EFFECTS OF EXPERIMENTAL METHODOLOGY AIMED AT INCREASING THE FORCE OF STRAIGHT REAR-HAND PUNCH IN KARATE

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ABSTRACT

This article presents a methodology aimed at increasing the force of the rear-hand straight punch at the torso-level (gyaku zuki chudan). To accomplish the tasks of the survey, a video-computerized system was used to record and analyze the parameters of the punches performed by the participants. The results concerning the force of the torso-level rear-hand straight punch were registered in identical ways for each of the participants in order to make sure that the survey was performed under uniform conditions. The input data was processed by means of kinematics analysis software. To prove the credibility of the data registered the necessary statistical analysis methods were applied.

If more and more coaches start using modern tools and methods to develop the sports and technical skills of their entrusted athletes, this will increase the quality of the karate training process.

Key words: methodology, karate, punches, rear hand, force

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INTRODUCTION

When analyzing the men's finals at the 22nd World Karate Championship (WKF) in Bremen, 2014, we observed that gyaku zuki chudan was one of the most commonly used and one of the most successful punches in karate. The study of the final matches indicates that in five of the final matches, 12 points were scored with this technique (Penov, 2015). Other factors that directed our attention towards this technique are the ones that relate to using the technique in the examination requirements for technical level in karate and complexity of the technique in comparison with other ones. From the comparative analysis performed regarding the existing systems for achieving a higher level in karate Shotokan and the system for technical preparation and control developed by Stanchev and Penov (2015), it was concluded that gyaku zuki is present in all systems for technical preparation. Another publication by Stanchev and Penov (2016) shows that the gyaku zuki chudan technique is the most com-

plex one amongst the other punches with the upper limb. The reasons listed above, as well as the acceptance of Karate as an Olympic sport, provoked our interest in studying the technique and in particular the force of the punch with the goal to optimize the preparation of karate practitioners. Therefore, in order to achieve the set goal, it was necessary to study the effect of the application of the developed experimental methodology, which aimed to improve the force of gyaku zuki chudan in karate. The punching action of gyaku zuki chudan in fact is a straight fist punch performed by the opposing arm with respect to the front leg (gyaku - reverse) without a significant shift in the center of mass of the competitor's body in the direction of the target (Penov, 2015).

Modern Karate employs a variety of punches, which is in fact specific for this sport. Punches are performed at three different levels of height: low, middle, and high (gedan, chudan, and jodan). Using punches at high maneuverability and dynamics in rapidly chang-

ing circumstances requires of competitors ultimately specialized technical preparation and physical and psychological force (Bishop, 1989; Higaonna, 1985).

Hand punches are easier to perform than kicks because they allow for maintaining the balance, which results from a more stable support. If the technique is performed correctly, its force, speed, precision, and the damage on the opponent cannot be denied (Habersetzer, 1998).

Gyaku zuki chudan, also known as the reverse punch, is a technique that is commonly used in karate kumite, a form of competitive combat (Emmermacher et al., 2005; Hofmann et al., 2008). Gyaku zuki is one of the most commonly used techniques when we analyzed the final matches of the World Karate Championship in Bremen, 2014. In the five matches in the men's finals, gyaku zuki was used 36 times, 12 techniques were realised and were given points (Penov, 2015). The punch involves a quickly performed series of motions involving various parts of the body (Stull et al., 1988). This punch has more variations and is more efficient than other Karate offences. It is highly valued by national-team competitors, who feel a lot more confident when performing this punch compared to performing other Karate techniques. Seventy percent of all Karate combinations rely heavily on punches as an efficient weapon. Therefore, a competitor must indeed perform good punches in order to score a point when fighting or in a Kumite match (Muhamad, Haqiyah, 2018).

A good karateka must possess quick reactions, good flexibility, high speed, and a great muscular force. In this case, reaction time, the speed of attack, and the force of the punch are the major assessment factors regarding Karate techniques. A number of studies define the correlation between the maximum speeds of the punching fist and the force of the punch by

means of using cinematography or mathematical models. Another series of studies examine Karate punches by means of cinematics. (Chiu, Shiang, 1999)

The coordination among the motions of punches performed with maximum force complies with the following two requirements (Pinto, Magini, Saba, 2007):

1. Gaining maximum speed of the striking unit before the beginning of the third phase.
2. Increasing the striking mass at the moment of impact.

