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KINESIOLOGY

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Movement structure and kinetics of the traditional straight punch: measurements in taekwon-do athletes

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Abstract

The main aim of this paper was to study the kinetics of the straight punch and to check the influence of the movement of the non-punching fist on the speed of the punching fist. The study was conducted on a group of 10 taekwon-do ITF (International Taekwon-do Fedearation) athletes. Having adopted the starting position the athletes executed the punch. In the study Smart-D system for complex movement analysis was used. Recording of the movement was made with accuracy of 0.3 – 0.45 mm and frequency of 120 Hz. Mean and standard deviation were used as descriptive statistics. Pearson correlation coefficient was used to verify the relationship between hands' kinetics. The maximum speed of the punching fist was 8.88 ± 0.98 m/s and the speed of the non-punching fist was -3.59 ± 0.67 m/s. The observations made allowed the author to assume that the length of time needed to execute a punch is mainly affected by the distance which the punching fist must cover and also the average speed of the punching fist. The speed which the punching fist develops depends on the acceleration which the fist achieves and also on the technique with which the movement is executed. The research has also observed that the speed of the punch is also affected by the time difference between the peak velocity of the punching fist and the peak velocity of the fist moving backwards (r=-0.73)

Introduction

Biomechanical optimisation of the combat sports' techniques can enhance the ability to learn and perform the fastest and most powerful strikes. That is the reason why many researchers attempt to find and identify the factors which influence efficient strike performance. Choi [1995] put forward his "Theory of Power", in which he emphasized the role of the mass, velocity, balance, concentration and control of breathing in gaining force. Vos & Binkhorse [1966], Blum [1976] and Walker [1975] analysed the kinematic aspect of the strikes and process of breaking hard objects with bare hands. Vences de Brito *et al.* [2011] found out that kinematics and neuromuscular activity in punches delivered by karate athletes occurs within 400 ms. The investigation also showed that arm movements reach peak angular velocity earlier than forearms do. There are a few more studies which investigated the karate straight punch [Nakayama 1983; Courtonne 1996; Link, Chou 2011].

The traditional taekwon-do punch have not yet been examined too often. Pieter *et al.* [1987] compared the straight punch performed by taekwon-do athletes using two different initial stances and suggested that there was a need for quantitive analysis to understand this particular technique better. Other research [Wąsik 2009] suggests that the highest velocity of the fist in this punch was registered on the 86 % of the arm's length.

Taekwon-do is a Korean self-defence martial art and a dynamically developing combat sport. The traditional version of taekwon-do ITF (International Taekwon-do Federation) comprises four events: sparring, patterns, power test and special techniques [Choi 1983; Choi, Bryl 1990; Choi 1995]. Power test involves breaking a declared number of boards with the use of five different techniques: using the punch and the outer edge of the hand, and also using kicks: the side kick, roundhouse kick and turning kick. Each broken board scores two points and the total of scored points decides who wins. The punch (in taekwon-do terminology referred to as *ap joomuk jirugi*) has a significant influence on the final result in a competition. Power test demands of the athlete to have the breaking surfaces appropriately prepared, to have an ability to achieve the required breaking stress energy as well as to have an impeccable technique [Bujak 2004].

Adopting previously used criteria for biomechanical analyses of sports techniques [Hay 1993], and especially the ways of measuring taekwon-do techniques [Wąsik 2010, 2011a, 2011b] in this study four stages of the chosen technique have been analyzed: starting posture, backward movement, acceleration and braking. Thus, the following questions arise:

1. At which moment is the speed the highest during the execution of *ap joomuk jirugi*?
2. How do the chosen kinematic parameters influence the velocity of the punch?

Providing answers to the above questions might help to choose a better and more efficient method of executing this kind of punch in self-defence as well as in winning the power test event in taekwon-do ITF.

Materials and methods

Subjects

The study was based on 10 taekwon-do ITF (International Taekwon-do Federation) 10 male athletes. The researched group included European Junior Champions, Polish Junior Champions and other athletes who had practised taekwon-do for a minimum of 4 years. They had degrees 1 Dan to 4 cup. They train regularly 3 to 5 times a week. Athletes and their parents agreed to take part in this study voluntarily.

