

**NATIONAL SPORTS ACADEMY “VASSIL LEVSKI”**

**DEPARTMENT “WRESTLING AND JUDO”**



**IVO KAMENOV GEORGIEV**

**SIGNIFICANCE OF STRIKE FORCE FOR  
INCREASING THE  
EFFICIENCY IN MARTIAL ARTS**

**AUTHOR’S SUMMARY OF  
DISSERTATION**

**for acquiring the educational and scientific degree “PH.D.”  
Professional field 7.6. Sport,  
Ph.D. Program “Theory and Methods of Sports Science”**

**SOFIA, 2025**

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**The dissertation has been discussed and proposed to be officially defended by the Department “Wrestling and Judo” at NSA “Vassil Levski”.**

**The dissertation comprises 252 standard pages illustrated with 20 tables, 32 graphs in the main body, and seven appendices including 14 graphs and 139 tables. The reference list includes 147 literary sources, of which 63 are in Cyrillic, 46 are in Latin, and 38 are Internet sources.**

**The defense of the dissertation will be held on July 15, 2025, at 12:00 a.m. in Hall A3 at NSA “Vassil Levski”.**

## **INTRODUCTION**

Martial arts have their origins in a distant past. There is evidence that martial arts have been practiced in nearly every part of the world since the dawn of civilization. Kyokushin Karate is a martial art originating in Japan in the early 20th century, created by Masutatsu Oyama. It later established itself as a sport in the early 1980s and has since experienced significant development. Today, Kyokushin Karate is one of the most widely practiced sports and karate styles. As a style, Kyokushin Karate is part of the World Karate Union (KWU), which is recognized by the Olympic Committee and is striving to become part of the Olympic family. Kyokushin Karate also exists independently within other karate organizations, which are recognized to varying degrees by state institutions worldwide.

In Bulgaria, Kyokushin Karate has existed as a style since the late 1970s. The Bulgarian Kyokushin Karate Federation (BKKF) was officially registered in 2008. It is a member of the European Karate Federation (KWF) and the World Karate Federation (KWU). BKKF promotes the Kyokushin style in its pure form, and the competition rules followed are the oldest in Kyokushin Karate. Later, based on Kyokushin Karate, combat sports such as kickboxing and Kudo emerged.

Research indicates a lack of sufficient scientific studies examining the strike force with both upper and lower limbs, as well as a deficiency in systems for evaluating and controlling strike force to optimize the training process in sports such as Kyokushin Karate, kickboxing, Kudo, and Muay Thai. These martial arts are evolving both as sports and as art forms, rooted in their traditions. Their further development depends to a great extent on sports science.

The study of strike force and its role in enhancing effectiveness in combat sports is a timely and interesting topic. The creation of a test battery that assesses the current state of the strike force would contribute to optimizing the training process.

Combat sports are complex, non-cyclic sports that comprehensively develop physical attributes. Since no such test battery currently exists, its creation would make a significant contribution to coaching practices in Kyokushin Karate, kickboxing, and Kudo.

A physical preparation test battery should include a test that measures the kinetic energy and power of strikes. Another important aspect of the methodology is the improvement and updating of technical training in accordance with modern trends and rule changes, which is not only necessary but mandatory. A biomechanical analysis of techniques in combat sports can help validate the efficiency of commonly used techniques.

In conclusion, the topic explored in this dissertation is timely and necessary for modern coaching practices in all combat sports. Researching the importance of strike force for increasing efficiency in combat sports would enhance the overall preparation of athletes in Bulgaria and contribute to sports science.