In order to improve and further perfect karate techniques, athletes should perform each technique repeatedly, with maximum concentration and dedication. This, however, will not be enough unless the training is based on proper physical and physiological principles (Marques, Gianino, 2010).

MATERIALS AND METHODS

This survey aims to study the effect of applying this methodology for the purposeful increase of the force of the straight read-hand punch at torso level - gyaku zuki chudan in karate. In order to fulfill the aim, we set the following tasks:

1. To evaluate the importance of the force of punches for the technical mastery of karate.
2. To develop a methodology for purposeful development of the force of punches.
3. To analyze the effect of applying the specific methodology.

Participants

The survey was conducted by means of a video-computerized system for registration and analysis of the force of karate punches. Twenty male participants, aged 19 to 26, took part. All participants are competing in karate on the National Sports Academy's team and possess technical levels from 4rd kyu to 1st dan (Table1).

Table 1. Competitors surveyed

Participants	Weight	Dan/Kyu	Belt
1	49	1 dan	Black belt
2	120	4 kyu	Second blue belt
3	64	3 kyu	Brown belt
4	78	1 dan	Black belt
5	52	3 kyu	Brown belt
6	90	2 kyu	Second brown belt
7	73	1 dan	Black belt
8	85	1 dan	Black belt
9	56	1 dan	Black belt
10	80	3 kyu	Brown belt
11	60	3 kyu	Brown belt
12	97	1 dan	Black belt
13	76	1 dan	Black belt
14	87	1 dan	Black belt
15	92	3 kyu	Brown belt
16	67	3 kyu	Brown belt
17	100	1 dan	Black belt
18	82	1 dan	Black belt
19	71	2 kyu	Second brown belt
20	58	4 kyu	Blue belt

To accomplish the tasks assigned, the athletes in question were divided into two groups: a control group and an experiment group. Both groups performed six rear-hand straight punches at torso level onto a designated target. For a period of six months, a special experimental methodology was applied to the experimental group to develop the physical quality “force” of the gyaku zuki chudan. During the same period of six months, a standard methodology was applied to the control group, used to increase the force of the studied impact. The methodology used for both groups is presented in Table 4 and 5.

The grouping of the participants is presented in Table 2 and 3.

Table 2. Group organization - experimental group

Participants	Weight	Dan/Kyu	Belt
1	49	1 dan	Black belt
2	120	4 kyu	Second blue belt
3	64	3 kyu	Brown belt
4	78	1 dan	Black belt
5	52	3 kyu	Brown belt
6	90	2 kyu	Second brown belt
7	73	1 dan	Black belt
8	85	1 dan	Black belt
9	56	1 dan	Black belt
10	80	3 kyu	Brown belt

Table 3. *Group organization - control group*

Participants	Weight	Dan/Kyu	Belt
11	60	3 kyu	Brown belt
12	97	1 dan	Black belt
13	76	1 dan	Black belt
14	87	1 dan	Black belt
15	92	3 kyu	Brown belt
16	67	3 kyu	Brown belt
17	100	1 dan	Black belt
18	82	1 dan	Black belt
19	71	2 kyu	Second brown belt
20	58	4 kyu	Blue belt

Protocol

The solution to the first task in our study, namely to reveal the importance of force when performing the punch to the mastery of Karate, requires an overview of the major physical laws that illustrate the force and its magnitude, of biomechanics, and of the biomechanics of Karate punches, in particular.

Force is a vector value that is characterized by a point of application, direction of motion, and magnitude. The magnitude of the force is equal to the product of the object's mass and the acceleration generated by the impact of the force. The acceleration of the object generated by the force F is proportional to the magnitude of F and is inversely proportional to the object's mass. (Arakchijski, 2002).

To obtain the force values of *gyaku zuki chudan* in karate, the following formula will be used - $F=m.a$, where F - is the force of the punch measured in Newtons (N), " m " – is the mass of the hitting hand, " a " – is the measured acceleration during the punch.

The implementation of the punches was recorded by means of Sony PJ740 video

camera, at 50 frames per second. The camera was positioned perpendicularly to the sagittal axis of the punches, and the point of view was at the height of the punches.