Table 1. ITF taekwon-do athletes' characteristics.

	Male athletes (n=10)	
Variables	Mean ± SD	Range
Age [years]	16.8 ± 0.3	16 - 18
Body mass [kg]	70.8 ± 7.4	58 - 80
Height [cm]	180.0 ± 2.8	175 - 182

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 execute the straight punch forward with the left foot at the front three times. The analysis covered 30 attempts altogether. The structure of the movement is presented in figure 1.

The case study relied on an Italian system called Smart-D, made by BTS S.p.A., used for complex movement analysis. 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. Obtained data concerning the movement and speed of characteristic points on the athlete's body were analyzed, which allowed 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: the peak velocity of the punching fist (v_A), the maximum braking acceleration of the fist moving backwards (a_s), the peak velocity of the fist moving backwards (v_B), as well as difference in time needed to obtain the peak velocity of the punching fist and the minimum speed of the fist moving backwards (Δt).

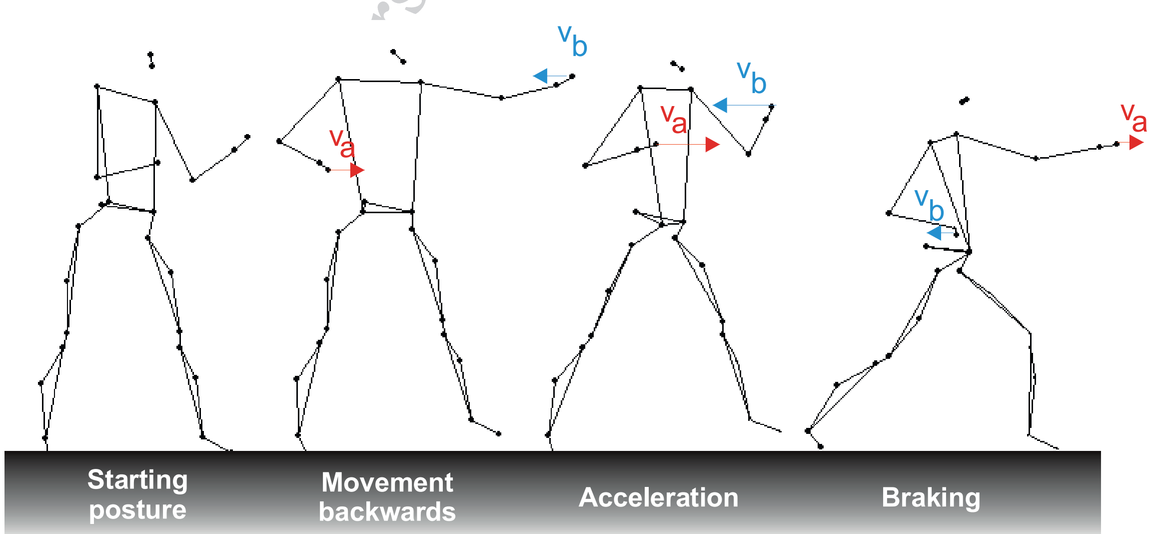

Figure 1. Movement structure of the straight punch (in Taekwon-do referred to as *ap joomuk jirugi*).

Statistics

For the recorded parameters the average values and standard deviations (SD) were calculated. Pearson correlation coefficient was used to verify the relationship between hands' kinetics. The significance level was set at $p<0.05$. All the statistical calculations were carried out with the use of MS Excel 2000.

Results

Ap joomuk jirugi, a punching technique, can be divided into four phases: starting position (preparatory phase), backward movement, acceleration and braking (closing phase).

Starting posture: the practitioners stand in the position called *niunja sogi palmok debi maki* with the right foot moved to the front. They prepare to execute the punch. The fist itself does not actually change its location or the speed. The athletes need time to concentrate in order to execute a precise movement.

