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Influence of different versions of the straight forward punch on the obtained force, energy and power – measurements of taekwon-do ITF athletes' performance

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Abstract

Background and Study Aim. The aim of the study was the knowledge about the values of force, energy and power obtained during performance of the straight punch in two different techniques.

Material and Methods. 15 taekwon-do ITF (International Taekwon-do Federation) athletes were asked to participate in the study. They were asked to perform the traditional and sports version of the punch three times each. The research was carried out with the use of Smart-D system manufactured by Italian BTS Spa company and used for complex analysis of movements.

Results. The research shows that the average delivery time of 0.170 ± 0.007 s of the sports version punch is significantly shorter than that of its traditional version whose average is 1.060 ± 0.142 s ($p<0.01$). The kinetic energy of 2299 ± 320 J and force of 3284 ± 555 N were obtained in the traditional technique of the punch. The force of this strike is comparable to the force obtained in the roundhouse kick. The other technique (i.e. the sports one) obtained only 916 ± 60 J and 1308 ± 173 N ($p<0.01$). Thus, a greater force and a greater energy were obtained in the traditional technique. However, the calculated power of 5630 ± 247 W is considerably higher for the sports technique of the strike, which signifies a high pace of energy production (the traditional strike achieved only 2598 ± 283 W).

Conclusions. Having analyzed the obtained results it can be stated that the aim of a strike determines the way the strike is delivered. The traditional taekwon-do punch is used to perform mechanical work and produce a maximum kinetic energy, which is necessary for breaking, whereas the sports punch requires a short time of delivery, which gives great power, i.e. high rate of energy production. That is the reason why it is used in combat.

Key words: taekwon-do • analysis of movement • kinetics of punch • biomechanics of combat sports

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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 [1] 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 [2], Blum [3] and Walker [4] analysed the kinematic aspect of the strikes and process of breaking hard objects with bare hands. A continuation of that research was noted in the following years [5-8], when an attempt at describing a dynamic theory of strikes occurs together with a more comprehensive registration of strike kinematics.

Taekwon-do practitioners have a wide range of kicks at their disposal, thus most of the research is concerned with this kind of techniques [9-17]. However, some of the research on biomechanics of taekwon-do practitioners concentrates on the technique used by the upper parts of the body. For instance, Pieter and his colleagues [18] compared a straight forward punch performed from two different starting positions and suggested that a quantitative research was needed so as to obtain a better understanding of that particular technique. The punch executed from the front stance was examined with respect to the mechanical work being performed and the force obtained [19].

Efficient execution of strikes in combat sports is affected by a number of factors, including their force, energy, power, etc. However, it does happen that the terms of mechanical work, energy and power are not always appropriately understood by many specialists in the world of sport. For example, great *power* does not necessarily translate into a greater *force* of the strike, doing more harm to the opponent or breaking a higher number of boards. These effects are produced by *kinetic energy* and not *power*. Confusing these terms happens to lead to misunderstandings.

The terms of *mechanical work* and *energy* are closely connected with each other. It is rather apparent as these two have the same unit in the International System of Units (SI), which is [J]. In order to obtain energy, a certain amount of work needs to be done, or in other words, performed work provides energy. This relation is shown in equation (1) [20,21]:

$$W = mgh + \frac{mv^2}{2} \quad (1)$$

where: W – mechanical work, m – mass, g – gravity, h – height, v – velocity, mgh – potential energy, $1/2mv^2$ – kinetic energy

Equation (1) shows that the velocity of a fist, for example in a taekwon-do strike, at the very moment of making contact with its target is generated by work (W). If the direction of the thrown strike is horizontal (parallel to the floor), then the fist does not have gravitational potential energy, but only the kinetic energy. In such case equation (1) takes on the form of equation (2):

$$W = \frac{mv^2}{2} \quad (2)$$

This energy acts on an opponent or the target object. The right side of equation (2) shows that the kinetic energy, and thus the amount of the work done depends on the mass of the body (m) put in motion and the fist velocity (v) at the moment of making contact with the target. In order to present the force produced at the moment of an impact equation (2) can be rewritten in the form of equation (3):

$$F = \frac{m \times v^2}{2s} = \frac{E_k}{s} \quad (3)$$

where: E_k - kinetic energy, s – distance

Equation (3) shows that the force of the strike is directly proportional to the kinetic energy of the fist and inversely proportional to the distance, over which the kinetic energy will be absorbed. The acting force, which translates into potential damage done to the opponent or the object being broken might be increased by an appropriately adjusted distance for the intended impact aimed at an opponent or a target object.