Video recordings of the punches were processed by means of Kinovea video-computer program for cinematic analysis, in order to measure the acceleration of the punching hand for each of the participants. The acceleration values were measured in meters per square second (m/s^2). (<https://www.kinovea.org/>)

In order to calculate the mass of the striking arm, we used the percentage of total body weight and the mass of the hand in males, which is 5,7% (Plagenhoef et al. 1983).

The data was further analyzed and averaged with regard of the phase periods (Rathee, Magnes, Davis, 2014; Arakchijski, 2002a).

Figure 1 presents a series of frames illustrating the motions in the case of a straight punch with the rear-standing arm at the torso level (*gyaku zuki chudan*) from a standstill. Projecting the elbow before the wrist is clearly seen.

Figure 1. *Straight punch with the rear-standing arm at the torso level (gyaku zuki chudan) from a stand-still*

According to most traditional karate experts, a significant factor that affects the acceleration of the punching unit is the reversive motion of the non-punching arm in the direction that is opposite to the target. Nevertheless, the biomechanical reasoning for the influence of the reverse motion of the non-punching limb on the kinematic and dynamic characteristics of the punching unit has not been provided yet. Stll, Kimura et.al. (2007) discovered a veritable positive correlation between activity of the muscles providing the reverse motion of the non-punching arm and the maximum values of the speeds of the punching unit. Penov (2015) also observed a veritable correlation $r = .89$

between the maximum values of the speeds of the punching and the reverse units ($p \leq .001$).

For each of the groups, we made two measurements of the force of gyaku zuki chudan. The first measurement for both groups was made before the use of the indicated methods for increasing the impact force. The second measurement records the progress of the two groups, which was achieved after the training period and the application of the respective methodologies.

The exercises applied to the experimental group, aiming to develop the force of the rear-hand straight punch at the torso level - gyaku zuki chudan, are presented in Table 4.

Table 4. *Dose of the exercises aiming to develop the force of the rear-hand straight punch at the torso level – gyaku zuki chudan*

Exercise	Months	I	II	III	IV	V	VI
	Dosage						
1. Bench-press with 85-100% of F-max	Week 1	2X5	5X5	5X3	3X2	5X2	5X1
	Week 2	3X5	5X5	5X3	4X2	5X2	5X1
	Week 3	4X5	3X3	5X3	5X2	3X1	5X1
	Week 4	5X5	4X3	5X3	5X2	4X1	5X1
2. Bench-press at 40% of F-max	Week 1	2X8	3X10	4X10	5X10	6X10	6X10
	Week 2	2X8	3X10	4X10	5X10	6X10	6X10
	Week 3	2X8	3X10	4X10	5X10	6X10	6X10
	Week 4	2X8	3X10	4X10	5X10	6X10	6X10
3. Performing gyaku zuki chudanwith an elastic band	Week 1	2X10	3X10	4X10	5X10	4X10	3X10
	Week 2	2X10	3X10	4X10	5X10	4X10	3X10
	Week 3	2X10	3X10	4X10	5X10	4X10	3X10
	Week 4	2X10	3X10	4X10	5X10	4X10	3X10
4. Shot-putting a heavy ball - 3 kg.	Week 1	2X10	3X10	4X10	4X10	3X10	2X10
	Week 2	2X10	3X10	4X10	4X10	3X10	2X10
	Week 3	2X10	3X10	4X10	4X10	3X10	2X10
	Week 4	2X10	3X10	4X10	4X10	3X10	2X10

5. Lifting weight with one arm from lying position	Week 1	2X15	3X15	3X12	4X10	5X10	4X8
	Week 2	2X15	3X15	3X12	4X10	5X10	4X8
	Week 3	2X15	3X15	3X12	4X10	5X10	4X8
	Week 4	2X15	3X15	3X12	4X10	5X10	4X8
6. Delivering gyaku zuki chudan onto a heavy punching bag - 100 kg.	Week 1	2X10	3X10	4X10	4X10	4X10	4X10
	Week 2	2X10	3X10	4X10	4X10	4X10	4X10
	Week 3	2X10	3X10	4X10	4X10	4X10	4X10
	Week 4	2X10	3X10	4X10	4X10	4X10	4X10

Description of exercises used by the experimental group for the development of force when performing gyaku zuki chudan punch.