Backward movement: the athletes move the attacking fist backwards so as to increase the distance needed for acceleration. This results in increasing the energy in order to obtain the highest peak velocity possible.

Acceleration: using the harmonious movements of different parts of their bodies to their advantage the athletes make their fists accelerate. There is a sudden increase in the fist velocity, which reaches its peak when the maximum velocity is obtained. The change in the fist velocity is not only a result of the work of the upper limb muscles, but also of the technique employed.

Braking: just after the peak velocity is obtained, the process of sudden braking occurs so as to allow the upper limb to become stable.

For one of the measurements conducted Figure 2 presents an example of the changes in the speed of punching fist v_a and the changes in the speed of fist v_b travelling backwards towards the hip. Until 0.35 s the speed of the punching fist is only slightly more than 0. Between 0.45 and 0.60 s the variable decreases to -1.14 m/s. This is connected with the

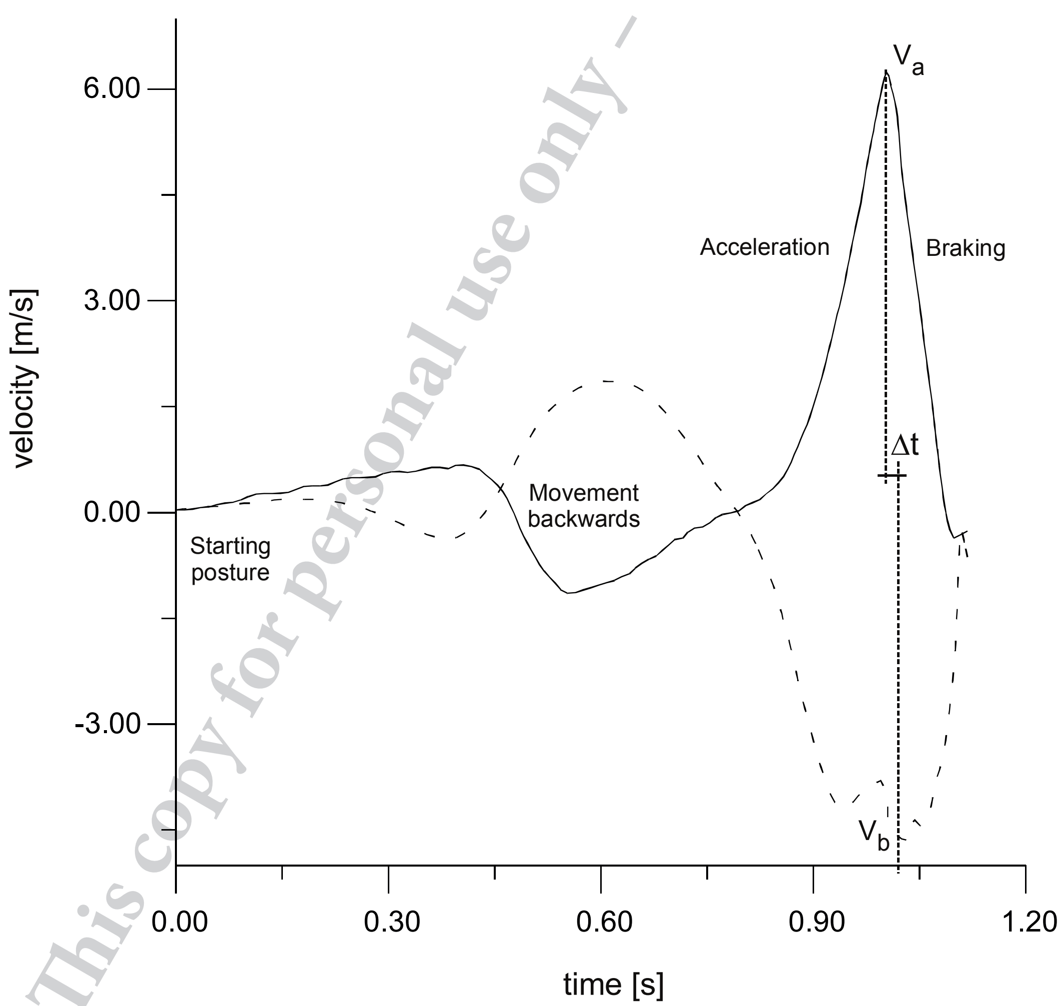

Figure 2. Changes in the speed of the crossing fists during the execution of *ap joomuk jirugi* in relation to time (solid line - striking hand, broken line - opposite hand going back to the waist).

