ORIGINAL ARTICLE
SCIENCE OF MARTIAL ARTS

Influence of acceleration of the fist on the effectiveness of the straight punch in taekwondo

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Received: 15 May 2017; **Accepted:** 11 June 2017; **Published online:** 27 December 2017

AoBID: 11602

Abstract

Background & Study Aim: In its traditional version the taekwon-do straight punch is an important element in the coaching of martial arts practitioners. In sports competition, these strikes are used most often when attacking or counter-attacking, and also in power tests, they are a considerably significant technique when it comes to granting a victory. This is the reason why this study has focused on the relationships between acceleration and other kinematic factors involved in the execution of the straight punch (in taekwondo referred to as *ap jumok jirugi*) and whether from the biomechanics point of view, there are differences between the dominant and non-dominant hand.

Material & Methods: There were 8 taekwondo ITF practitioners included in the analysis. They adopted the same initial stance and performed the traditional straight punch. The tests were carried out with the use of a motion analysis laboratory called *Human Motion Lab. The equipment used recorded the indicators specifying the spatial and time structure of the motion of the marker fastened to the subject's fist.*

Results: Duration of the strike 1.00 ±0.23 s; maximum velocity 8.05 ±1.59 m/s; acceleration of the strike 95.39 ±45.47 m/s^2; acceleration of the braking 222.08 ±93.17 m/s^2. The peak velocity highly correlates with the acceleration of the punch ($r = 0.81$, $p<0.01$) and braking acceleration ($r = 0.79$, $p<0.01$). It is noticeable that the obtained acceleration of the strike does not affect the duration of the movement ($r = 0.28$, $p<0.01$). The more the acceleration of the strike increased, the higher the braking acceleration was ($r = 0.65$, $p<0.01$). The maximum velocity shows to have a moderate influence on the duration of the strike ($r = 0.51$, $p<0.01$).

Conclusions: For any of the recorded indicators no statistically significant differences were registered between the dominant and non-dominant hands during delivery of the traditional straight punch, which could indicate low lateralisation of the upper limbs in this particular movement task.

Keywords: analysis of movement • ap jumok jirugi • biomechanical analysis • ITF • power test

Conflict of interest: Authors have declared that no competing interest exists

Ethical approval: The research was approved by the Human Subjects Research Committee of the local university

Provenance & peer review: Not commissioned; externally peer reviewed

Source of support: Departmental sources

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INTRODUCTION

Biomechanical analysis – the use of technical sciences for the analysis of biological systems [27].

Power test – a sports event in taekwondo ITF consisting of breaking boards [28].

Ap jumok jirugi – is the straight punch in traditional taekwondo.

L-stance – the stance is about 2.5 centimetres (1 inch) wide, measured from the inside heel of the front foot to the back heel of the rear foot. It is approximately one-and-a-half (1.5) shoulder widths long, measured from the footsword of the rear foot to the toes of the front foot. The weight is distributed about 70% on the rear foot and 30% on the front foot. The rear leg is bent so that the knee-cap is over the toes of the rear foot and the rear foot is pointed in about 15 degrees. The front leg is bent proportionally, with the front foot pointing in about 15 degrees. The rear hip is aligned with the inner knee joint of the rear knee [4].

It is common knowledge that a correct sports technique must be in line with the principles of the human biomechanics. The ways in which martial arts have been coached have changed over the years. This has always resulted from science-based analyses and conclusions drawn from extensive research. Such developments have necessitated adjustments in the process of coaching and curricula to new principles [1-3].

In the traditional version of taekwondo (International Taekwon-do Federation; abbreviation ITF) straight punches make an important element in the coaching process. In sports competition, they are used most often when attacking or counter-attacking [1], and in *power tests*, they are a considerably significant technique when it comes to granting a victory [4].

Power tests involve breaking the number of boards which a competitor specifies prior to attempting breaking them. In this case, the most significant element of the whole movement seems to be the ability of a competitor to maximise their energy and power.

