Original Article

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The influence of effective distance on the impact of a punch - Preliminary Analysis

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Abstract

Introduction: Distance between competitors in fighting sports and their target have an influence on kinematics of motion and as an consequence, its effectiveness. Therefore, the aim of this study is to extent the knowledge about influence of effective distance affects velocity of an object after hit. *Material and Methods:* Analysis were performed based on captured data of a male competitor with black belt in taekwondo (age: 20 yrs., body mass: 65kg, height: 171 cm). During data capturing, he performed sport punch strike 3 times with his left upper limb, and 3 times with the right one. The target was a ping pong ball. Data capturing was performed in HML (Human Motion Lab). *Results:* Velocities of sport punch strike were in range from 6.20-8.01 m/s. Significant increase in passed momentum to the object were in-between 1.12-1.73% of effective distance. However, when effective distance were in-between 3.70-3.95%, there were significant decrease (nearly half) in velocity of hit object. *Conclusions:* Our findings allows to formulate assumptions for further analysis, which states, that when maximum velocity of a punch occurs closer to the moment of hitting a target (Δd), the higher it will be in a moment of that hit ($r=0.95$; $p<0.01$). Therefore, it allows to assume, that the lower will be a value of Δd, the higher will be destructive force for target (ΔE).

Keywords: impact punch, biomechanics of martial arts, distance, taekwon-do

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INTRODUCTION

In many martial arts it is crucial to be able to make a contact with objects on optimal force. Ability to perform using maximum destructive force is necessary during breaking hard objects on the shows, in full-contact formula of competition or in extreme situations in self-defence. For combat sports, such as point fighting or light formula in kick-boxing or in taekwon-do ITF (International Taekwon-do Federation), it is forbidden by the rules, to hit opponent with uncontrolled force [1]. Therefore competitors needs to dose a value of hitting force in order to win. That is a reason, why distance between competitors or hitting target (material object) is important variable, which needs to be taken into account during analysis of hitting effectiveness.

Correlation between force and velocity is characterized by lower production of force in quasi-linear connection to a velocity during multi-joint motion [2]. It was noticed, that there is no significant difference between velocities of straight punches for boxers in different weight categories [3]. However, there were differences between force values of those punches. It was assumed, that there is strong correlation between velocity of a strike and effective mass which goes behind it.

We know, that for combat sport competitors, distance to a target affects kinematic of motion and as a consequence, its effectiveness [4]. Recent findings indicates, that velocity, distance and time are the essence of martial arts [5]. Distance is a main factor reffered to a effective training of martial arts [6]. Distance have an influence on general changes in forces and momentum, which allows us to assume, that its depends on velocity of extension of limbs and their alignment before hitting a target. It was noticed, that hits from bigger distance can generate more force than those from short distance [6,7].

Analysis of strikes kinematic shows, that their velocity is increasing gradually, to eventually reach maximum value at some characteristic point, and then its values drops (usually suddenly) [8]. Product of mass and velocity is called momentum. Momentum could not be created or destroyed, it could be only passed [9]. Therefore, to pass the highest momentum, there is crucial to hit the target with the highest possible velocity. Moreover, physics law said, that force is derivative of momentum in time.

The unknow is, how stroked object is changing his velocity, depending on a distance. For that reason, new term “effective distance” (Δd) was created. It is characterized by distance between occurrence of maximum velocity of the punch to a moment of collision with the target, set in percentage value of a length of a limb. Analysis of this aspect will allow to discuss about effectiveness of taekwon-do competitor, who perform straight punch technique (in terminology of taekwno-do: *ap joomok jirugi*). This motor competence may increase effectiveness of teaching methods of effective striking, with correct distance and dosed strength.