Table 2. Kinematical parameters affecting efficiency of the punch

	Mean ± SD	Range
Maximum speed v_A (m/s)	8.88 ± 0.98	6.24 to 10.52
Braking acceleration a_s (m/s²)	-344.62 ± 78.18	-425.73 to -145.36
Minimum speed v_B (m/s)	-3.59 ± 0.67	-2.02 to -4.42
Δt (s)	0.042 ± 0.025	0.017 to 0.092

change of movement direction of the punching fist, which is a movement characteristic of Taekwon-do and is called a "backward movement". After 0.6 s the speed of the fist starts to increase dramatically so as to reach its peak value v_A=6.24 m/s within the time of 1 s. Next, a sudden decrease in the speed of the fist occurs, which is a result of the fist braking. The moving in the direction opposite to the direction of the punch reaches the minimum value v_B=-4.64 m/s within the time of 1.017 s.

Table 2 presents the kinematical parameters (speed, acceleration and time) affecting the efficiency of the punch.

Figure 3 presents the linear regression between peak velocity of attacking fist and the difference in time needed to obtain the peak velocity of the punching fist and the minimum speed of the fist moving backwards.

Discussion

The above observations show that the chosen form of punch examination which uses modern movement analysis systems makes it possible to obtain precise information on the execution of the punch. Attempts at describing the kinematics of karate punches have been made earlier [Blum 1975; Walker 1975]. With the use of the stroboscopic method the peak velocities of the punching fist in karate obtained the values ranging from 5.7 to 9.8 m/s [Wilk *et al.* 1982]. The average velocity of

