Analysis of Direct Punch in Professional Defence Using Multiple Methods

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***Abstract*— This article is focused on a complex analysis of a direct punch. The direct punch is only one technique in a complex system – a professional defence. The professional defence is a necessary part of a physical protection, which is a basis in every security system. During this research, several methods were used for the measurement of velocity, force, body movement, etc., during a punch. The main goal was to find out the most significant characteristics of a direct punch. The second goal was to find some dependencies among groups of people with different training level in professional defence. Some parts of these experiments were published in the past, but this article contains the results of all the methods used.**

Keywords- direct punch; professional defence; complex analysis; velocity; force

I. Introduction

The direct punch is one of the basic elements of the majority of martial arts, sports and systems [1][2]. In professional defence, the direct punch is used to stop an attacker and to increase the distance between the defender and the attacker.

The direct punch (Figure 1) is delivered by the arm following a direct line. The hitting area is a closed fist [4]. In the following experiment, the punch was delivered by the back hand.

Figure 1. Direct punch [3]

The professional defence [5] is a field which is primarily focused on the legal protection of personal interests against an attack. It covers various areas - the theory and the practice of defence, attack and prevention, scientific disciplines such as the tactics (e.g., skill in the counter attack), the strategy (the precautionary action) and the operation (the behaviour after a conflict situation). Moreover, it includes the knowledge of somatology and the chosen parts of crisis management, especially the phases of the conflict and solutions to conflict situations [5]. The professional defence is a necessary part of a physical protection, which is a basis in every security system. Without good quality physical protection, we cannot have effective security technologies and whole security system. The professional defence is the protection of client's interests against the attack. The motivation is a salary, because it is a full-time job. On the other hand, a self-defense is the protection of our own interests against the attack. We can help other person too but our motivation is not the salary but a justice and a willingness of the help.

The aim of this article is to describe the complex analysis of the direct punch. This study took five years and, during this time, five methods of measurement were used – the measurement of the velocity (camera Olympus i-Speed 2) [6-8], the measurement of the force (strain gauge type SRK-3/V and strain gauge L6E-C3-300kg) [3][9][10][11], the measurement of the body movement (system VICON) and the measurement of the local muscle load (EMG = Electromyography). The second aim is to find some dependencies among groups of people with different training level. All results from each experiment are published together in this article in separate sections.

During our study, the strain gauge type SRK-3/V suffered from many errors [12]. That was the reason why it was replaced by strain gauge L6E-C3-300kg. The results for the first strain gauge are not presented in this article because the data was corrupted, therefore irrelevant.

In Section 2, the measurement of the velocity is described. Section 3 presents the measurement of the force. Next, in Section 4, we describe the measurement of the movement during the direct punch. In Section 5, we divided people into four groups according to their training level. In Section 6, the results and the most important graphs and tables are presented. We conclude in Section 7.

Our motivation is a lack of research in this area. In Czech Republic, prof. Straus [13] did the similar research with less people and with help only one method of the measurement. In the world, this area has less quality research and articles.

II. Measurement of Velocity

A high-speed camera Olympus i-Speed 2 [14] was used for measuring of velocity. This camera had a CMOS 800x600 sensor, full resolution recordings to 1000 fps (fps = frames per second) and 33000 fps maximum recording speed [15]. We used a recording speed of 1000 fps [8].

The measuring station (Figure 2) consists of a punching bag and a construction of its suspension. A paper with two perpendicular lines was stuck on the right of the punching bag. The horizontal line was for leading the hand during movement. The aim of the vertical line was to determine the beginning of data analysis. The result was that all direct punches were measured in the same distance from punching bag. This distance was 60mm. The end of the measuring was at the moment when the movement of the hand stopped on axis “x” – the deformation of punching bag was at the maximum [6][7][8].

Figure 2. Measuring station with camera [8]

A total of 61 participants took part in the experiment; 48 men and 13 women.

During the experiment, each person made one, two or three strikes. During the measurement, the target was positioned in such manner that the center of the punching bag was in line with the striking person´s shoulder. That way the punches have the maximum velocity and force (as there is no decomposition of force or velocity into the other axes). The person was made to stay in the same place for the whole experiment. Any unnecessary movement (e. g. lunge etc.) would lead to data distortion [8].