MATERIAL AND METHODS

Analysis were performed based on captured data of a male competitor with black belt in taekwondo (age: 20 yrs., body mass: 65kg, height: 171 cm). During data capturing, from side standing position (according to the terminology of taekwon-do: niunja sogi palmok debi maki), he was performing the traditional straight punch (ap jumok jirugi). The stance is characterized by being in the front to the target, with one leg on the front (from the same side as non-striking upper limb), and other in the back (the same side as striking upper limb). The initial position of striking hand is with clenched fist stick to a side of a trunk and bended in elbow joint. Strike is performed by extending elbow joint while fist is closing to a desired target. The movement end before full extension in elbow joint. Two circumstances were analyzed. First, when strike were performed into the air (no physical target) and second into a ping pong ball which was hung from the ceiling. There were three strikes for two circumstances, for each upper limb.

For the purpose of this research motion analysis lab HML (Human Motion Lab) was used. The facility included ten NIR Vicon MX-T40 cameras with the resolution of 4 MP (2352 x 1728 px) as well as 10-bit grayscale. The system have registered data with accuracy of 250 frames per second. The measurement space has a cylindrical shape of the ellipsoid height with the height of 3 m and on the basis of the axes 6.47 m, 4.2 m. Indicators registered structure of spatial-temporal motion of marker placed on the fist, specifying its position changes as a function of time.

Using this method, resultant maximum velocity of the fist and a ball after being hit was computed. Then difference in time (Δt), effective distance was computed, which states for distance between reaching maximum velocity of a fist to its contact with the target (figure 1,2).

The Human Subjects Research Committee of the University scrutinized and approved the test protocol as meeting the criteria of Ethical Conduct for Research Involving Humans. All subjects in the study were informed of the testing procedures and voluntarily participated in the data collection.

RESULTS

In table 1, there is presented a computed maximum velocities during straight punch and maximum velocities of a ball after contact with the fist, for both hands. Additionally, differences in time and effective distance (in percent) were computed. For each hand, the highest maximum velocity was performed at the third trial, and the lowest at the second. The highest effective distance value were shown in first trial, and the lowest at the third one. Figure 1 and 2 shows graphical presentation of changes in velocities of fist and a target (ball), depending on a velocity of a fist in a moment of contact with target. The right moment of a contact of the fist with a ball is connected with higher and faster increase of velocity of a target after a contact. Figure 3 shows linear regression between maximum value of object after contact with fist and effective distance (Δd).

Table 1. Chosen kinematic indicators for straight punch.

Upper limb	Number of trial	Max velocity of First [m/s]	Max velocity of Ball [m/s]	Δt [s]	Δd [%]
Left	1	6.90	4.76	0.028	3.70
	2	6.20	7.98	0.016	1.63
	3	8.01	9.91	0.008	1.12
Right	1	6.84	3.50	0.040	3.95
	2	6.23	6.75	0.020	1.73
	3	7.40	9.30	0.008	1.36

Δt – time between an occurrence of maximum velocity of a fist and a moment of contact with target; Δd –effective distance, which states for distance between occurrence of maximum velocity of the punch to a moment of collision with the target, set in percentage value of a length of a limb.