There are a number of factors which seem likely to affect the strength of a given punch. However, according to the classic physics, it could be simplified and presented as a straightforward dependence $F = m \bullet a$. This suggests that force is closely related to the acceleration of a given object at every moment multiplied by its effective mass [5]. According to Blum [6], karate practitioner's effective mass is the total mass utilised on the delivery of the strike. However, determining this mass is problematic in the case of a punch the effective mass might include the summation of the mass of the hand, the forearm, the upper arm and the trunk [7]. The literature also tells us that some other factors likely to affect strike efficiency include the distance from and height of the target [8, 9].

Scientists and academics conducting research into taekwon-do techniques most frequently focus on the study of kicks [10–14]. Although analyses of hand strikes and punches are by no means common, there are still a few studies to be found in the available literature. For instance, Stull and Barham [15] compared the velocity values and force values obtained by competitors practising shotokan karate, kempo, kung-fu and taekwon-do during the execution of the straight punch. Pieter et al. [16] determined the velocity and force values for the straight punch and also the side and roundhouse kicks. They suggested that quantitative research is carried out to facilitate a better understanding of those techniques.

This is the reason why this study has focused on extending the knowledge of the relationships between acceleration and other kinematic factors involved in the execution of the straight punch (in taekwondo referred to as *ap jumok jirugi*) and whether from the biomechanics point of view of there are differences between the dominant and non-dominant extremity. This is a further step towards a better understanding of the strikes in martial arts and specifically a better comprehension of the traditional straight punch in taekwondo.

MATERIAL AND METHODS

Participants

Eight male athletes (age: 20.5 ±4.1 years; body mass: 68.3 ±7.02 kg; height: 173.6 ±5.9 cm) practising taekwondo ITF were analysed. In the tests, having adopted the L-stance (according to the terminology of taekwondo: *niunja sogi palmok debi maki*), they performed the traditional straight hand strike into the air (no physical target). The strikes were performed using both the right and left hand 3 times each. In total 48 attempts were registered.

The Human Subjects Research Committee of the local university scrutinised and approved the test protocol as meeting the criteria of Ethical Conduct for Research Involving Humans. All the subjects in the study had been informed of the testing procedures and voluntarily participated in the data collection.

Protocol

For the purpose of this research a motion analysis lab HML (Human Motion Lab, Poland) was used. The facility included ten NIR Vicon MX-T40 (Vicon, USA) cameras with the resolution of 4 MP (2352 x 1728 px) as well as 10-bit grayscale. The system allows to capture up to 370 frames per second at a full resolution. The indicators registered the structure of the spatial-temporal motion marker placed on the athlete's fist, specifying its speed changes as a function of time. Using this method, the resultant maximum speed of the fist was recorded.

Statistical analysis

For each indicator, the mean value, as well as standard deviation, were calculated. Normality of the distribution was verified by Shapiro-Wilk test. The differences between the compared groups were assessed on the basis of the t-test. Statistical significance was adopted at the level of $p<0.01$. All the calculations were made using SPSS Statistics 20.0 (IBM, USA).

RESULTS

The largest variation in results (relative to average maximum speed and acceleration of fists during the execution of the straight hand strike without physical target) concerns acceleration (120 %) and acceleration of the braking (76 %) (Table 1). There were no statistically significant differences in maximum speed of the strike between the left and right hand (Table 2).

The peak velocity highly correlates with its acceleration of the punch ($r = 0.81$, $p<0.01$) and braking acceleration ($r = 0.79$, $p<0.01$). The obtained acceleration of the strike does not affect the duration of the movement ($r = 0.28$). The more the acceleration of the strike increased, the higher the braking acceleration was ($r = 0.65$, $p<0.01$). The maximum velocity it enters moderate interactions on the strike duration ($r = 0.51$, $p<0.01$) (Table 3).

DISCUSSION

The data obtained by the recording of the tests under this study show that the peak velocity of the fist during execution of the traditional straight punch was 8.05 ±1.59 m/s (Table 1). Similar values were recorded for karate athletes [17]. In another study higher values were recorded reaching 11.5 m/s [18]. When comparing the velocity values obtained to the velocity values of other strikes

Table 1. Selected average maximum values (M) of the recorded indicators during execution of the traditional straight punch by male taekwondo ITF athletes (n = 8).