## **STRIKE FORCE IN THE COMBAT SPORTS KYOKUSHIN KARATE, KICKBOXING, MUAY THAI, AND KUDO: KEY CONCEPTS**

Each of the combat sports—Kyokushin Karate, kickboxing, Muay Thai, and Kudo—has its own specific rules for awarding victory in a competitive bout. However, they all share two key criteria: point superiority and forcing the opponent to give up through a strike delivered with sufficient strength and speed to a vital point at an exact time and from the correct distance. It turns out that the quality of strength and its expression through striking techniques are crucial in combat sports, as they can lead to victory by significantly reducing or completely halting the opponent's abilities. According to Dasheva (2006), strength is a person's ability to act upon or resist external objects through the body's system of levers, achieved through muscle contractions. Some authors, such as V. Yordanov (2017) and Wolf (2009), discuss the concept of starting (explosive) or reactive strength. Starting strength is the ability of the neuromuscular system to develop the greatest possible increase in force from the onset of contraction (Wolf, 2009). Reactive strength is the muscular power generated during a stretch-shortening cycle of a heightened impulse. It depends on maximal strength, the speed of force development, and reactive tension capability (Martin et al., 1993). Reactive strength is the most important component for pushing off with the legs, which initiates every movement, whether it is pushing off the mat or ring, and thus begins every attack, counterattack, or evasive action. Reactive strength training requires minimal equipment and can often be done using only body weight. In the 1970s, plyometric training was developed in the former Soviet Union and later in other Eastern Bloc countries (Yordanov, 2017).

Other authors define speed-strength as the muscle's ability to overcome resistance with a high speed of contraction (Sirenyakov, 1995; Smirnov & Dolgopolova, 2007).

Penov (2021) states that force is a quantitative measure of body interaction, leading to a change in the body's position or state of motion. According to

Arakchiyski (2002), force is a vector quantity characterized by point of application, magnitude, and direction. The magnitude of the force equals the product of an object's mass ( $m$ ) and the acceleration ( $a$ ) caused by the applied force. The acceleration generated by the force  $F$  is proportional to  $F$  and inversely proportional to the object's mass  $m$ —Newton's second law (Arakchiyski, 2002).

Physicist Dr. Simon Foster from London, who studied the boxer Manny Pacquiao's punches, derived the formula  $P = mv$  (momentum = mass  $\times$  frequency) and  $\Delta P = m\Delta v / \Delta t$  (change in momentum = mass  $\times$  change in frequency/change in time). Foster explains that punch force equals the change in momentum (source) (<https://mma.bg/statii/osnovni-umenia/kak-da-udryame-po-silno>).

We determine the force of the support reaction according to Newton's third law:  $F = -F$ . If one body acts on another with force  $F$ , the second body reacts with an equal and opposite force. In combat sports, this law applies when muscle effort is used to extend the lower limbs, especially when delivering a strike with either upper or lower limbs. This effort adds force to body weight, increasing the support reaction. As a result, both the support (e.g., the floor) and the person undergo a certain amount of movement, which is equal in size and opposite in direction, depending on their respective masses (Penov, 2021).

The main strike velocity is the speed of translational, rotational, or rotational-translational motion of the fist. These components determine the power and effectiveness of a strike at all distances in combat. Increasing speed and properly utilizing rotation significantly enhance strike force (Romanov, 1979).

According to Romanov (1979), a strong punch is a crucial factor in boxing success, particularly at the highest levels. He notes that methods like hard sparring cause injuries without effectively developing punch strength. He emphasizes that applying biomechanical movement principles—proper hip, shoulder, leg, and rotational work—determines the effectiveness of the strike.

## **WORKING HYPOTHESIS**

Our working hypothesis is based on the assumption that by establishing the strike force and its relation to sports achievement – the sports result in Kyokushin Karate, kickboxing, Muay Thai, and Kudo, we will create regulatory tables for evaluation and control and thus optimize the training and competitive process, as well as the selection in combat sports. The expected outcome of our research is to enrich the theory of sports preparation with our contributions and to significantly enhance the methodological aspects of technical training, particularly in perfecting strikes with both upper and lower limbs. Additionally, we aim to provide sports pedagogues with objective methods for determining the effect of training.



# **AIM, TASKS, ORGANIZATION, AND METHODS OF RESEARCH**

## **AIM OF THE RESEARCH**

The primary objective of this research was to optimize the training process in the sports of Kyokushin Karate, kickboxing, Muay Thai, and Kudo by establishing the relationship between the strike force and sports achievement.