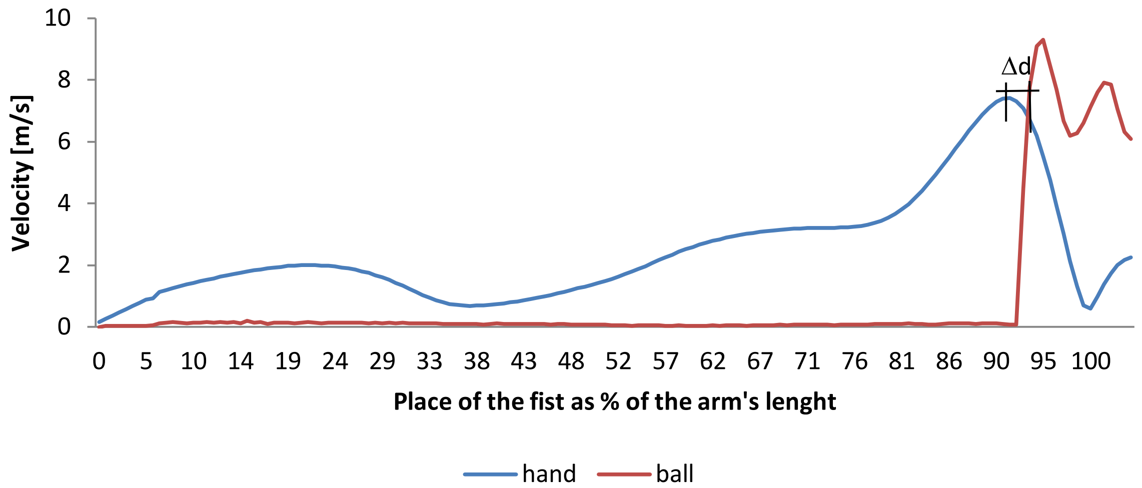

Figure 1. Example of a graph, presenting changes of velocity of a fist (blue line) and ping pong ball (red line) before and after a contact, when effective distance does not exceed 1.5%.

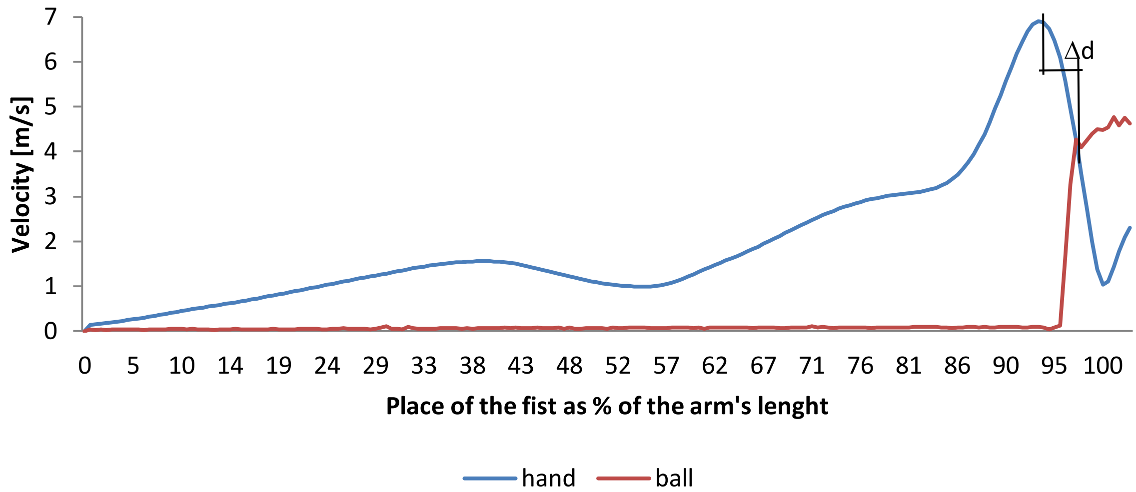

Figure 2. Example of a graph, presenting changes of velocity of a fist (blue line) and ping pong ball (red line) before and after a contact, when effective distance exceed 3%.

