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## THE PHYSICAL BASES OF BRAKING HARD OBJECTS IN TAEKWON-DO

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The sight of a human braking hard objects with his hands or feet is commonly associated with martial arts. A sight like that may often be perceived as a sign of super-human abilities. Power braking is one of four sport competitions of Taekwon-do ITF. Therefore the search for new solutions will enable to achieve above average results. It is possible that the forces occurring during the power braking tests may be ten times higher than the weight of the competitor. How is it possible that our body is able to withstand these forces? Where can we look for ways of braking even more wooden boards? The thing that separates Taekwon-do from other martial arts is its Theory of Force, which consists of the following factors: weight, speed, balance, concentration and breath. The two first of the mentioned factors are typically scientific but the following factors may also be described by scientific methods. Balance is the result of correctly set specific weight of the competitor. Concentration in other words the focus of a punch, this association with optics is justified due to the resemblance between the focus of light and the focus of force during the power braking test. Breath can be described by the mechanics of gases. Every person that studies Taekwon-do will at some point of their carrier come across the problem of braking hard objects. This thesis contains the scientific analyses of braking hard objects and boards that are suspended.

*Key words:* Taekwon-do, power braking.

The sight of a human braking hard objects with his hands or feat is commonly associated with martial arts. A sight like that may often be perceived as a sign of super-human abilities. Power braking is one of four sport competitions of Taekwon-do ITF. Therefore the search for new solutions will enable to achieve above average results. It is possible that the forces occurring during the power braking tests may be ten times higher than the weight of the competitor. How is it possible that our body is able to withstand these forces? Where can we look for ways of braking even more wooden boards?

The competition of Taekwon-do according to ITF (International Taekwon-do Federation) is a quadrotlon and consists of: patterns, sparring, special techniques and power braking. Each of this, events is conducted in individual and team categories,

both for male and female competitors. Teams consist of 5 competitors plus one additional competitor as reserve in case of an injury.

The sport event of power braking tests the strength of competitors, based on the amount of standardized wooden boards (30x30cm 2cm thick) that the competitor is able to break, the boards are placed in a special machine that secures the same braking conditions for all competitors. For braking 1 board referees award 2 points, in case of fracturing the board without completely breaking it referees award 1 point. The event of male power braking consists of the following tests:

1. Ap Jumok Jirugi (fist punch).
2. Sonkal Yop Terigi (open hand punch).
3. Yopcha Jirugi (side kick).
4. Dollyo Chagi (round-house kick).
5. Bandae Dolyo Chagi (reversed round-house kick).

Female power braking consists of the following tests:

1. Sonkal Yop Terigi.
2. Yopcha Jirugi.
3. Dollyo Chagi.

The winner is appointed by adding points awarded to all team members. In case of a draw the competitors choose one of the tests and perform one additional test.

What influences the dynamic force of a human being from the scientific point of view?

The thing that separates Taekwon-do from other martial arts is its Theory of Force, which consists of the following factors: weight, speed, balance, concentration and breath. The two first of the mentioned factors are typically scientific but the following factors may also be described by scientific methods. Balance is the result of correctly set specific weight of the competitor. Concentration in other words the focus of a punch. This association with optics is justified due to the resemblance between the focus of light and the focus of force during the power braking test. Breath can be described by the mechanics of gases.

Every person that studies Taekwon-do will at some point of their carrier come across the problem of braking hard objects and will wonder where to gain the strength needed to successfully complete such a test. As we all know, according to Newton's theory, the force of an object is directly proportional to its mass and acceleration.

$$F = m \cdot a . \quad (1)$$

While conducting an elementary analyses, we can observe the following relation between mass and acceleration. Starting with the formula for the distance constant accelerated motion:

$$s = v_0 t + \frac{at^2}{2} \text{ knowing that } a = \frac{\Delta v}{t} \rightarrow t = \frac{\Delta v}{a} \text{ one can observe that } a = \frac{2\Delta v^2}{s},$$

$$F = m \cdot \frac{2\Delta v^2}{s}, \quad (2)$$

Assuming that the distance of the fist for a particular human is constant and does not change in a significant way, velocity is the most important factor influencing the force.

One can observe the same results when analyzing the formula for kinetic energy:

$$E_k = \frac{m \cdot v^2}{2}. \quad (3)$$

How is it possible for a human to break wooden boards ?

Let us try to estimate the forces accruing during the power braking tests. Let us concenter a punch trying to break a wooden board shown on the drawing 2. Described by the formula (2).

Assuming that, the fist of “m” mass and “v” velocity stops completely after the test. Therefore the change of velocity  $\Delta v$  is equal v.

Let us consider the test of Ap Jumok Jirugi (fist punch). The punching mass: the arm (2,5% of total body weight), the forearm (1,6% of total body weight) and the punching fist (0,6 of total body weight). For a competitor weighing 60 kg we assume that the total braking mass will be (1,6 kg + 1 kg + 0,4 kg) 3 kg, and it's velocity will be very high , about 5,5 m/s (drawing nr 1). This theoretical simulation is not able to show the full force of the punch due to the fact the competitor during the test uses more then just the mass of his arm, and it is imposible to estimate what percentage of his body weight is involved in this process, hens this simplification.