According to the definition of power it is possible to illustrate it by dividing both sides of equation (1) by time t during which the work is done:

$$P = \frac{W}{t} = \frac{mgh}{t} + \frac{1/2mv^2}{t} \quad (4)$$

where: P – power, t – time.

In special circumstances equation (4) will take the following form (the strike being executed is parallel to the floor):

$$P = \frac{E_k}{t} \quad (5)$$

In a number of situations in taekwon-do or in karate efficiency is indicated by kinetic energy production, which is expressed in the right side of equation (4) [19]. As far the amount of kinetic energy is concerned it needs to be taken into account that it can be produced quickly or that it can also be produced slowly. The key assumption is that the power is determined how fast kinetic energy is produced (equation 5). Hence, the greater the velocity is, the greater the power is obtained, which can be clearly seen in equation (4). Equations (3), (4) and (5) show that a given amount of kinetic energy can be produced by a great force acting over a shorter distance or a smaller force acting over a longer distance. Using force over a longer distance usually requires more time so that the rate of kinetic energy transfer could be lower. However, according to formula (4) it will have less power.

The aim of this paper is to evaluate the values of force, energy and power obtained while executing a straight punch in two attempts and performed with the use of a different technique in each of the attempts. Having adopted commonly used criteria for sports technique biomechanical analyses [22], and the techniques used in taekwon-do in particular [23, 24], the following research questions have been addressed:

How do different punch patterns affect the kinematics of the strike?

Do the techniques used have biomechanical foundations for using them?

The answers to the above questions may contribute to selecting a more efficient method of executing this kind of strikes in taekwon-do sports events as well as in self-defence.

Material and Method

The study was based on 15 taekwon-do ITF (International Taekwon-do Federation) athletes comprising 5 female athletes and 10 male athletes whose average age was 16.5 ± 0.8 year, average weight was 64.1 ± 9.0 kg and average height was 176.5 ± 6.0 cm. The researched group included European Junior Champions, Polish Junior Champions and other athletes who had practised taekwon-do for a minimum of 3 years. Athletes and their parents agreed to take part in this study voluntarily. For the purpose of this study each of them adopted the same starting position and performed the straight forward punch three times in the traditional version and three times in the sports version, which gave a grand total of 60 strikes – 30 strikes in each of the two versions. Figure 1 presents the structure of those punches.

In the traditional version each athlete adopted the L-stance forearm guarding block (in taekwon-do terminology referred to as *niunja sogi palmok debi maki*) with the front right foot and performed the punch by throwing the left fist forward (in taekwon-do terminology referred to as a*p joomok jirugi*) [25,26].

In the sports version each athlete standing in a fighting posture with the front right foot executed a boxing-type punch with their left fist.

The 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.

The parameters, which were obtained from the markers located on the athletes' wrists, defining the space and time structure of the athlete's movements were analysed. This enabled the author to calculate the total punch duration, time needed to develop the maximum velocity and the maximum fist velocity. For all the values obtained mean values and standard deviation were calculated. The analysis of the differences between the mean values for the punches executed in the traditional and sports versions was done on the basis of t-test for two mean values at the significance level of $p<0.01$. The values of force, energy and power were computed on the basis of equations (1), (3) and (5). The errors for these values were computed with the use of exact differential. Statistical analysis was done with the use of MS Excel 2000.

Results

Figure 2 shows example curves reflecting the changes in fist velocities in time obtained for two types of the taekwon-do straight punch for one punch delivery of a given athlete: the punch in the traditional version (broken line) and the punch in the sports version (solid line). The punch in the sports version obtained the maximum velocity of 5.48 s and time of 0.175 s. The punch in the traditional version obtained the maximum velocity of 7.20 m/s and time of 1.392 s. Table 2 shows the mean values of the kinematic parameters affecting efficiency of the punch while Table 3 presents the computed dynamic parameters of the strikes.