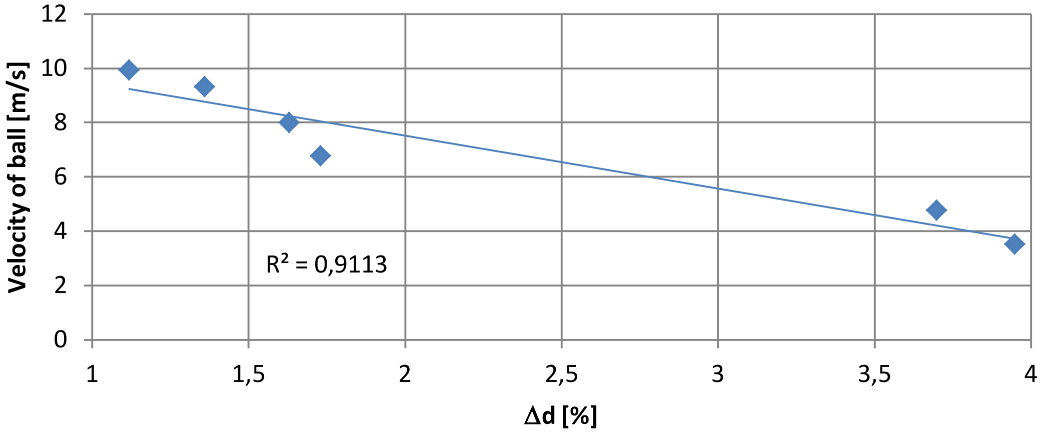

Figure 3. Graph presenting linear regression between maximum velocity of a ping pong ball and distance of reaching maximum velocity of a fist to a moment of contact with target (Δd [%]) ($p<0.01$).

DISCUSION

After conducted research, we can conclude, that adequately adjusted distance during straight punch have significant influence on passed velocity for stoke object. Computed velocities of a straight punch are in range of 6.20-8.01 m/s. This corresponds with results of other research [10], but in scientific papers it is possible to found higher values [11,12]. However, it needs to be taken into account, that differences might came from margin of error of capturing devices.

In this research, there is shown significant increase of a momentum passed to target occurs in a values of 1.12 to 1.73% of effective distance (figure 1). However, when its values reach up to 3.70-3.95% Δd, there was sudden decrease in velocity of a ping pong ball after a contact of fist comparing to lesser values. Therefore, inappropriately adjusted effective distance during a straight punch could gravely affects its effectiveness. This difference is very low (2,5% Δd and 0.003 s). Then, ever slightest differences could be essential for effectiveness of a strike. It is worth highlighting, that highest differences were shown during first strike, and the third strike was faster for both hands. Moreover, the second strike was slowest. Competitor could observe how the ball is behaving and then he had feedback about effectiveness of his strike. So each time he made correction, reducing effective distance, but in the second strike, lower % Δd was traded for maximum velocity. The third strike was with both maximum speed and correct distance. This correction may come up with both experience and learning process.

Walker [13] states, that Energy used in purpose of damaging or deforming collided object is true to followed dependence

$$\Delta E = \frac{(1-e^2)mMv^2}{2(m+M)}$$

where: ΔE – Energy is used for damaging or deforming colliding object; e – coefficient of elasticity; m – effective mass of a limb; M – mass of collided object.

From the equation above we can conclude, that velocity in a moment of contact with object is significantly affects energy used for damaging or deforming of collided object. Our findings shows, that the lower is a value of Δd, the higher will be a value of velocity of the fist in a moment of contact with object (Figure 3). Then we can assume that value of Δd will be inversely proportional to a value of destructive force (ΔE).

Third Newton's law of motion states, that when one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body. That is why correct distance is crucial, as destroying a target or damaging our own body is depended on it. Then, this topic is also important in terms of injury prevention in martial arts and combat sports.

In theory of combat sports there is a low of only on possibility [14]. It states, that in extreme cases, one strike could decide on life and death of a man. Correctly adjusted distance could increase a chances and possibilities of a competitor of combat sports. In the preventive actions, policeman and security guards in many cases is not allowed to use maximum destructive force. His task is to immobilize, not to kill. Optimization for a value of striking force could be achieved by controlling a distance to consciously decrease a striking force.

Presented issue of influence of effective distance on effectiveness of a strike corresponds well with the principle of „maximum gain from minimal effort". Adequately adjusted distance is connected with anticipation. Through anticipation it is possible to program proper technical actions in a sports fight and to correct them depending on the changing conditions of a contest [15,16].

CONCLUSION

Presented findings allows to formulate assumptions for further analysis, which states, that when maximum velocity of a punch occurs closer to the moment of hitting a target the higher it will be in a moment of that hit. Skilled martial arts athletes use pre-release information to facilitate early and appropriate body positioning. The kinematic movement pattern of the opponent is also used to coordinate the adequately adjusted distance , timing and movement. We have a hope, that our considerations in this paper will contribute for better and full understanding of factors, which have influence of kinematic of striking upper limb. Presented results and consideration could serve as a frame of reference for other researchers and could set the aim for further research in interdisciplinary approach.

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