III. Measurement of Force

The strain gauge sensor L6E-C3-300kg (Figure 3) works as unilaterally cantilever bending beam [10]. During force delivery, the biggest deformation of sensor is in places with the thinnest walls – there are metal film strain gauges which change their electrical resistance depending on deformation. Strain gauges are plugged in Wheatstone bridge and this way it is possible to convert the difference of resistance to an electrical signal which we can processed [10].

Figure 3. Strain gauge sensor L6E-C3-300kg [10]

The sensor is connected to the computer, which is used for data storage, through the strain gauge. The strain gauge type TENZ2334 is an electronic appliance that converts the signals to data that is stored in memory. The core of the appliance is a single-chip microcomputer that controls all of the activities. The strain gauge sensor is connected to this appliance via four-pole connector XLR by four conductors. The number of values measured by the sensor averages around 600 measurements per second while the data is immediately stored in the memory of a device with a capacity of 512 kB [5].

The strain gauge sensor mentioned above was placed on the measuring station according to the following schematic (Figure 4):

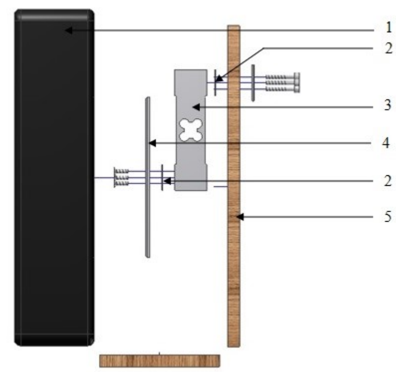

Figure 4. Measuring station schematic [10]

1 – punching bag (made from hardened vinyl filled with foam)
2 –template
3 – strain gauge sensor L6E-C3-300kg
4 – board (200 x 200 x 5 mm)
5 – punching bag base

A total of 220 participants took part in the experiment; 192 men and 28 women. All participants were between 19 and 25 years of age. During the experiment, each person made ten strikes.

IV. Measurement of Movement During Making of Direct Punch

The aim of this experiment was to visualize body movement during making of the direct punch. The system VICON, which is located in University Hospital in Brno (Figure 5), was used for this experiment. The laboratory is equipped with 8 video cameras (in height 1,4 m – 2,5 m) and illuminated by rings radiating infrared light with wavelength of 780nm. Retro-reflexive markers and infrared light allow scanning of the whole trajectory of motion with accuracy of few hundredths of a millimeter. The type of cameras used was MX20+ with the resolution of 1600 x 1280 pixels and the frequency of 120 fps (frames per second).

Figure 5. Preview of VICON laboratory

Special markers (retro-reflexive markers) were placed on selected body parts (Figure 6).

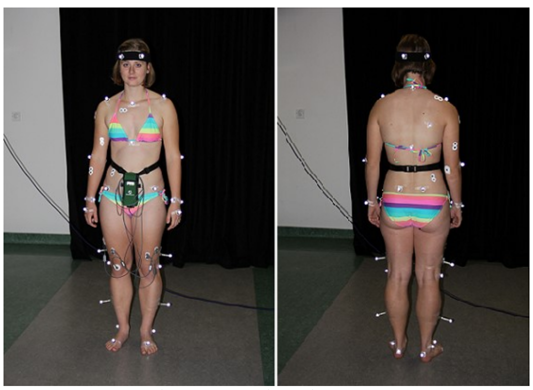

Figure 6. Marker placement

During this experiment, a local muscle load was also measured with the help of EMG. The main hypothesis is that the level of training affects the utilization of individual muscles. The better trained person uses more muscles and makes the technique more effective. EMG is used in medicine, but it can also be used for measuring a local muscle load. An eight-channel EMG (3000 Hz) was used and it was connected to great muscles via electrodes. The monitored muscles were (Figure 7):

- *M. palmaris brevis* (1)
- *M. biceps brachii* (2)
- *M. triceps brachii* (3)
- *M. deltoideus, spinal part* (4)
- *M. trapezius* (5)
- *M. pectoralis major* (6)
- *M. latissimus dorsi* (7)
- *M. obliquus externus abdominis* (8)