## **TASKS OF THE RESEARCH**

To fulfill the aim of the research, we set the following tasks:

1. To conduct questionnaire research regarding the opinions of elite athletes in combat sports on the methods and means for increasing the strike force.
2. To perform a biomechanical analysis of the main upper and lower limb strikes in the sports of Kyokushin Karate, kickboxing, Muay Thai, and Kudo.
3. To conduct a comparative analysis of the strike force among different combat sports.
4. To compare the strike force levels of world-class athletes and national-level athletes in the combat sports Kyokushin Karate, kickboxing, Muay Thai, and Kudo.
5. To develop a regulatory framework for evaluating the strike force of athletes practicing Kyokushin Karate, kickboxing, Muay Thai, and Kudo within the weight range of 70-80 kg.

## **OBJECT OF RESEARCH**

**The object** of this research is to establish a system for evaluation and control of the force of main strikes in the sports of Kyokushin Karate, kickboxing, Muay Thai, and Kudo by establishing the relationship between strike force and sports achievement.

## **SUBJECT OF RESEARCH**

**The subject** of this research is the strike force in the combat sports Kyokushin Karate, kickboxing, Muay Thai, and Kudo.

## **RESEARCHED SAMPLE**

The research was done among 30 athletes practicing Kyokushin Karate, kickboxing, Muay Thai, and Kudo.

## **ORGANIZATION OF THE RESEARCH**

The organization of the work and fulfillment of the research tasks were conducted in several stages.

During the **First Stage** (September 2023 – December 2023), we performed some tasks related to the preliminary preparation of the experimental work and clarification of the theoretical framework of the research issues. We also conducted two questionnaire surveys with world-class athletes practicing Kyokushin Karate, kickboxing, Muay Thai, and Kudo.

During the **Second Stage** (January 2024 – June 2024), we developed the model of the pedagogical experiment and created sets of exercises to be implemented in the training process.

We specified the devices and equipment for registering the strike force in the combat sports Kyokushin Karate, kickboxing, Muay Thai, and Kudo.

During the **Third Stage** (July 2024 – December 2024), we conducted a pedagogical experiment with 30 athletes practicing the combat sports of Kyokushin Karate, kickboxing, Muay Thai, and Kudo. We filmed the performed strikes and performed a biomechanical analysis.

During the **Fourth Stage**, we processed the information obtained from the experimental research and wrote the dissertation.

## **RESEARCH METHODS**

### **Analysis of Literary Sources**

Before conducting the main experiment and throughout the research, we studied numerous literary sources in Cyrillic and Latin, which outline the major characteristics of combat sports, their significance, and the basics regarding the development of the strike force in combat sports.

### **Inquiry**

We carried out two inquiries among 18 world and continental champions in Kyokushin Karate, kickboxing, Muay Thai, and Kudo. The first one included 13 questions related to the means and methods of technical preparation, primarily focusing on how to increase the speed-strength indicators of the strike through technical execution. The second questionnaire included 12 questions related to the means and methods of physical preparation, primarily focusing on methods for increasing the strike force in combat sports.

### **Biomechanical Analysis**

Strikes in combat sports were recorded using two standard video cameras with a frame rate of 25 frames per second, which determines a time interval between frames of 0.04 seconds. The use of this type of camera provides entirely satisfactory results, considering the natural frequency of the movements being studied. The optical axis of the camera was perpendicular to the plane in which the movements were performed.

The recordings of the strikes in combat sports were digitized and edited to include one full movement cycle. The video files were processed using a video-computer analysis system (Arakchiyski, 2002), which allows for the registration of vertical and horizontal spatial coordinates of selected points on the subjects' bodies while performing the specified exercises. Subsequently, the coordinates

were processed using a corresponding software module of the system, which enables the determination of the kinematic characteristics of the analyzed points as a function of time. To smooth the digitized data, a low-frequency digital filter with a cutoff frequency of 10 Hz and partial damping was used in advance. In cases where the registered points were temporarily hidden, a modified cubic spline interpolation was applied to restore the missing data. For a more accurate determination of the temporal structure, the raw data were reconstructed using modified cubic spline interpolation with a sampling frequency of 50 Hz, resulting in a time interval of 0.02 seconds between recorded points.