Discussion

The research results confirm the theoretical expectations. The data presented in Table 1 indicate that the mean values of velocity and time for different variants of the straight punch execution are statistically

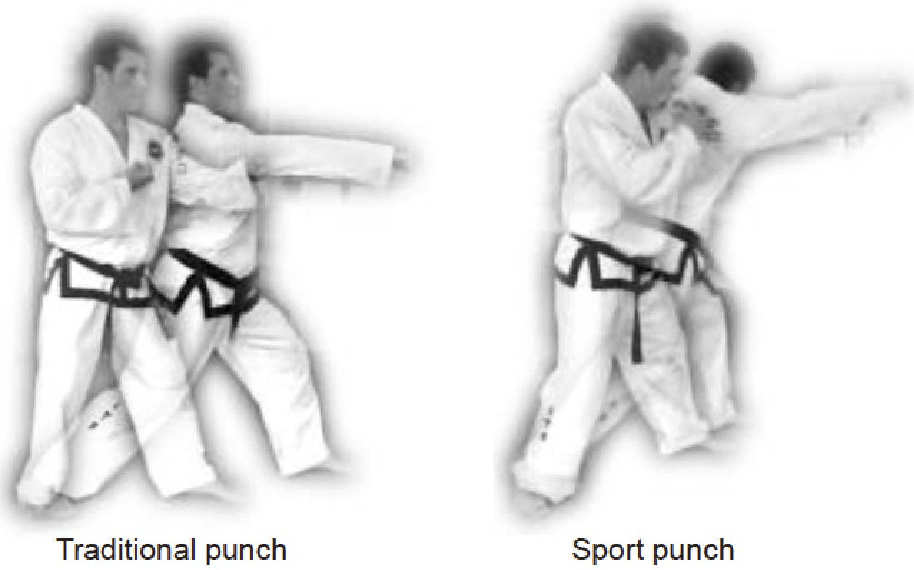

Figure 1. The structure of the movement in the traditional and sports versions of the punch in ITF Taekwon-do

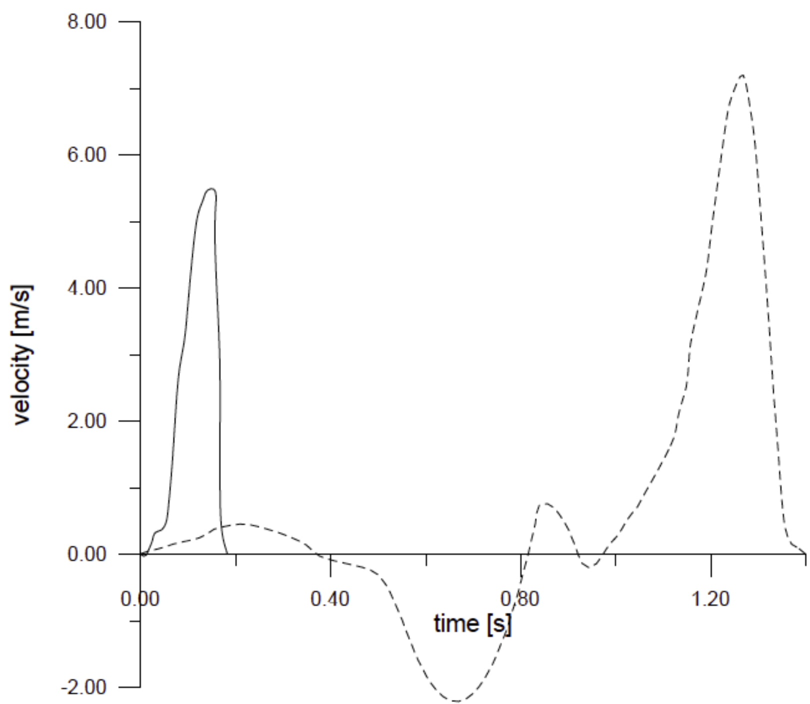

Figure 2. Example graph of fist velocity changes during execution of the straight punch: boxing style (solid line) and traditional one (broken line)

Table 1. Kinematic variables and indicators affecting efficiency of the punch

Variables and indicators	sports punch SD	Range	traditional punch SD	Range	p
Total punch duration [s]	0.170 ± 0.007	0.1590.182	1.060 ± 0.142	0.8301.330	p<0.01
Time needed to develop the maximum velocity [s]	0.162 ± 0.007	0.1521.75	0.884 ± 0.081	0.711.030	p<0.01
Velocity [m/s]	5.34 ± 0.32	4.895.92	8.46 ± 1.14	6.7110.52	p<0.01

Table 2. Calculated dynamic variables and indicators of the strikes

Variables and indicators	sports punch ± Dx	traditional punch ± Dx
Force [N]	1308 ± 173	3284 ± 555
Energy [J]	916 ± 60	2299 ± 320
Power [W]	5630 ± 247	2598 ± 283