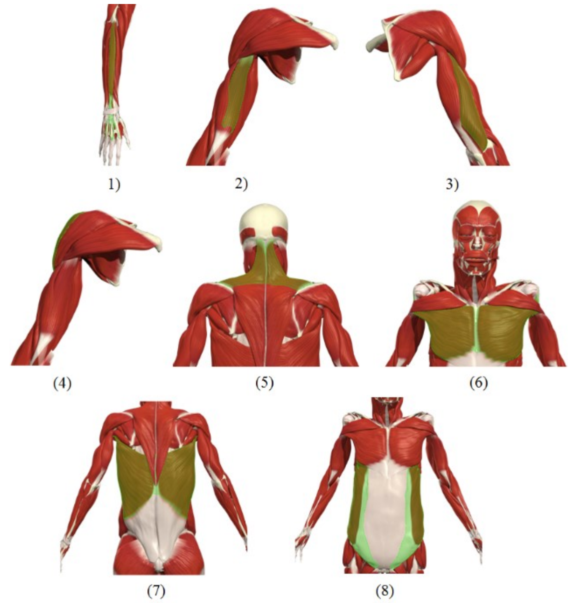

Figure 7. Monitored muscles

The experiment was performed with 21 participants: 15 men and 6 women in age of 19 – 30 years. Each direct punch was performed 10 times in a row.

V. GROUPS OF PEOPLE

These experiments were done at Tomas Bata University in Zlin and in University Hospital in Brno. Most people who participated in the experiment were students from 19 to 30 years of age.

Based on previous training and experience, the participants were divided into the following categories [3][6][7][8][9][10][11][12]:

- Untrained – These people have never done any combat sport, martial art or combat system. They had no theoretical knowledge of the striking technique. The technique was presented to these people before the experiment for safety reasons. Noted further as UTM (for men) and UTW (for women).
- Mid-trained - These people had the theoretical knowledge of striking techniques and did attend the Special physical training course for at least six months. The course was focused on self-defence and professional defence. Noted further as MTM (for men) and MTW (for women).
- Trained – These people have attended the Special physical training course for two or more years or practiced a combat sport or martial art for the same time period. Noted further as TM (for men) and TW (for women).
- Self-trained - These people did practice or still do practice (for less than 2 years) some combat sport, martial art or combat system. As there is no

guarantee of the quality of the training they are separated into their own category. Noted further as STM (for men) and STW (for women).

TABLE I. NUMBER OF PARTICIPANTS

Methods of measurement	Total number of participants	Men	Women
Measurement of velocity	61	48	13
Measurement of force	220	192	28
VICON + EMG	21	15	6

A different number of people participated in each experiment (see Table 1).

VI. RESULTS

In this section, the results will be presented with the help of graphs and tables. The aim was to show the most important and interesting results.

During the data analysis, two pieces of software were used – MINITAB and Microsoft Office Excel.

A. Results from the measurement of the velocity

Figures 8 to 10 depict the dependencies of mean velocity as a function of time. It is expected that trained men have the highest velocity and untrained women the lowest velocity. But these big differences are very interesting, together with differences among each group according to training level.

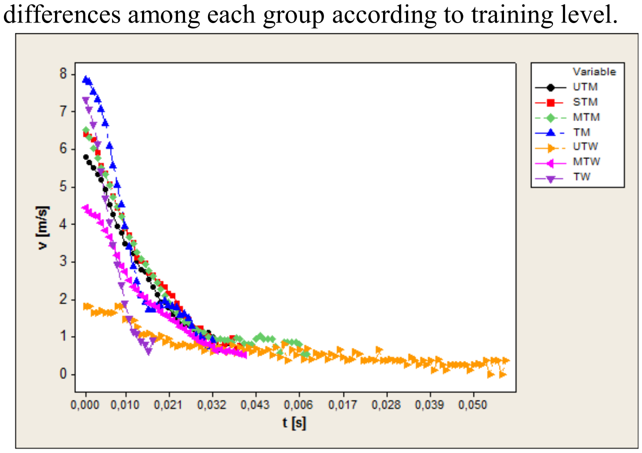

Figure 8. Dependence of mean velocity on time [8]