To analyze the dynamic structure of the studied strikes in combat sports, the system's capability for automated biomechanical analysis of internal force fields was used, without the need for a force plate. Based on the spatiotemporal characteristics obtained from the kinematic analysis and the athlete's anthropometric data, the system allows for the determination of force vectors acting in the studied segments. For each strike with either an upper or lower limb, an Excel file is generated, enabling flexible interpretation and graphical representation of the results.

### **Apparatus Methods**

To achieve the goals and tasks we set, we used a device for measuring the force of strikes with both upper and lower limbs. The entire group of subjects was tested on a tactile impact pad, model "PowerKube."

The technical specifications of the "PowerKube" tactile impact pad include controlled compression technology, which effectively manages the pad's compression up to 12 cm, making it suitable for measuring all types of strikes. It precisely measures the three qualities of force, speed, and endurance of strikes in combat sports. The device records strike power in watts (W), kinetic energy in joules (J), and force in franklins (f).

The research platform is a cube with built-in sensors and a striking surface measuring 305 mm x 305 mm x 305 mm. It features a stainless steel support structure – a stable base for the striking platform that can be locked at any height up to 2 meters and allows for rapid adjustment at any angle of attack, over a radius of more than 270 degrees.

The equipment also includes a 109 cm/43" 4K Interactive View Board display – an intuitive 10-point touchscreen compatible with finger, stylus, and glove input, with an adjustable tilt of up to 40 degrees, and a scratch-resistant 7H hardness screen. Data obtained can be shared via USB-C connectivity.

The research equipment is operated by a high-performance mini-computer with a pre-installed and registered operating system and graphical user interface, fully compatible with the software managing the tactile impact pad.

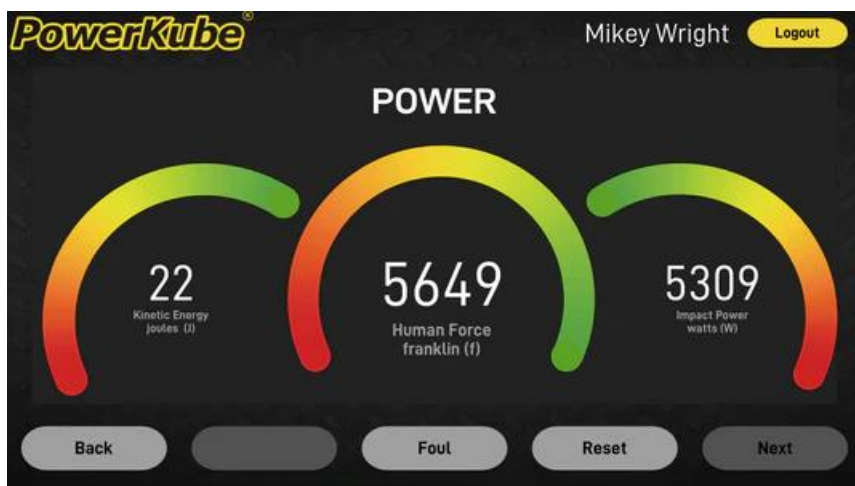
The software includes a specialized coaching module that tracks force, speed, and endurance, allows for the creation of unlimited athlete user profiles, setting of weight categories, comparison of performances across different categories, and analysis of various strikes from combat sports. It also supports the addition of strikes not included in the base software.

For the purposes of this research, we added the following strikes: gyaku tsuki (reverse punch with the rear hand from karate), kage tsuki (hook to the torso), and shita tsuki (uppercut). Among the leg strikes, we added hiza geri (knee strike).