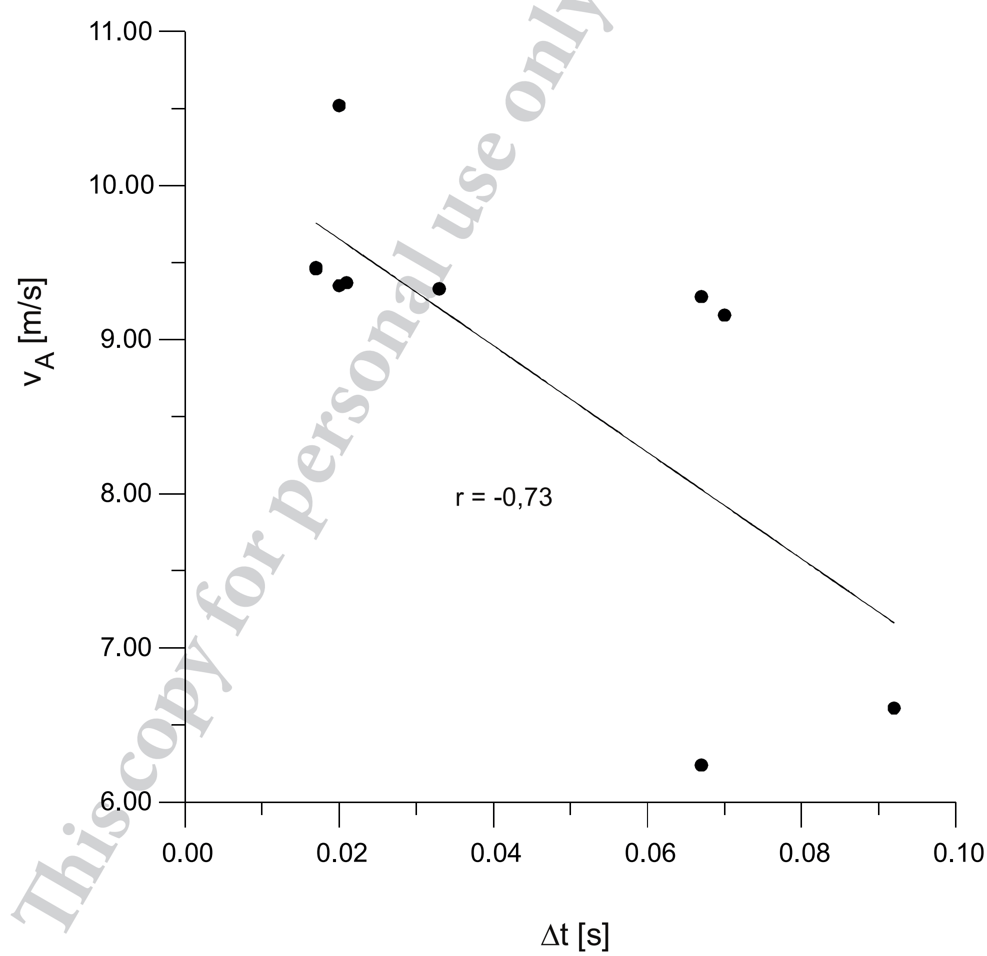

Figure 3. Linear regression between of the peak velocity of fist v_A and time difference Δt.

the fist executing a similar punch obtained in the present study in Taekwon-do practitioners was 8.88 m/s with the value being similar to the time results obtained earlier [Stull, Barham 1990].

When comparing the values presented in Table 2 it can be noticed that there are kinematic parameter differences between the athletes with different experience. The top athletes developed the fist velocity over 11 m/s. However, due to the fact that there were fewer highly-qualified athletes than those with limited experience the mean fist velocity value was smaller. The weakest result of 8.99 m/s was obtained by an athlete who held the blue belt (4th cup).

When looking at the values in Table 2 kinematic parameter differences between advancement of the athletes can be observed. The best athletes obtained fist velocities exceeding 10.52 m/s (1st dan). However, due to the fact that there were fewer highly qualified athletes than less experienced athletes the average fist velocity is lower. The weakest result of 6.24 m/s was obtained by a male blue belt holder (4th kup).

An interesting observation was made that in each of the examined athletes the time (Δt) between the peak velocity of the punching fist (v_A) and the peak velocity of the fist moving backwards (v_B) (fig. 2). That difference turns out to significantly affect the obtained peak velocity of the punch (r=-0.73) ($p<0.05$) (fig. 3). This dependence shows that the smaller the difference in time needed to obtain the speed v_a and v_b of the fists, the higher the velocity of the punch. Thus, the more precise the coordination of the movements of the limbs, the higher the peak velocity of the punch as well as the more powerful punch will be possible to be achieved [Ernst 1992; Wąsik 2009].

The observations made provide an opportunity to assume that the time needed to execute a punch is mainly affected by the distance which the punching fist must cover [Falco *et al*. 2009] and also the average speed of the punching fist. The speed which the punching fist develops depends on the acceleration which the fist achieves and also on the technique with which the movement is executed [Hay 1993]. The above data have also indicated that the speed of the punch is also affected by the difference in time Δt.

Sports competition system makes it possible to achieve mastery and development to one's maximum abilities. It prepares a competitor to perform to the maximum of his abilities. In a sports competition each movement which is not fast enough might result in losing a precious point, but in a real fight it might result in health damages. In anti-terrorist units it is often a split second that decides about life and death when it comes to taking down a criminal. That is the reason why in high-class fighters uncomplicated and simple but fully-controlled movements are observed. Being fast and precise these movements are well calculated in terms of time and space.

The punch is a means of gaining advantage over the opponent in taekwon-do, karate or in kick-boxing. Deep understanding of the importance of the means of action is an introduction to comprehending the clue behind the chosen way of acting. The ways of performing punches or dodges, and others (these, by practitioners, are referred to as techniques) are described in handbooks on specific combat sports. At present, however, both athletes and their instructors are becoming increasingly aware of the importance of optimisation of the technique of movement. Hence, biomechanical identification of movement is an important element of many research projects [Bae 1990; Bercades, Pieter 2006; Buchanan 2004; Gang *et al*. 2009].