Variable [indicator]	M	SD	Min	Max
Strike duration [s]	1.00	0.23	0.60	1.67
Maximum velocity [m/s]	8.05	1.59	4.59	10.88
Acceleration [m/s^2]	95.39	45.47	11.04	209.85
Acceleration of the braking [m/s^2]	222.08	93.17	54.07	367.98

Table 2. Selected average maximum values (M_1 & M_2) for both hands.

Variable [indicator]	Dominant hand		Non-dominant hand		Deference $M_1 - M_2$	
	M_1	SD	M_2	SD	results	p-value
Strike duration [s]	0.98	0.28	1.02	−0.18	0.7	0.71
Maximum velocity [m/s]	8.16	1.29	7.94	1.87	0.22	0.67
Acceleration [m/s^2]	92.82	32.67	97.97	−56.35	5.15	0.74
Acceleration of the braking [m/s^2]	231.93	92.44	212.23	95.51	19.7	0.53

Table 3. Correlations between selected kinematic indicators ($p<0.01$).

Variable [indicator]	Strike duration	Maximum velocity	Acceleration
Strike duration [s]	-		
Maximum velocity [m/s]	0.51	-	
Acceleration [m/s^2]	0.28	0.81	-
Acceleration of the braking [m/s^2]	0.56	0.79	0.65

(performed by men), for example, the sidekick: 5.20-6.87 m/s [19], and the spinning back kick: 5.95-8.35 m/s [20], it can be concluded that *ap jumok jirugi* is a straightforward strike of high velocity.

The average duration of the strike was 1.0 ±0.23 s, being similar to the values obtained in another study [21, 22]. Rybicki et al. [23] state that the duration of the sports straight punch delivered by taekwon-do athletes are between 30 m/s to 50 m/s. A significant difference in the duration between the execution of the sports and traditional versions of the straight punch can be seen. This was also reported in another study [23], which shows that the traditional punch used when breaking boards do not need to be performed in a short time as it aims at generating high energy which is to be transferred to the object being broken in order to destroy it.

In the case of the recorded accelerations, a high variance can be observed. Thus, a high degree of differentiation of those indicators was present. Although the athletes were of similar age and performed a certain standardised movement technique, they represented different clubs. This might have resulted in various habits concerning the movement, which also might have been taken after their coaches. The results obtained in the study might also reflect the degree of the athletes' advancement. It is accepted to define high acceleration values as "g", where 1g = 9.81 m/s^2 (gravitational acceleration), 0g relates to the state of weightlessness [24]. The obtained results show (Table 1) that the fist in the phase of the driving of the strike develops the average acceleration of 95.39 ±45.47 m/s^2 (ca. 10g), and in the braking phase, the acceleration is 222.08 ±93.17 m/s^2 (ca. 20g). Thus, in the phase of the braking, the acceleration is twice as high as in the phase of the driving of the strike. It is commonly known that when a human body is exposed to high acceleration values, those values could be harmful to human tissue as it happens in vehicle accidents or when falling. The greatest gravity loads occur when catapulting from an aeroplane reaching as much as 22g [24]. Hence, duration of exposure to acceleration proves relevant, i.e. the shorter the time a human body is exposed to acceleration, the safer it is for the man. In this case, the duration of the exposure to acceleration is not at all significantly long.

The difference between those two accelerations investigated herein might result from the fact that the acceleration of the driving of the strike develops over a relatively long time while the time needed by the athlete to stop the driving fist is very short. It might suggest bigger loads to the upper limb when braking without having a physical target. When a strike is aimed at, for example, a punch bag, part of the energy involved in the punch is transferred to the target of the punch. Thus, it can be expected that injuries might occur when a target unexpectedly disappears during a fight, for example when dodging an expected blow. On the other hand, when an athlete repeatedly performs strikes into the air without having a physical target, it might facilitate better adapting to possible loads.