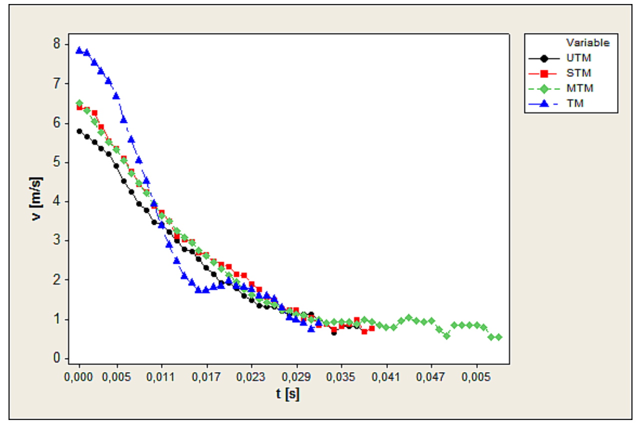

Figure 9. Dependence of mean velocity on time for men

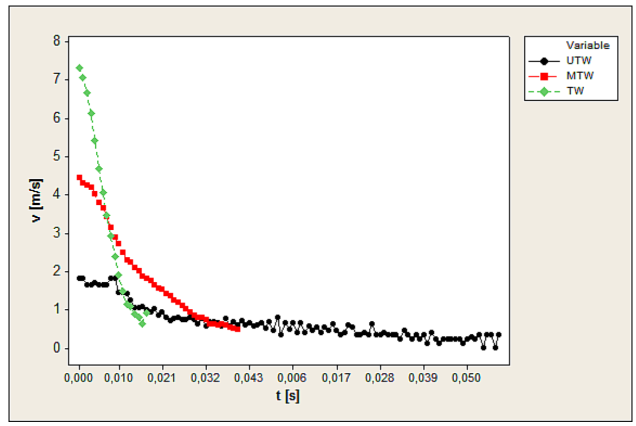

Figure 10. Dependence of mean velocity on time for women

Clear differences among groups according to training level are evident from Figure 8 to 10. There are not only differences in maximum velocity, but also in time of direct punch. Very interesting is the fall of velocity. There is a very sharp fall in groups of trained men and women. Other groups have a less sharp fall.

Table 2 presents the statistical data from the measurement of the velocity.

TABLE II. VELOCITY [8]

	Mean	Standard deviation of mean	Coefficient of variation	Minimum
UTM	3.06	1.6	52.61	0.77
STM	3.16	1.76	55.83	0.7
MTM	3.05	1.82	60.35	0.57
TM	4.55	2.43	54.25	1.15
UTW	0.67	0.44	66.66	0
MTW	2.14	1.25	58.25	0.47
TW	3.65	2.37	64.29	0.69
	Median	**Maximum**	**Number of samples**	
UTM	2.81	5.86	10	

STM	2.76	6.44	7
MTM	2.76	6.52	32
TM	4.46	7.87	39
UTW	0.58	1.82	1
MTW	1.82	4.46	16
TW	3.35	7.34	6

B. Results from the measurement of the force

Figure 11 and 12 show the dependence of the mean force as a function of time. In Figure 12, we display only a part of the whole graph of force for increased readability.

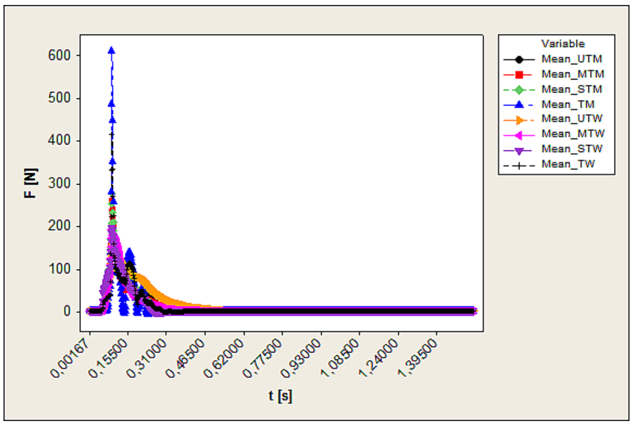

Figure 11. Dependence of mean force on time – whole [3]