1. *Bench-press with 85-100% of F-max* – The exercise is performed with a bar. The intensity is 85-100% of F-max. This exercise develops the maximum force of the upper limb. It is performed in sets of 1 to 5 repetitions. For the first 45 days, a set with 5 repetitions is performed, during the next 45 days a set with 3 repetitions is performed, during the next 45 days a set with 2 repetitions is performed, and during the last 45 days a set with 1 repetition is performed at 95 - 100% of F-max.

2. *Bench press with 40% of F-max.* This exercise develops the explosive force of the upper limbs. It is performed after a very good general and special warm-up. The dose is 8 to 10 repetitions, as sets increase from 2 to 6. The intermission between the sets is 30 seconds. The athlete performs a bench press with 40% of the weight used for one repetition attempt.

3. *Performing gyaku zuki chudan with an elastic band.* This exercise is performed with an elastic band that is attached to the wrist of the punching hand. Ten repetitions with each hand are performed. The intermission between sets varies from 30 sec to 1 min. The number of sets increases until the fourth month of the preparation, and then decreases. A 3-meter long, 5-centimeter thick elastic band is attached to the wrist of the athlete while the other end of the elastic band is at-

tached to a horizontal bar or a wall-bar.

4. *Shot-putting a heavy ball (3 kg).* This exercise develops the explosive force of the upper limbs. It is performed with a 3-kilogram ball, which is shot-put towards a wall bag, as the motion replicates the gyaku zuki chudan punch. The dose in a single set is 10 repetitions. The number of sets increases until the fourth month of preparation, and then decreases.

5. *Lifting weight with one arm from lying position.* This exercise develops the force of the upper limbs and improves the intramuscular coordination of muscles, which is particularly needed for the performance of gyaku zuki chudan. The exercise is performed from a lying position, as a 12-16-kilogram weight is moved upwards in a trajectory that replicates gyaku zuki chudan motion. The intermission between sets is one minute. It can be seen from the dose table that in months 1 - 3 the volume of series increases and in months 4 - 6 the volume goes down, but the intensity increases.

6. *Delivering gyaku zuki chudan onto a heavy punching bag (100 kg).* This is a special exercise aimed at developing the force of the upper limbs. The technique is delivered onto a heavy punching bag (80-100 kg). The dose is 10 repetitions per arm, as a correct and forceful performance of gyaku zuki chudan is sought. The intermission between sets is 30 seconds.

The exercises applied to the control group, aiming to develop the force of the rear-hand straight punch at the torso level - gyaku zuki chudan, are presented in Table 5.

Table 5. Dose of the exercises aiming to develop the force of the rear-hand straight punch at the torso level - *gyaku zuki chudan*

Exercise	Months Dosage	I	II	III	IV	V	VI
1. Bench Press with 75-85% of F-max	Week 1	2X15	5X15	5X12	5X10	4X8	3X6
	Week 2	3X15	5X15	5X12	5X10	5X8	4X6
	Week 3	4X15	3X12	3X10	5X10	5X8	5X6
	Week 4	5X15	4X12	4X10	3X8	5X8	5X6
2. Push-ups	Week 1	2X30	3X30	4X30	5X40	5X50	4X60
	Week 2	2X30	3X30	4X30	5X40	5X50	4X60
	Week 3	2X30	3X30	4X30	5X40	5X50	4X60
	Week 4	2X30	3X30	4X30	5X40	5X50	4X60
3. Performing gyaku zuki chudan with a 1-kilogram dumbbell	Week 1	2X10	3X10	4X10	5X10	4X10	3X10
	Week 2	2X10	3X10	4X10	5X10	4X10	3X10
	Week 3	2X10	3X10	4X10	5X10	4X10	3X10
	Week 4	2X10	3X10	4X10	5X10	4X10	3X10
4. Delivering gyaku zuki chudan onto a punching pad.	Week 1	2X10	3X10	4X10	4X10	3X10	2X10
	Week 2	2X10	3X10	4X10	4X10	3X10	2X10
	Week 3	2X10	3X10	4X10	4X10	3X10	2X10
	Week 4	2X10	3X10	4X10	4X10	3X10	2X10

Description of exercises used by the control group for the development of force when performing gyaku zuki chudan punch.

1. *Bench-press with 75-85% of F-max* – The exercise is performed with a bar. The intensity is 75-85% of F-max. This exercise develops the force of the upper limb. It is performed in sets of 15 to 6 repetitions.

