Improving the Efficiency of Martial Arts by Studying the Fighting Techniques' Biomechanics

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Abstract: Considering that we live in a world where the number of aggressions is steadily increasing, it is becoming increasingly necessary to improve self-defense techniques that allow us to keep up with the existing threats. One way to achieve this goal is to study the biomechanics of the martial arts techniques. The present paper presents a comparative study on how to make Krav-Maga and Karate-Do martial arts techniques more effective, this being an extension of the results obtained by the authors and published in previous studies. Starting from the hypothesis that plantar pressure is a factor that can indicate the efficiency of a stroke in techniques which are characteristic of martial arts, it was intended to correlate it with the position of the executant, a position which influences the value of the punching and kicking speed. In order to verify this hypothesis, there were studied three types of techniques from the two martial arts, seven repetitions of each type. Techniques were studied both at the beginning of the training and after correcting the position of the athlete, this being possible after sustained training. The obtained results confirmed the hypothesis from which the study started, this fact leading to better efficiency of the studied techniques. It is obvious that the presented method can also be used in other martial arts, the performance of executants being greatly improved.

Key words: Biomechanics, efficiency, martial arts, self-defense.

1. Introduction

Krav Maga and Karate-Do are combat disciplines that fall under the definition given by R. L. Petre in 2014, which states that "combat discipline is any sporting discipline that includes the acts and phisical and mental actions necessary to carry out actions of attack, defense, counterattack, escape, blocking, etc." [1]. The two martial arts studied in this paper differ both in history and learning technique. Unlike Karate-do, which was documente hundreds of years ago, Krav Maga was created in the 1970s as an Israeli self-defense martial art. If Karate practitioners can verify their level by participating in competitions organized by specialized federations, "Krav-Maga is highlighted by the efficiency it demonstrates in real, uncontrolled conflicts with aggressors superior in force, agility and skills" [2], this not being a competition discipline.

The basic components of sport training, defined in [1] by R. L. Petre are technical, tactical, physical, psychological and theoretical training. The physical, technical and tactical training of the practitioners leads both to the improvement of the speed at which kicks are executed, reaching the upper bound imposed by the individual characteristics of each individual.

The study of the biomechanics of the martial arts techniques leads to a better understanding of how the principles of physics influence the execution, allowing the identification of the factors that contribute to improved training efficiency. The studies may contribute to the improvement of the methodology used in research, which would represent a starting point for validating new ways of biomechanical analysis of martial arts.

2. Methodology

The hypothesis from which we have started, used also in papers such as [3],[4],[5] was that plantar pressure is an indicator that can show the way in which martial arts techniques could be improved. To determine the extent to which some techniques in Krav-Maga and Karate-Do have been streamlined, the correlation of plantar pressure with the position of the performer was tracked, a position that influences the value of the punching and kicking speed. In order to verify this hypothesis, three types of techniques were studied in the two martial arts [6],[7], similar in execution, seven repetitions of each type. The techniques were studied in different stages of training, aiming to correcting them with the position of the athlete.

The kicks studied in this experiment were as follows:

2.1. The Direct Punch Stroke

- "Makot egrof smol-Yamin" from Krav-Maga - The position of the legs from which this technique is correctly executed is called "amidat motza" - the parallel legs with the left in front and the weight distribution must be equal on both legs at the level of the sole, the weight being distributed on the forefoot.
- "Gyaku tsuki" from Karate-Do - The weight is specifically distributed on the heel.

2.2. "The Chase Kick"

- "Beita Beredifa" from Krav-Maga - The weight will be distributed on the front of the foot that kicks.
- "Mae geri gedan" - The weight is specifically distributed on the heel on the ground in case of the foot that does not hit.

2.3. Kicking to the Chin with the Leg

- "Beita regila lasanter" from Krav-Maga - It is very important to keep the heel on the ground in case of the foot that does not hit.
- "Mae geri jodan" - The weight is specifically distributed on the heel on the ground in case of the foot that does not hit.

Plantar pressure was determined using a Pedar-X system (Novel, GmbH, Germany, [8]) (Fig. 1) at the Biomechanics Laboratory of the Department of Mechatronics and Precision Mechanics of the Polytechnic University of Bucharest. The equipment consists of the Pedar-X unit which acquires the pressure data exerted on the instrumentalized insoles of the athlete during the kicks and ensures the communication with the collection, processing and storage equipment (laptop or PC). The insoles have 99 sensors covering the entire plantar surface. The Pedar-X system offers multiple information, such as: maximum/mean pressure, contact area, pressure center, etc. Real-time data is transmitted via Bluetooth to a laptop or PC, and can be displayed in pressure / time graphs and force / time graphs.