**Figure 1.** *Research Equipment PowerKube*

The patented metric of PowerKube, Impact Power, combines power (measured in watts) with energy (measured in joules) to form a single, concise indicator that accurately reflects a combat athlete's striking force. By merging the speed-related impact (power) with the efficiency of energy transfer during the strike (energy), Impact Power provides a definitive measure of an athlete's ability to deliver powerful and effective strikes, offering a clear and comprehensive picture of their striking capabilities.



**Figure 2.** *Equipment display showing the values of the indicator “power”*

## **Sports-Pedagogical Testing**

The primary task was to assess the effectiveness of executing basic strikes in various combat sports and to compare the results with sports achievements. We applied an ascertaining experiment.

The research groups consisted of 30 male athletes practising Kyokushin Karate, kickboxing, Muay Thai, and Kudo. They were divided into two groups.

1. The group of elite athletes “champions”, consisting of 16 men—medal holders and champions from World and European Championships, and many-time winners of professional matches.
2. The group of athletes on “National level”, consisting of 14 men, ranking in the top 10 of the National Championships.

The sports-pedagogical testing was conducted from July 2024 to December 2024 at Senshi Gym facilities in Varna, where the PowerKube equipment was purchased and mounted for the purposes of this research.

Based on the conducted biomechanical analysis, three upper limb strikes and three lower limb strikes commonly used in the combat sports of Kyokushin Karate, Kickboxing, Kudo, and Muay Thai were selected. In preparation for the sports-pedagogical testing, a profile was created for each participant, which included their name, height, weight, type of sport, and sports achievements. After a thorough general and specialized warm-up, the main phase of the testing was conducted. Each subject performed the selected strike 10 times with maximum speed and force.

The strikes were executed after a light and sound signal provided by the PowerKube equipment. After the completion of the testing, the collected data were saved to a digital storage device and processed using mathematical and statistical methods.

The identified factors and dependencies are presented with their qualitative (verbal), quantitative, and statistical characteristics.

A video-computer analysis system was used to register the kinematic characteristics.

The first part of the research focused on studying the biomechanical features of hand and leg strikes in combat sports. The biomechanical characteristics of the striking motion within an open kinematic chain and the extension of the lower limbs during upper and lower limb strikes were investigated. The biomechanics of limb extension ensure the acceleration of the striking segment, while the extension of the lower limbs primarily contributes to the integrated acceleration of the entire body.

Kyokushin Karate competitors performed basic hand strikes from a stationary stance – Gyaku tsuki chudan (rear-hand straight punch to the torso), Shita tsuki (uppercut to the torso), Kage tsuki (hook punch to the torso), as well as basic leg strikes used in karate: Gedan mawashi geri (low kick), Mawashi geri chudan (roundhouse kick to the torso), and Hiza geri (knee strike). It is essential to note that Kyokushin karate athletes performed hand strikes without protective gear or gloves.

Athletes in kickboxing, kudo, and Muay Thai performed the following upper limb strikes: right or left straight punch (to the head), uppercut, hook, and the following lower limb strikes: low kick (to the thigh), mawashi geri (roundhouse kick to the torso), and knee strike.

Strikes were executed from the preferred fighting stance, using either the left or right arm. After performing the strike, the athlete would return to the starting fighting stance at an appropriate distance, based on their anthropometric parameters.

The experiment examined the changes in the horizontal component of velocity at the following key points on the athlete's body: ankle, knee, hip joint, shoulder, elbow, and wrist of the striking arm. Movements of the non-striking arm, which supports the reversal movement, were also analyzed. Subsequently,



the maximum values of the horizontal velocity component for the listed body points were determined.

Mathematical calculations were used to determine the velocities and accelerations of the recorded points, as well as the temporal structure of the exercises and key dynamic and energetic parameters.

## **Math-Statistical Methods**

### **1. Frequency Analysis**

### **2. Variation Analysis**

- Mean values ( $\bar{X}$ ).
- Minimum ( $X_{\min}$ ) and maximum ( $X_{\max}$ ) values of the indicators.
- Range (R).
- Standard deviation (S).
- Error in the arithmetic mean ( $m_x$ ).
- Coefficient of variation (V%).
- Skewness (a) and kurtosis (e).