2. *Push-ups*. This exercise develops the quality of force stamina of the upper limb. The dose is 30-60 repetitions per set. The intermission between sets varies from 30 seconds to 1 minute. From the dose table it can be seen that the volume of the sets increases from the first month to the sixth. The exercise is performed on the fists as the elbow joints bend and extend.

3. *Performing gyaku zuki chudan with a 1-kilogram dumbbell*. This exercise develops the force of the gyaku zuki chudan punch and the force stamina of the upper limbs. The technique is performed with a 1-kilogram dumbbell. The dose of the exercise is 10 repetitions per set, as the number of sets increases until the fourth month and decreases after that. The intermissions are of 30 seconds.

4. *Performing gyaku zuki chudan onto a*

punching pad. This exercise improves the technical performance with the upper limb - gyaku zuki chudan. It is performed in pairs, as one partner holds the punching pad at the level of the waist. The trainee performs gyaku zuki chudan at maximum force. The number of repetitions per set is 10, with each hand. The intermissions are of 30 seconds. The number of sets increases until the fourth month and decreases after that.

The results received regarding the force of the gyaku zuki chudan punch of both groups were measured in identical ways in order to provide the same test conditions for both groups. The data received were discussed with specialists in order to eliminate possible mistakes.

Statistical Analysis

The results obtained from the video recording were processed by means of mathematical and statistical methods, including descriptive statistics and Student's *t*-Test: Two-Sample Assuming Unequal Variances.

Descriptive statistics were used for summarizing a given data set. The measure of central tendency included the mean ($\bar{X}$) and measures of variability included the standard deviation

(S), the minimum and maximum variables, coefficient of variation (V%), range (R) and the kurtosis and skewness. The coefficient of variation (V%) provides information about the dispersion of the studied variable and offers possibilities to compare the variation of the different indicators. It is accepted that the variation is low and the sample is homogenous when the values are up to 10-12%; between 10 and 30% the sample is approximately homogeneous and over 30% the variation of the indicator is high and the sample is strongly inhomogeneous.

The normal distribution is proved by the coefficient of skewness and kurtosis when the empirical data are $\leq$ of the theoretical depending on the number of the sample.

The analysis of the differences in the distribution between the control and test groups was performed with a Student's t-test for two samples suggesting unequal variations. The student t-test is used to determine the significance of the difference between the means of two data sets. In essence, the test compares the difference in mean values against the observed random changes in each group.

If we perform a *t*-Test to compare the mean values, the main hypothesis is that there is no difference between the mean samples. In other words, it is established in the null hypothesis that any differences in the mean values are random, ie. is equal to zero: $H_0: \mu_1 = \mu_2$ or, $H_0: \mu_1 - \mu_2 = 0$. In most cases, it is sought whether the null hypothesis can be rejected, and the alternative hypothesis accepted, i.e., that the mean values are not equal to zero.: $H_a: \mu_1 \neq \mu_2$ or, $H_a: \mu_1 - \mu_2 \neq 0$.

The data were analyzed by following standard procedures, with the statistical package for the Social Science (SPSS) v.19 for MAC (IBM, New York, NY, USA).

RESULTS

The force of a punch depends on the correct execution of all phases that comprise its performance. Figure 2 illustrate punches with the left and the right arm respectively that were performed by the participants in the survey during the video-recording sessions. Later, all recorded performances were compared with the correct execution of the punch.

Figure 2. *Gyaku zuki chudan performed by the author, R. Penov, PhD*

Learning the force of the backstroke at the level of the torso (gyaku zuki chudan) in karate is an important part of the training process and is associated with the proper execution of the punch, as well as the inability of the opponent to perform appropriate defensive techniques. Therefore, it was important for us to prove that the created experimental methodology led to improvement of the force of gyaku zuki chu-

dan punches in karate. As a result of the applied training methodology, improvements in the parameters of the force of gyaku zuki chudan were achieved. The results obtained from the measurements made before and after the application of the indicated methodologies are presented in Figure 3 and 4.

Figure 3. Generalized results of the two measurements for the control group

Figure 4. Generalized results of the two measurements for the test group

In order to illustrate the progress of the two groups more clearly, Figure 5 presents a comparison between the achieved results of the two groups for the period of training.

