroke force were analyzed. Average maximal stroke force values (F_{\max}) of yop-chagi were as follows: 9015 ± 2382 N for right limb and 8294 ± 2308 N for left one. Equivalent values of F_{\max} of dwit-chagi were: 8569 ± 2381 N and 7751 ± 2570 N. Average F_{\max} values of the strokes tested were similar and very slightly higher (by 6%) compared to those of yop-chagi.

The values of F_a were different: 4426 ± 2110 N for the right limb and 4454 ± 2293 N for the left one during yop-chagi. Equivalent values F_a of dwit-chagi were: 4798 ± 1324 N and 3827 ± 1380 N. Average stroke values F_a were similar to maximal stroke values F_{\max} and slightly higher for yop-chagi (by 3%) than for dwit-chagi.

The comparison of the values of average stroke parameters for both limbs is given in figure 1. Higher values of the parameters were mostly recorded during strokes executed by the right limb during yop-chagi, with the exception of F_a , I , F_{a_w} ($_w$ is a relative value). The right limb during dwit-chagi played a dominant role in all strokes which was corroborated by the parameters measured. Statistically significant differences ($p < 0.05$)

were found between average velocity of the increasing force G and relative values of stroke impulse during side kick. Comparing both measuring techniques the differences were found between F_a , G , F_{a_w} , I_w and G_w as well.

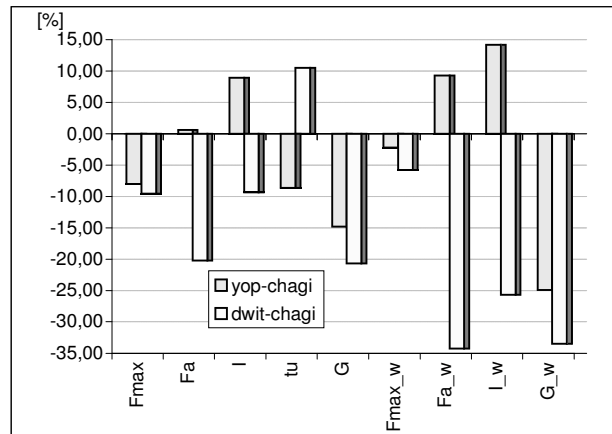


Fig. 1. Relative differences of average indices of the left limb strokes related to the right limb strokes, w – relative value

Figure 2 shows mean values F_{max} of measured kicks with a trend line and a standard deviation value. There were significant connections between the body mass and F_{max} plus F_a for yop-chagi stroke executed by the right side of the body ($p < 0.04$) and between the body mass and F_a for dwit-chagi stroke executed by the right leg ($p < 0.04$). Only the result achieved by the athlete with 78 kg weight did not follow this trend. This can be explained by a better technique of that athlete (1 dan) compared to that presented by the athlete with 91 kg weight (2 kup). He was the best of all athletes tested.

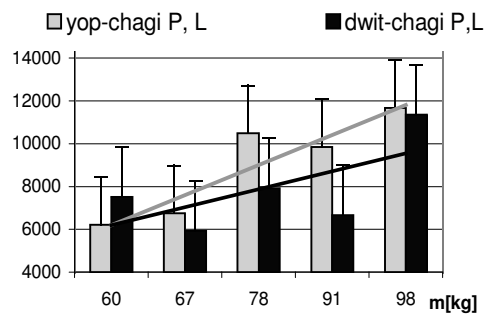


Fig. 2. Relation between maximal force (F_{max}) and athlete's body mass during yop-chagi, dwit-chagi, P – right limb, L – left limb

The impulse stroke of side kick was found to be slightly (9%) for the left limb (42 ± 15 Ns) than for the right one (38 ± 13 Ns). Contrary to this situation, during dwit-chagi the impulse stroke is higher (9%) for the right limb (34 ± 8 Ns) than for the left one (30 ± 12 N/s). Average time of getting maximal stroke force for yop-chagi was 0.009 ± 0.002 s, and for dwit-chagi – 0.008 ± 0.001 s. The average velocity of the increasing force G for both sides of the body (yop-chagi: 965249 ± 467441 N/s, dwit-chagi: 1230153 ± 349985 N/s), which is higher for spinning back kick (12%), was also analyzed.

Comparing both types of the strokes measured we found statistically significant differences in impulse stroke ($p < 0.02$) and maximal force stroke ($p < 0.04$) between side kick and spinning back kick executed by the right leg.

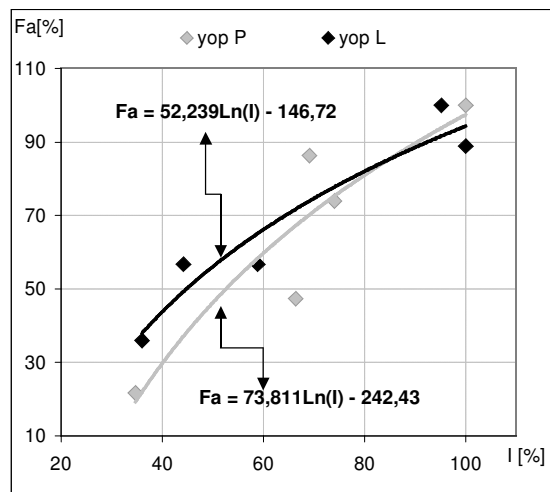


Fig. 3. Relation between stroke impulse (I) and an average stroke force (F_a) during yop-chagi, P – right limb, L – left limb