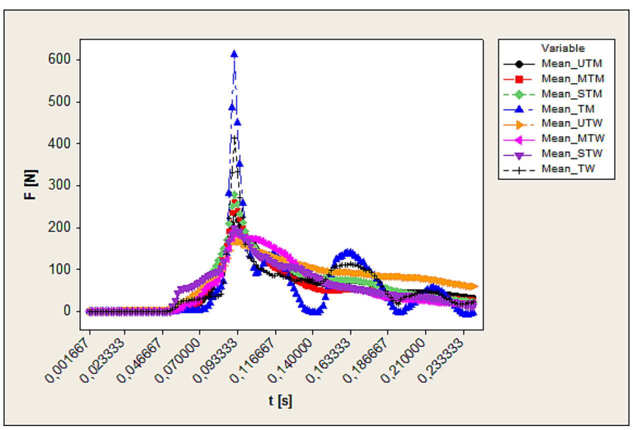

Figure 12. Dependence of mean force on time – partial [3]

Figure 13 and 14 show dependencies of mean force as a function of time for men and for women separately.

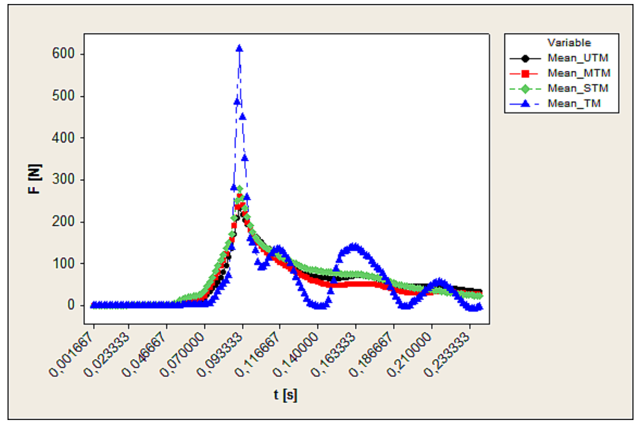

Figure 13. Dependence of mean force on time for men [3]

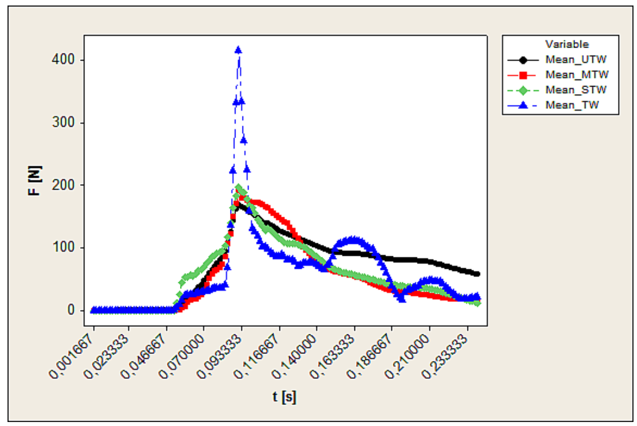

Figure 14. Dependence of mean force on time for women [3]

Table 3 shows the results for each category – especially the mean value for the force, the maximum force and the standard deviation.

TABLE III. RESULTS OVERVIEW FOR EACH CATEGORY

	Mean	**Standard deviation of mean**	**Coefficient of variation**	**Maximum**
UTM	23.148	48.08	240.59	233.76
MTM	17.522	44.512	313.25	260.37
STM	28.42	55.91	228.37	279.12
TM	27.75	88.92	499	612.7
UTW	15.17	36.157	265.72	169.9
MTW	20.76	45.779	254.28	192.09
STW	81.66	66.21	88.7	220.2
TW	40.78	78.56	256.9	415

C. Results from VICON system and EMG

For this experiment, the participants were a trained and an untrained woman, with the scanned marker placed on the back of the hand and in one case on the elbow. The process of direct punch was compared. As it is depicted in Figure 15, there is a difference in arm trajectory. It is clear that trajectories for direct punch of the untrained woman are absolutely different. Also, the marker on the elbow shows a visible round motion. The trained woman has both trajectories almost the same and direct.