The pedar system is an accurate and reliable pressure distribution measuring system [9],[10] for monitoring local loads between the foot and the shoe. It connects to highly conforming, elastic sensor insoles that cover the entire plantar surface of the foot, or to sensor pads for the dorsal, medial or lateral areas of the foot.

Main system features include pressure picture in 2D, 3D and isobar view, step selection and step timing analysis, calculation of regional loadings and simultaneous video recording.

Fig. 1. Pedar-X system [8].

Because the system is mobile and flexible, the athlete has not been limited in any way when executing the kicks.

The speed of the kicks was determined by video recording of the athlete during the experiment, the athlete having passive makers near joints areas, and the processing of the obtained images. The video recording was made using a GoPRO hero 4 camera. The GoPro Hero4 camera delivers best-in-class video at resolutions up to 4K at 30fps or 1080p at 120fps or 720p at 240fps and it is widely used for capturing fast moving activities.

The image processing to determine the average speed, maximum instantaneous speed and to trace the path was done using the Kinovea software. This software is used for video analysis in sports, as well as ergonomics and animation. The data analyzed can be exported to Excel, OpenOffice Calc and plain text.

Kinovea is a video player that can be successfully used by all sport enthusiasts. It offers a wide range of options for studying the technique of your athletes or of yourself: slow motion, magnification, tracking, measuring, comparison. It offers observational references, flat and perspective grids and it is free and open source [11].

3. Results and Analysis

The obtained results confirmed that the determination of plantar pressure [12] is a good method to be used not only in foot manufacturing [13] but also in improving the way techniques in the martial arts are performed, translating into the increase in the speed at which the practitioner kicks his opponent.

The first measurements performed (at the begining of the training) showed that the weight distribution that causes a certain plantar pressure indicates an incorrect position from which the kick is performed. After sustained training, the athletes managed to correct their positions from which they performed the kicks, this being reflected into a weight distribution according to the norms existing in the practiced martial art.

Plantar pressures determined by the Pedar-X device are expressed in kPa, displaying both peak pressures and mean pressures. The 2D and 3D images obtained with this device are displayed so that each pressure range corresponds to a certain color. (Fig. 2)

In the case of a direct punch executed by the Krav-Maga practitioner, it can be noticed that if initially there are large differences between the plantar pressure on the right and the left leg, and the weight distribution is higher on the heel (Fig. 3), as a result of the training the plantar pressure becomes similar on

both legs, and the weight of the athlete is distributed on the forefoot (Fig. 4).

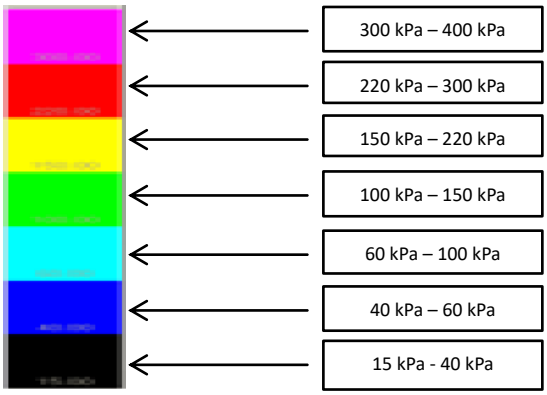

Fig. 2. Pedar-X pressure range.

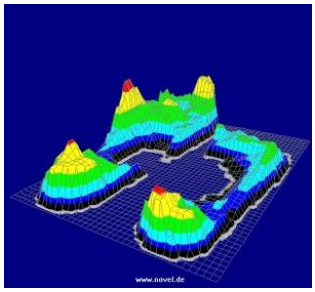

Fig. 3. Plantar pressure before correcting the position.

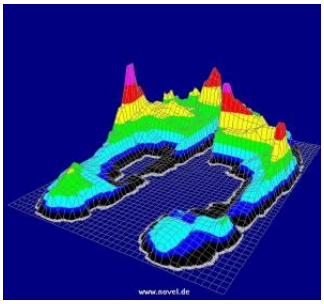

Fig. 4. Plantar pressure after correcting the position.

Correcting the athlete's position has led to an increase in the average speed and maximum instantaneous speed with which he performs the kick, making it more efficient (Table 1).

Table 1. Speeds for Punch, KRAV MAGA

	medium speed (m/s)						
before	3,42	3,88	4,15	3,82	4,2	4,08	4,21
after	4,24	3,92	4,54	4,22	4,48	4,92	4,6
	maximum instantaneous speed (m/s)						
before	8,14	7,64	8,77	9,1	10,54	7,72	8,83
after	9,3	10,16	7,91	11,83	11,32	10,96	10,1

In the case of the Karate-Do practitioner, the plantar pressure changes as a result of the technique, and the weight distribution is higher for the heel (Fig. 5, Fig. 6).