This study attempts to indicate which elements affect efficiency of the punch in order to, according to the main idea of the biomechanics, achieve the

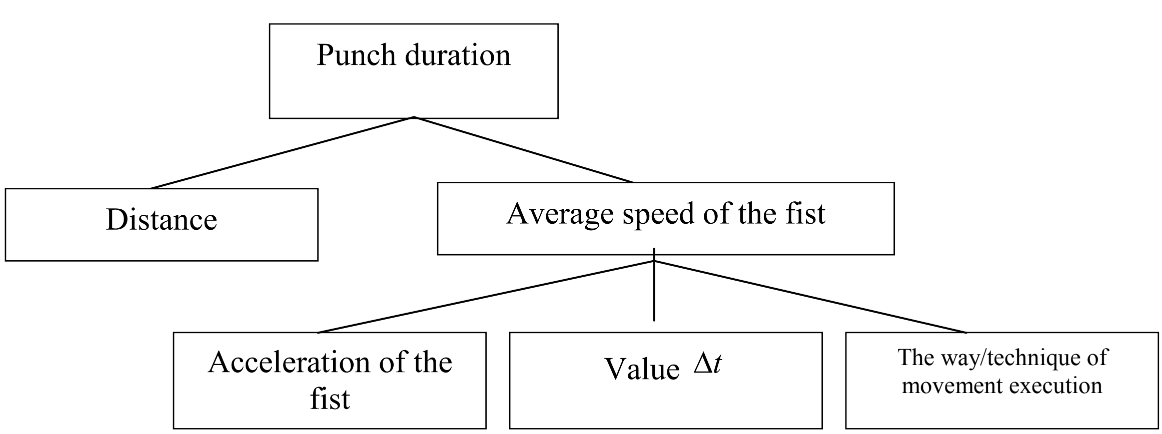

Figure 4. Diagram with the factors affecting punch duration

best movement parameters with the minimum work input. This study being only a small section of that problem does not exhaust the subject. The results and considerations presented herein can be used for comparative purposes for other studies and help to shape development of further research.

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Struktura ruchu i kinetyka tradycyjnego uderzenia prostego ręką: pomiary zawodników taekwon-do

Słowa kluczowe: analiza ruchu, kinetyka ciosu, biomechanika sztuk walki

Streszczenie

Głównym celem tych badań było poznanie kinetyki uderzenia prostego ręką oraz sprawdzenie jaki wpływ na prędkość pięści ma ruch przeciwnej ręki. Badaniom poddano 10 zawodników taekwon-do ITF (International Taekwon-do Federation). W trakcie badań stojąc w tej samej postawie startowej każdy z badanych wykonywał trzykrotnie tradycyjne uderzenie pięścią. Do badań użyto systemu do analizy ruchu włoskiej firmy BTS Spa o nazwie Smart-D. Rejestrację dokonano z dokładnością 0,3–0,45 mm. Zapisu dokonano z częstotliwością 120 Hz. Dla wszystkich tych wartości obliczono odchylenie standardowe przy użyciu MS Excel. Uzyskana średnia prędkość maksymalna pięści 8,88 ± 0,98 m/s, prędkość ręki przeciwnej -3,59 ± 0,67 m/s. Z przeprowadzonych obserwacji można przypuszczać, że na czas uderzenia wpływa: dystans, jaki ma pokonać pięść i średnia prędkość pięści. Wysoka wartość prędkości pięści zależy od przyśpieszenia, jakie jesteśmy w stanie nadać ręce, oraz od techniki wykonania ruchu. Badania dowiodły, że na prędkość uderzenia ma wpływ różnica w czasie między osiągnięciem maksymalnej prędkości ręki uderzającej i minimalnej prędkości ręki cofającej się do biodra ($r=-0,73$) ($p<0,05$).