Figure 5. Generalized results after the training period

As Table 6 indicates, the average force of the test group was significantly higher than that of the control group. Respectively, the dif-

ference between the average forces of the two groups was 209 N in favor of the group that used the experimental methodology.

Table 6. Descriptive statistics – results

Indicator/Group	$\bar{X}$	S	Ex	As	R	X-min	X-max	V%
Control Group	1182	25	-0.78	1.25	46	1163	1209	2.07
Experimental Group	1391	43	-1.27	0.43	81	1352	1433	3.07

The results from the descriptive statistics are presented in Table 6.

The coefficient of variation for the control group was 2.07%.

The coefficient of variation for the Experimental group was 3.07%.

It is evident, from the coefficients of variation (V%), that the coefficient for two groups was within the range of $V=12\%$, which allows to consider the sample as highly homogeneous.

In order to prove statistically that the method applied to the experimental group led to an increase in the force of gyaku zuki chudan compared to the applied method on the control group, the values obtained from the second measurements of the impact force for the control and experimental groups were tested for hypotheses, which determined whether

the methodology applied to the experimental group had led to an increase in the force of the impact compared to the methodology applied to the control group. To ensure this, the Student's T-test for independent samples was applied. Referring to the results obtained from Student's t -Test for t -stat = 2.5, t -Critical bifurcation = 2.1 and $P(t) = 98\%$, at $\alpha = .05$ it was confirmed that the null hypothesis should be rejected. Therefore, due to the fact that t -stat > t Critical two-tail and p -value ($P \leq t$ with two tails) was less than .05 and $P(t) \geq 95\%$, the alternative hypothesis could be accepted. Therefore, there was a significant difference in the results achieved by the two groups, which was in favor of the group working on the experimental methodology. These results can be seen in Table 7.

Table 7. Student t-Test – results

t-Test: Two-Sample Assuming Unequal Variances	Mean	df	t - Stat	P(T<=t) one-tail	t Criti- cal one- tail	P(T<=t) two-tail	t Criti- cal two-tail	P(t)	α
Experimental group	1391 N	15	2.5	0.0118	1.75	0.0236	2.1	98%	0.05
Control group	1182 N								

DISCUSSION

Gyaku zuki chudan is the most commonly used and the most powerful technique. In order to be better than the opponent and to be able to make the right judgement, the Karateka’s goal is to minimize the overall duration of motion regarding the technique that is being used (Hofmann et.al. 2008).

In a study of his own, Nelson Kautzner, Marques Junior (2012), examinesd 54 matches in 22 Shotokan Karate competitions in the discipline of kumite for women. Gyaku zuki chudan was the most commonly used technique. His studies revealed that 37% of all techniques used in real competitions were namely straight punches with the rear-standing arm at the torso level (gyaku zuki chudan). Another study of Penov (2015), the world championship finals for men, Bremen, 2014, proved the thesis that this punch was one of the most commonly used techniques.

When examining other similar studies that utilize a force platform, the average values of maximum force received are 1567-2218 N, which is close to the values that were received in our study (Aguiar de Souza, Marques, 2017). Voigt (1989) registered the maximum force of 10 experienced participants. The results varied from 2345 N to 4866 N, as the average was around 3334 N. Gullledge and Dapena (2008) studied 12 elite Karate athletes in order to estimate the maximum force of the reverse punch. The average maximum punch force measured was 1450 N.

Stanchev and Penov (2016) found that gyaku zuki was the most complex technique

to be performed with the upper limb in comparison with others.

Kimura et.al. (2007), found a veritable positive correlation between the activity of muscles that promote the reverse motion of the non-punching arm and the maximum values of speeds of the punching unit. Penov (2020) illustrated one of the common mistakes when performing gyaku zuki chudan, namely the absence of the reverse motion and its halt due to projecting the elbow of the non-punching arm.

Another important element of the technical performance is the wrist rotation of the punching arm in the final phase of the punch. Venkatraman & Nasiriavanaki (2019) did a study that proved that a gyaku zuki performed with a rotation of the wrist in the final phase of the punch provided a greater force than it does when the wrist’s rotation is missing.