Correcting the athlete's position has also led to an increase in the average speed and maximum instantaneous speed with which he performs the punch stroke (Table 2).

The average speed and maximum instantaneous speed were obtained by analyzing the punch path. (Fig. 7)

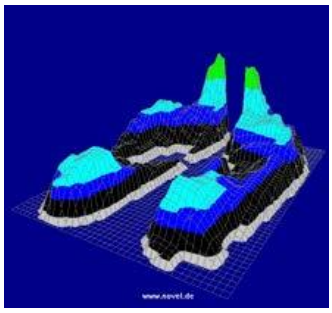

Fig. 5. Plantar pressure before correcting the position.

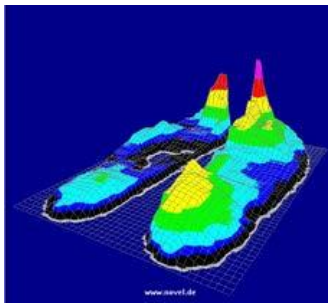

Fig. 6. Plantar pressure after correcting the position.

Table 2. Speeds for Punch, KARATE-DO

	medium speed (m/s)						
before	3,42	3,91	3,33	3,82	4,17	3,65	4,02
after	5,22	6,19	5,88	5,14	5,67	6,37	5,48
	maximum instantaneous speed (m/s)						
before	6,33	6,48	7,31	7,15	6,54	7,46	7,33
after	10,67	9,6	10,19	10,43	9,34	11,72	10,41

Fig. 7. Punch path in Krav Maga and Karate.

In the chase kick, one can notice that the Krav-Maga practitioner initially exercises a plantar pressure that has a higher value towards the heels (Fig. 8), but after correcting the position as a result of repeating the technique, weight distribution became higher on the right forefoot (Fig. 9).

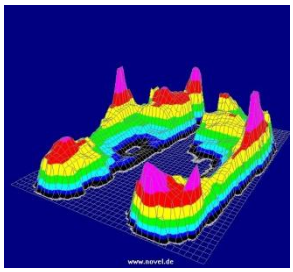

Fig. 8. Plantar pressure before correcting the position.

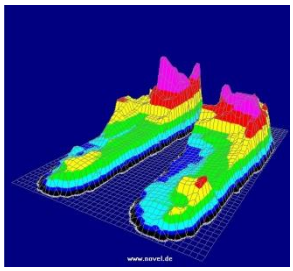

Fig. 9. Plantar pressure after correcting the position.

From the measurements made as a result of video recording, it can be noticed that the values of the average speed and the maximum instantaneous speed have increased as a result of the the correction of the athlete's body position. (Table 3)

Table 3. Speeds for CHASE KICK, KRAV MAGA

	medium speed (m/s)						
before	5,58	5,24	6,29	4,93	4,53	5,3	5,16
after	6,97	5,44	6,81	6,13	5,78	6,92	6,21
	maximum instantaneous speed (m/s)						
before	8,92	11,86	8,43	8,59	9,12	9,95	10,75
after	9,46	12	13,17	11,25	14,32	12,66	12,04

Executing the same type of kick by the Karate-Do practitioner leads to a redistribution of weight from the forefoot to the heels. (Fig. 10, Fig. 11)

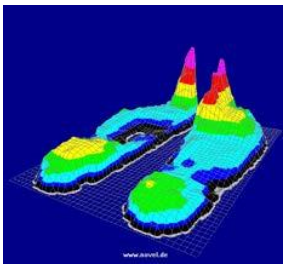

Fig. 10. Plantar pressure before correcting the position.

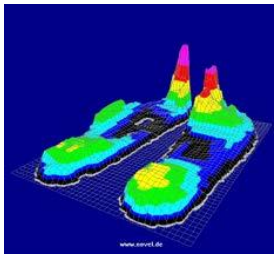

Fig. 11. Plantar pressure after correcting the position.

The differences between the average speed values and the maximum instantaneous speed before and after correcting the position from which the kick is performed are significant, the second ones being clearly higher. (Table 4)

Table 4. Speeds for CHASE KICK, KARATE-DO

	medium speed (m/s)						
before	4,51	4,78	3,92	4,29	4,75	5,16	4,92
after	4,26	5,95	6,21	6,04	6,67	6,38	6,27
	maximum instantaneous speed (m/s)						
before	8,46	6,75	6,88	8,82	7,37	7,18	7,86
after	10,13	9,44	11,28	8,72	10,57	11,36	11,85

The average speed and maximum instantaneous speed were obtained by analyzing the kick path. (Fig. 12)

Fig. 12. Foot path in Krav Maga and Karate.