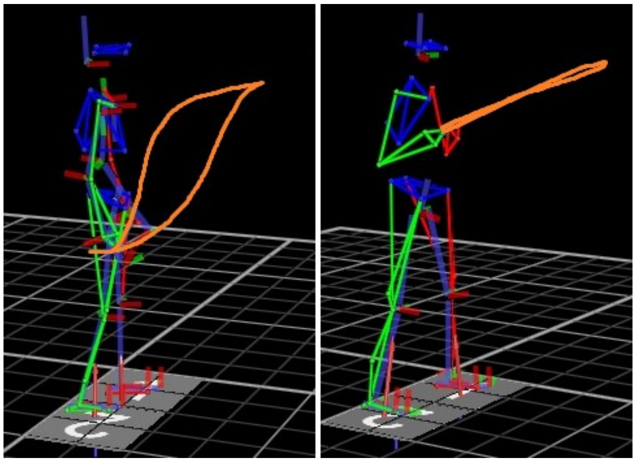

Figure 15. Untrained woman (left) and trained woman (right) – direct punch

Figure 16 and 17 show that the EMG diagram for both women are very similar. The most visible difference is in utilization of abdominal muscles and triceps.

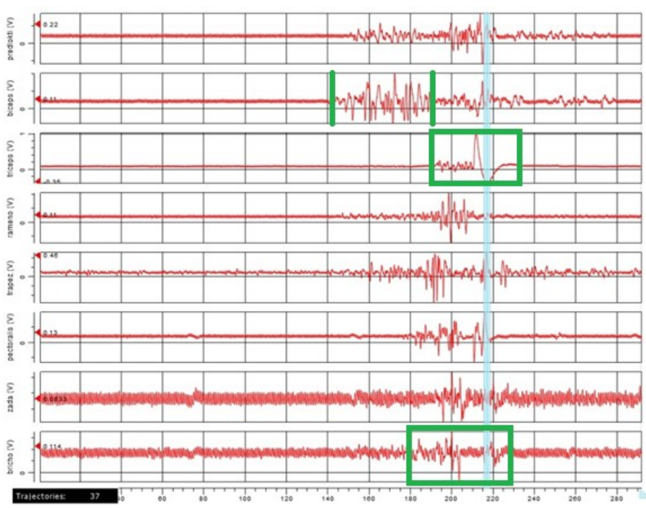

Figure 16. EMG diagram for the untrained woman – direct punch

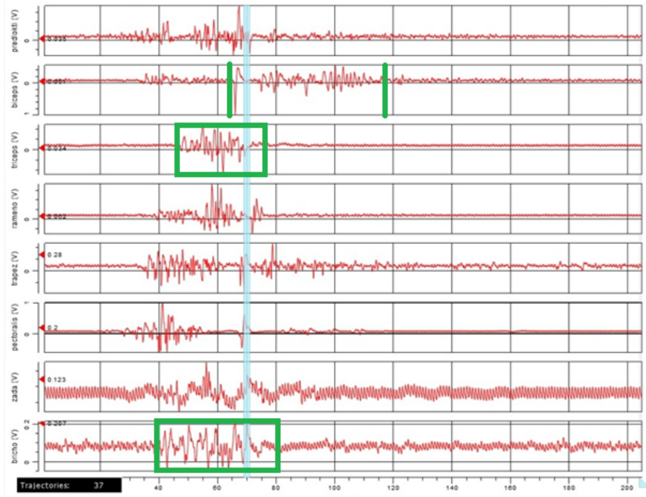

Figure 17. EMG diagram for the trained woman – direct punch

The trained woman (Figure 17) used these muscles more intensely than the untrained woman. A smaller difference is in the time of utilization of biceps that is shorter for the untrained woman (Figure 16).

VII. CONCLUSION

During a long term study, five methods were used for the analysis of the direct punch.

The first method was to measure the velocity of the direct punch. Very interesting results are in the column Maximum, because we can see that differences between trained men and trained women are not too big. The difference is only 0.53 m/s (6.73%). In the case of force, the difference is bigger, 197.7 N (32.27%).

The fall of velocity and force is also very interesting. There is a very sharp fall in the group of trained men and women. Other groups have a less sharp fall.

The body movement was visualized very precisely with the help of the system VICON. We can see significant differences between the two groups of people divided according to their training level.

This complex analysis showed that is possible to measure significant differences among people with different training level. In the future, the data analysis will be continued and the aim will be to find other dependencies.

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