Jacek Wąsik et.al. (2019) studied the force of pressure of the lower limbs when performing gyaku zuki chudan onto a training pad and in the air by means of a training platform. The following values are registered: punching without a purpose - 1150.27-1329.72 N for the front leg and 621.78-748.13 N for the rear one; punching onto the pad: 912.28-697.76 N for the front leg and 721.44-670.63 N for the rear one. The conclusions of the research show that during the application of a punch - gyaku zuki, the thrust of the legs forward carries more weight (the leg that is opposite to the punching arm). The presence, or respectively the absence, of a movable target when delivering the punch reflects on the force of pressure on both feet of the studied participant, as the punch-

es delivered onto a target decrease the force of pressure of the two feet of the participant studied onto the floor. The study of the support pressure when performing punches can lead to certain conclusions regarding the methodologies aiming to increase the force of the punch by using the support reaction.

When regarding close-range punches, highly qualified karateka are capable of generating higher punch forces that are impossible to achieve by beginner karateka. This, to some extent, may result from the capability of coordinating the duration of limb movement. It seems that there is a functional use of this synchronization since the value of the time interval is in negative correlation with the maximum punch force and the acceleration, and is also in negative correlation with the time interval in which the force increases. The average values of the forces achieved by professionals is 2.69 kN. (Roberts et. al, 2013).

Another study of Loturco et.al. (2016) proved that the energy transmitted from the punch onto the target varied in a wide range depending on how heavy the hands and the gloves were and on the contraction forces of the wrist.

The survey conducted with 12 karate black-belt holders showed that the so-called "reverse punch" delivered an average force of 325 pounds, as the strongest ones reached 412 pounds (Venkatraman et.al. 2019).

Vinicius Aguiar de Souza and André Matos Marques (2017) performed an intriguing survey on the relationship between age and expert knowledge on the one hand and the maximum force of the reverse punch of Shotokan practitioners. By means of tenso-indicators they studied the maximum force of the punch of eight male black belts of Shotokan Karate-do aged 20.25 ± 4.13 , height 1.74 ± 0.04 m; body mass 72.41 ± 9.62 kg, sports experience 7.64 ± 4.33 years. The effect of the age and

sports experience variables on the maximum force was analyzed by means of a linear regression model. The results and their study indicated that the two variables of age and sports experience had a statistically significant correlation to the maximum force of the punch. This correlation was displayed in the square form where a decreasing effect was observed that determined the behavior of the maximum force of the punch. The maximum force of the punch for the entire test varied from 1310.82 N to 2314.53 N with an average of 1812.01 N. - all similar values to the ones received in our study. A negative correlation was observed between age and the standard deviation. This indicates that the experience accumulated through the years can have a stabilizing effect. Conclusions were drawn that age and sports experience correlate with the maximum force of the punch. These influences, however, have a critical point, beyond which they bring a decreasing effect onto the maximum force of the punch. The critical point regarding age is 31 years and the critical point about experience is 11 years. Beyond these critical points the karate practitioner will be advised to search for ways to compensate the previously mentioned decreasing factors by means of food or additional training supervised by a professional. The short duration of the motion in martial arts limits quantitatively the visual and proprioceptive correction which can be applied by the athlete (Brito et.al., 2011).

CONCLUSIONS

Further increase in impact force requires work to increase the physical qualities of the muscles involved in the impact movement. From the applied methodology with the experimental group there was an increase in the impact force by 150 N, while in the control group the increase in the impact force was 95 N. The respective difference between the aver-

age forces was 209 N after the training cycles carried out and was to the benefit of the group that had used the experimental methodology. In the control group the dose of the exercises was different from the one in the experimental group, and so were the intensity and the contents of the exercises. The experimental group worked with 85-100% intensity of F-max and a lower number of repetitions, while the control worked with 75% of F-max and a higher number of repetitions.

1. The parameter analysis of the force of the rear-hand straight punch at the torso-level - gyaku zuki chudan, as well as the application of the experimental methodology aimed at improving the force of this punch brought about observable positive results.

2. Increasing the force of the karate punch is of particular importance to the attacking techniques because an attack of high force and speed is difficult to block by the opponent, which may lead to winning the match.

3. The improvement of the force between the attempts of both groups is credible, which proves that the force measurement and the video analysis applied can be used in the sports training of karate practitioners and will contribute to improving their sports skills.

4. The statistical analysis performed proves that the experimental methodology applied aiming to make the force of the rear-hand straight punch at the torso-level has helped improve the results concerning the studied parameters.

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