For any of the recorded indicators, no statistically significant differences were registered between the dominant and non-dominant hands during delivery of the traditional straight punch (Table 2), which could indicate low lateralisation of the upper limbs in this particular movement task. This could result from the concept of the traditional taekwondo practice in which strikes are always performed with both, the right and left sides. The considerations that are included herein belong to the stage of longitudinal, interdisciplinary research leading towards a deeper understanding of the role of various factors that influence on the kinematics in taekwondo [25, 26]. However, the recorded results reveal certain dependencies. As it could have been assumed the peak velocity highly correlates with its acceleration of the punch and braking acceleration. The more the acceleration of the strike increased, the higher the braking acceleration was. The maximum velocity to have a moderate influence on the duration of the strike.

It is hoped that the considerations presented in this paper prove helpful for a comprehensive understanding of the kinematic factors affecting the traditional straight punch. In our opinion, good visualisation of the specificity of this phenomenon are diagrams of the changes of the velocity (blue line) and acceleration (red line) of the marker attached to the taekwondo ITF athletes' fists during the experiment (Figure 1).

The conclusions and test results presented in this paper could be used by other researchers for their comparative studies, and they could also work as a springboard for other interdisciplinary research.

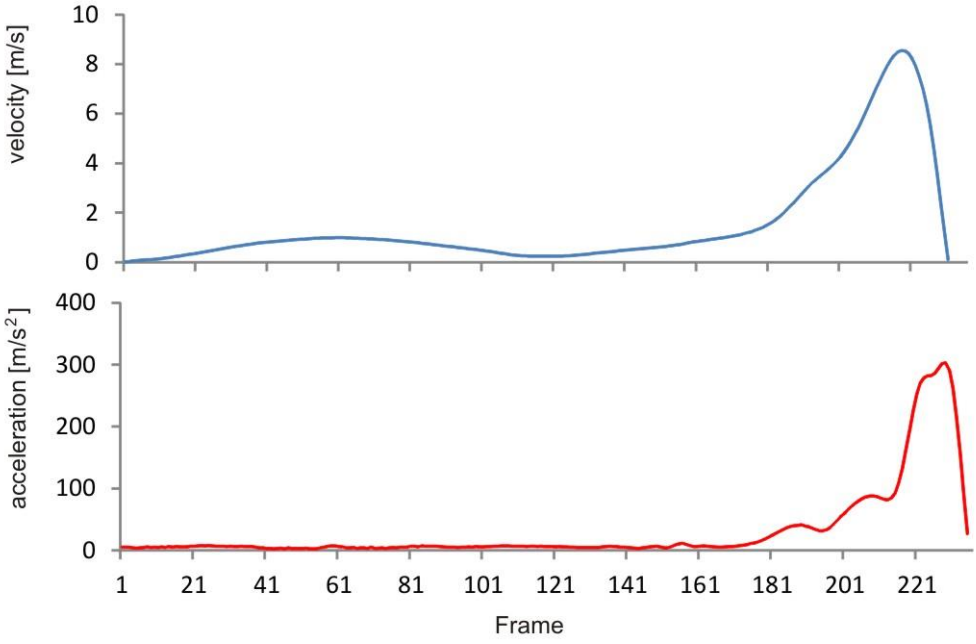

Figure 1. Example diagram of the changes of the velocity (blue line) and acceleration (red line) of the marker attached to the taekwondo ITF athletes' fists during execution of the traditional straight punch.

CONCLUSIONS

The performed research reveals that: peak velocity highly correlates with its acceleration of the punch and braking acceleration; the obtained acceleration of the strike does not affect the duration of the movement; the more the acceleration of the strike increased, the higher the braking acceleration was; the maximum velocity shows to have a moderate influence on the duration of the strike.

For any of the recorded indicators, no statistically significant differences were registered between the dominant and non-dominant hands during delivery of the traditional straight punch, which could indicate low lateralisation of the upper limbs in this particular movement task.

This is understandable, because the taekwondo training methodology and the message that is conveyed by this type of martial arts, together with the expression of this message in the shape of particular techniques, is connected with a comprehensive influence on the organism. The research data indicate that there are substantial arguments that allow us to state that participation in martial arts is connected with an integrated activity in different fields of central system development.

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Cite this article as: Wąsik J, Borysiuk Z, Balkó Š. Influence of acceleration of the fist on the effectiveness of the straight punch in taekwondo. Arch Budo Sci Martial Art Extreme Sport 2017; 13: 29-34