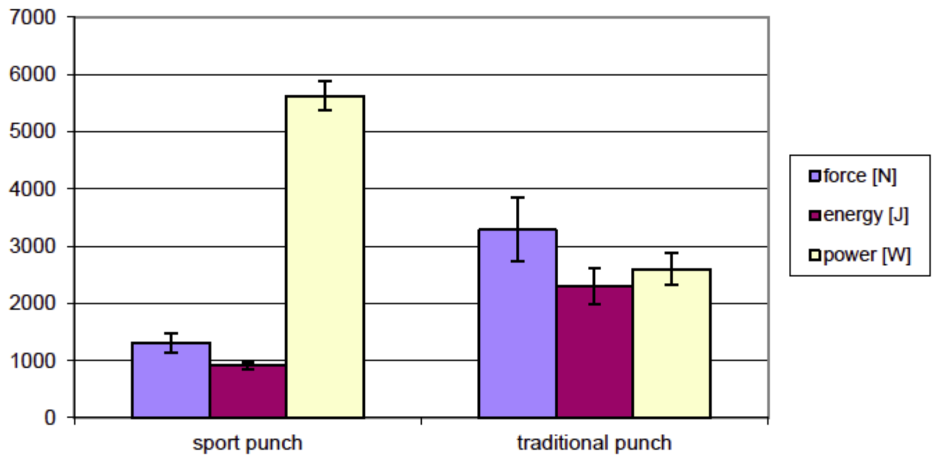

Figure 3. Dynamic parameters for the two versions of the straight punch execution

Figure 4. Athletes' opposite priorities

different ($p<0.01$). This makes it possible to draw a conclusion that the traditional version of the punch used in Taekwon-do ITF allows an athlete to achieve greater maximum velocities with an average of 8.25 ± 1.30 m/s than its sports version with the velocity of 5.38 ± 1.24 m/s. However, the duration of the sports strike proved to be shorter and its mean value was 0.170 ± 0.007 s, whereas the time of the traditional one was 1.060 ± 0.142 s.

The velocity values obtained in this research can be compared to the results obtained in other research studies. The sports version punch achieves velocities comparable to the ones obtained in the side kick [5], and the velocity of the traditional punch is comparable to the velocities obtained in traditional strikes delivered by karate athletes [6]. Moreover, it is greater than the velocity of the spinning kick and smaller than the velocity of the roundhouse kick performed by taekwon-do athletes [13].

Figure 2 shows the theoretical values of energy, force and power obtained in the two different versions of the straight punch execution. The traditional punch developed kinetic energy of 2299 ± 320 J and force of 3284 ± 555 N. The force of this strike can be compared to the force obtained in the roundhouse kick [9]. The other version of the punch obtained only 916 ± 60 J and 1308 ± 173 N. Thus, it was the traditional strike than managed to develop greater force and energy. However, the calculated power of 5630 ± 247 W is significantly greater in the sports version of the punch, which means a high rate of energy transfer (the traditional punch obtained only 2598 ±283 W).

The two punch versions discussed herein have biomechanical foundations for using them in Taekwon-do ITF sports events, namely in sparring and power tests involving breaking boards [25, 26]. In light contact sparring the objective is to score points. In order to increase one's efficiency it is imperative for an athlete to react as quickly as possible as the objective is not to knock-out an opponent, but to "touch" him/her and score a point. This is connected with producing strikes having great power. On the other hand, breaking boards or other objects is a situation in which reaction time is not of a great importance as the priority involves delivering the maximum kinetic energy to the object at the moment of the strike so that the greatest amount of the work is done on the object being struck.

These two versions of the punch reflect the opposite priorities of sports combat practitioners, which is shown in Figure 4. The priority of obtaining the greatest force is on one end and the priority of the reaction time on the other. The force priority is important when there are no time limitations and the action is aimed at producing the maximum kinetic energy. The reaction time priority results from a strict time limit, when the action is aimed at producing an immediate response.

In many self-defence situations or in full contact sparring these two priorities are often confused. The main dilemma usually faced is whether to strike once with a maximum force according to once-only-opportunity rule [27] and take the risk of losing control over the body in case of a block or a dodge, or whether to reduce the energy of the strike at the cost of an immediate response. In such situation the dilemma of developing the maximum energy at the cost of a short response time might become the very difference between life and death.

The research results and considerations presented in this paper can be used for comparison in other research papers or become a springboard for further research.

Conclusion

Summing up it can be concluded that the set objectives determine the strike movement patterns. They confirm that different versions of the straight punch execution must be analysed in terms of the set priority of a strike. The traditional taekwon-do strike is meant to produce the maximum kinetic energy, which is necessary for breaking objects, whereas the sports strike needs a very short reaction time, but it generates great power, i.e. the rate of energy production; thus it works best in combat situations.

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