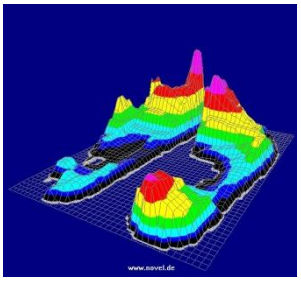

Fig. 13. Plantar pressure before correcting the position.

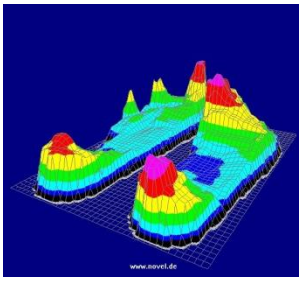

Fig. 14. Plantar pressure after correcting the position.

The kick to the chin with the leg properly executed by the Krav-Maga practitioner implies a higher weight distribution to the left foot heel. From Fig. 13 and Fig. 14 it can be noticed that before it corrected his position, the plantar pressure was higher to the forefoot, which led to a visible unbalance of the athlete and a lack of effectiveness.

Correcting the position from which the kick is executed also leads to the increase in the average and instantaneous speeds. (Table 5)

Table 4. Speeds for Kick to the CHIN, KRAV MAGA

	medium speed (m/s)						
before	5,09	5,86	5,69	4,75	5,4	5,09	5,47
after	5,71	5,77	5,91	6,42	5,64	6,92	6,63
	maximum instantaneous speed (m/s)						
before	12,01	14,24	13,09	12,31	12,55	9,85	11,9
after	13,08	13,77	13,92	14,45	13,55	13,86	14,17

In the case of a kick performed by the Karate-Do practitioner, there is a change in the weight distribution so that it gets higher to the heel, as shown in Fig. 15 and Fig. 16, leads to a significant increase in the average speed and instantaneous maximum speed with which he executes the kick, making it more efficient. (Table 6)

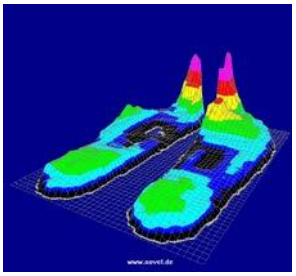

Fig. 15. Plantar pressure before correcting the position.

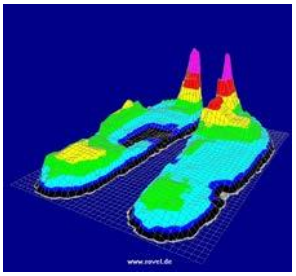

Fig. 16. Plantar pressure after correcting the position.

Table 6. Speeds for Kick to the CHIN, KRAV MAGA

	medium speed (m/s)						
before	5,63	5,39	6,31	5,87	5,26	6,54	4,45
after	6,64	6,77	6,02	6,64	5,87	6,56	6,22
	maximum instantaneous speed (m/s)						
before	9,35	8,57	8,12	6,63	9,28	10,44	9,38
after	11,71	10,1	10,85	12,81	10,32	10,96	11,43

Fig. 17. Foot path in Krav Maga and Karate.

The average speed and maximum instantaneous speed were obtained by analyzing the kick path. (Fig. 17)

4. Conclusions

The results obtained from the initial Krav-Maga martial art, which were later expanded on Karate-Do techniques, demonstrated that the measurement of planting pressure at different stages of the training is extremely useful in planning the training on a scientific basis. The distribution of the athlete's weight on the surface of the foot can sugerate if he performs the movement from the correct or wrong position. Correcting the position leads to better results, e.g. increasing the speed with which the athlete performs the kicks in the studied martial arts. The results of the measurements show that there is a clear correlation between plantar pressure and kicking speed. Using the Pedar-X device to determine planting pressure made possible to execute kicks more effectively for the two studied martial arts, Krav-Maga and Karate-Do, and also, the method can be extended to other self-defense sports as well. The study shows that the results of the measurements can be viewed in real time, making possible for the athlete to correct himself before he or she mistakenly catches the sports technique. Real-time correction increases the extent to which the method described in the paper leads to the improvement of martial arts effectiveness by studying the biomechanics of combat techniques, leading to higher performance in athlete's training.

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Diamanta Mihaela Visan is a graduate of the Faculty of Physics, Bucharest University. The diploma project was focused on mathematical and physical modeling in biology. She is also graduate of the Faculty of Economics and a Master of Human Resource Management. She is passionate about biomechanics, which is an area that can answer many problems faced by mankind. Previous experience has focused on didactic activities and teams management.

Doina Bucur has a PhD degree in Enginering Mechanics (Politehnica University of Bucharest (UPB), 2002), and a BSc degree in precision mechanics (UPB, 1982).

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