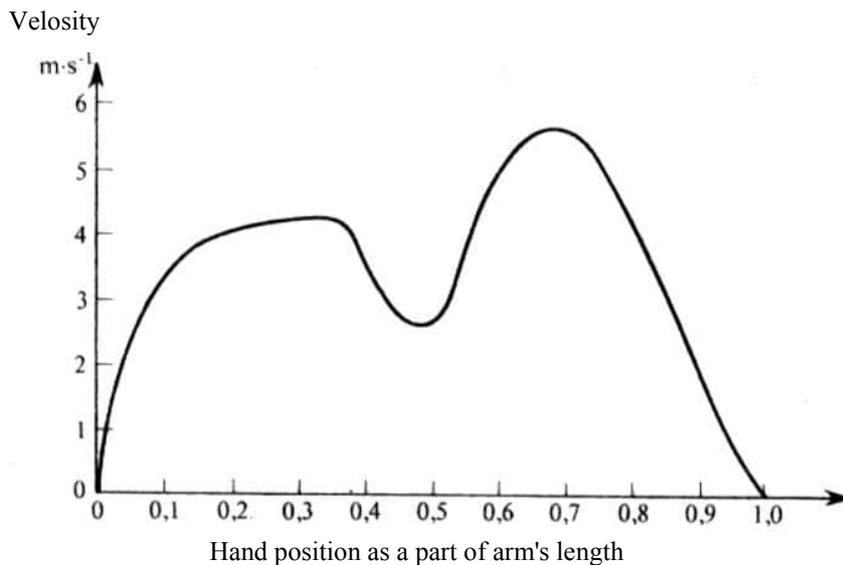


Fig. 1. The results of J.D Walker, American Journal of Physics. The fist achieves its maximum velocity when it is 70% stretched

Assuming that the arm of the competitor is 64 cm long, and the test beiges from his belt line which is 44 cm from the shoulder the distance of the fist can be easily calculated with the help of the Pythagoras equation and in this case is 63 cm. Therefore the force equal 2880 N and energy 8,25 J.

In some physics handbooks one can find the resistance capabilities of some materials, very often they are different for the same materials. This is the result of the way in which the test sample is prepared, wooden boards can be cut in different ways and concrete can be made with the same ingredients but in different

proportions. Therefore the force and energy needed to break a standardized concrete plate or a wooden board is different each time.

Table 1. wg [1]

	Wood	Concrete	Bone
F [N]	670	3100	5400
E <sub>k</sub> [J]	5,3	1,6	14

Table 1 contains the minimum of force and energy needed to destroy the mentioned materials. It is possible to see that even a relatively small person is able to break a wooden board. The same conclusion can be uttered considering the energy of the hand. What is more the force produced by the human hand is able to break more than one wooden board.

Based on the table 1, one can conclude that the minimum force needed to brake a concrete plate is 4,6 times bigger then the minimum force needed to brake a wooden board, which is not very surprising. But the minimum energy is 3 times lower in case of concrete, and it would suggest that in fact it is easier to break concrete then wood. This result comes from the fact that the given amounts of energy are needed to be delivered to the object in order to destroy it not the amounts of energy given by the competitor during the test. Concrete has the bigger capability dampening vibrations then wood. So in this case only a part of the energy is transferred, the amount of transferred energy depends on the material itself the mass of the competitor and the mass of the object.

Table 1 also contains the answer to the question: why doesn't the competitor sustain any injuries during the test? It is shown that the human bone is much more resistant to injury then concrete.

The correct positioning and setting of the fist is of great importance. According to formula nr 5, describing the pressure applied on the surface, the smaller the surface touching the object the bigger the pressure.

How can we break an unsupported object?

During martial art shows sometimes the competitors demonstrate the braking of objects only suspended with no device holding or supporting them. How is it possible that these objects can be broken.

Violent changes of the velocity are, according to the second Newton's principal of dynamics, accompanied by inertial force

$$F_b = -\frac{m(v_2 - v_1)}{t}, \quad (4)$$

$m$  – mass of the object,  $v_2 - v_1$  – the difference of velocity,  $t$  – time in which the velocity changed.

Inertial force, will substitute the machine holding the object during the test. As one can observe, based on the formula nr 6, the bigger the velocity of the attack, the bigger the inertial force of the object. So the object will be destroyed if:

$$F_c - F_b > F_{\min} \quad (5)$$

$F$  – Force of the attack,  $F$  – inertial force,  $F$  – the minimal force needed to destroy the object.

Various aspects of different techniques and their effects have been discussed, mainly those concerning the destruction of objects. Using the uttered conclusions, for example in the field of sport competition like power braking, can bring visible effects. The presented conclusions can show how dangerous these kinds of techniques can, be for a human being. The tradition of Taekwon-do assumes the strive for ethical and technical perfection. One can achieve grate respect in this environment by achieving good competition results, or displaying ones extraordinary capabilities by breaking several bricks.

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## **ФІЗИЧНІ ОСНОВИ ПРОТИДІЇ СИЛЬНИМ ВПЛИВАМ В ТЕЙКВОНДО**

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У статті проаналізовано фізичні основи чинників теорії сили, які покладені в основу бойового мистецтва тейквондо та визначають здатність людини протистояти сильній зовнішній дії, а саме – вага, швидкість, баланс, концентрація та дихання.

*Ключові слова:* тейквондо, зусилля протидії.

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