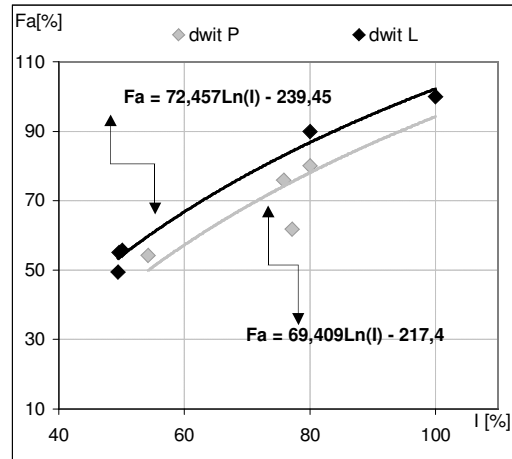


Fig. 4. Relation between stroke impulse (I) and an average stroke force (F_a) during dwit-chagi, P – right limb, L – left limb

The connections between the stroke impulse and the stroke force F_a of the kicks tested (figures 3 and 4) were examined as well. The stroke impulse (I) becomes stronger simultaneously with an increase in the average value of the stroke force F_a . High R -square coefficients for logarithmic curve approximation which describe the connections between the right limb ($R^2 = 0.8308$ – yop and $R^2 = 0.9836$ – dwit) and the left one ($R^2 = 0.8512$ – yop and $R^2 = 0.8034$ – dwit) were obtained.

5. Discussion

Based on the analysis of the values F_{max} and F_a of the strokes tested we can arrive at conclusion that the results are similar and the values obtained are slightly higher for yop-chagi (by 6% for F_{max} , by 3% for F_a) than for dwit-chagi. Statistical differences ($p < 0.05$) in strokes executed by the right and left limbs concern mostly relative values of the parameters analyzed. Moreover, these parameters differed, depending on the time of the contact between foot and stroke target. They were also greater for these strokes during which the athletes were able to use the stroke technique more effectively. Comparing yop-chagi and dwit-chagi strokes, we found statistically significant differences ($p < 0.05$) in maximal force and relative maximal force of the strokes executed by right limb. No crucial relationships between the time of getting maximal force stroke and stroke force value were observed. The technique of the stroke, different athlete's weight engaged during stroke, size and kind of stroking surface (yop-chagi – the heel and the outside of foot; dwit-chagi – the heel and the sole of foot) could influence the stroke force.

The size of plate (114 mm × 419 mm), against which the strokes were executed, could also determine the stroke force, especially during dwit-chagi in which an athlete had to turn through an angle of 180 degrees. In the studies conducted by PIETER et al. [15], the values of dwit-chagi stroke force were higher than these of yop-chagi (28%). In their study, the kicks were executed with the rear leg, while in our research yop-chagi was performed by front leg after one step forward. The way of performing kicks could also have an influence on the differences in kinetic stroke parameters. There is no point in comparing the forces of strokes which were executed against different devices because of varying stiffness and damping coefficient of shock-absorption layer [1], [2], [5].

Average values F_{\max} of Momtong Jirugi punch are approximately three times as low as those of kicks. Similar relationships were also reported by other researchers [1], [2], [7]. The time of getting maximal force punch differs only by 6% and 17% compared to dwit-chagi and yop-chagi, respectively. That parameter does not influence the strokes performed by the right and left limbs (0.0075 s). The correlation found between time of getting maximal force punch and stroke force value was not statistically significant. The right limb is dominant during punches as well as during kicks.

Recent research testifies to a linear correlation between energy of stroke executed against boxing trainer and stroke force or stroke impulse. Stroke force as well as stroke impulse are the equivalents of the work recorded during the stroke [9]. The value of stroke impulse is connected with a linear momentum which depends on different factors. The swing and stroke should be performed with engaging almost maximal body mass and stroke velocity [8]. The engagement of a greater body mass during the stroke can influence significantly the mechanism generating stroke force [5], which is connected with “putting hips” during the execution of taekwondo techniques [15]. The use of hips allows an athlete to shorten the distance between him and his opponent and is connected with the stroke effectiveness. It shows that body mass is not equal to the mass engaged in stroke.

The stroke force depends on an athlete’s weight. A statistically significant correlation between those parameters testifies to the capability of engaged body mass to increase the stroke force.

In this paper, the correlation between the impulse stroke and the force F_a of stroke is best described by a logarithmic curve and is validated by KARPIŁOWSKI et al. [10]. Dwit-chagi stroke is characterized by a higher correlation (6%) between stroke impulse I and F_a . It is (10.6%) used quite often in taekwondo competition [17]. In MAŁECKI’S study [13], the effectiveness of dwit-chagi and yop-chagi were 15% and 4%, respectively. A greater scatter of results in yop-chagi was observed which indicated irregularity of this kind of strokes.

6. Conclusions

1. Stroke force values are similar for both kicks tested. Dwit-chagi kick is technically more complicated and difficult to execute than yop-chagi which probably can influence the results obtained. The kind of motion during execution of both kicks (yop-chagi – linear, dwit-chagi – angular) affects the stroke values.

2. The differences in stroke force depend on athlete's weight. A statistically significant correlation between these parameters testifies to athlete's capability to increase the force stroke due to his greater body mass.

3. Statistically significant higher stroke force values on the right side were recorded for all cases where the right limb was dominant.

4. The size and kind of stroking surfaces could be responsible for the stroke force. No statistically significant correlation between the time of getting maximal stroke force and force stroke value was found.

5. Significant correlations were observed between the impulse stroke and the force F_{sr} of stroke executed against the plate which is best described by logarithmic curve. Similar conclusions were reported by KARPIŁOWSKI et al. [11] who examined the athletes striking against a striking bag.

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