### **3. Correlation analysis**

- Simple linear correlation coefficient ( $r$ ) for natural and normative values of the indicators.

Interval evaluation of the correlation coefficient at a significance level  $\alpha = 0.05$  and  $\alpha = 0.01$ .

### **4. U-criterion of Mann-Whitney**

### **5. Dispersion analysis - Kruskal-Wallis**

The statistical analysis of the data was performed using SPSS V.23 and Excel 2016.

## **ANALYSIS OF THE RESULTS**

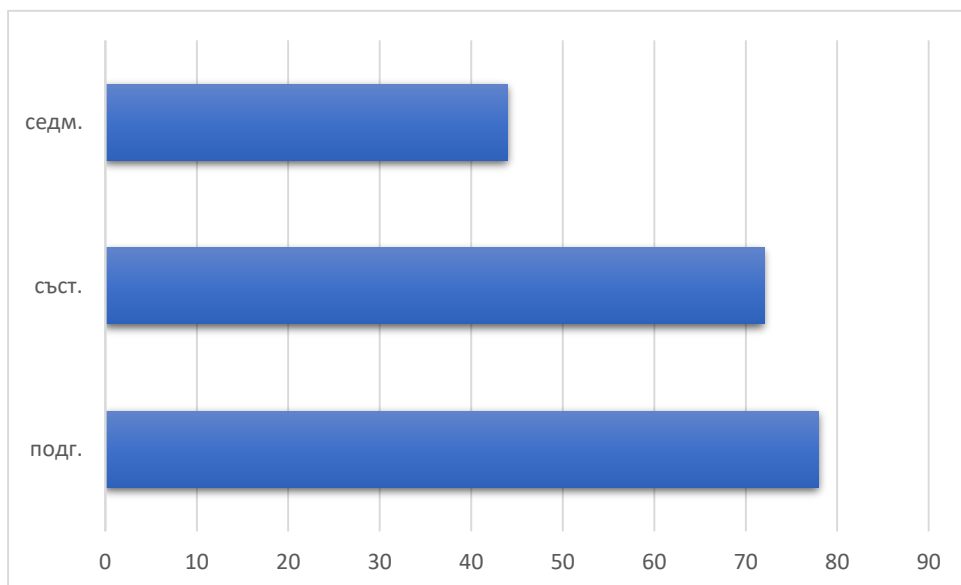
### **ANALYSIS OF QUESTIONNAIRE DATA**

To the question: **"Do you use the punching bag as a training method during the preparatory period, competition period, and the week of the competition to develop special endurance and striking force? Please specify the number of training sessions per week, number of sets (rounds), work and rest intervals."**

Seventy-eight percent of the respondents answered "Yes", while 22% answered "No". The majority of champions in combat sports such as Kyokushin Karate and Kickboxing train with a punching bag during the preparatory period. The reported work intervals ranged from 20 to 1800 seconds (30 minutes), with the most common interval being 180 seconds (3 minutes), cited by 46% of respondents. Rest intervals between rounds ranged from 10 to 180 seconds, with 60 seconds being the most frequently cited, by 50%. Regarding the number of sets (rounds), the values 3, 10, and 20 were each selected by 17% of respondents.

During the competition period, 72% of athletes reported using the punching bag to improve their striking power. Thirty-three percent reported a work interval of 180 seconds (3 minutes). Forty-four percent used a rest interval of 60 seconds. The number of sets (rounds) 2, 3, and 8 was reported by 18% of respondents each.

During the week of the competition, 44% stated that they use the punching bag in their training to increase strike power, and 50% reported using 3-minute work intervals.



**Figure 3.** *Amount of work with a punching bag during the different stages of preparation*

## **STRUCTURE AND BIOMECHANICAL ANALYSIS OF THE MAIN UPPER AND LOWER LIMB STRIKES IN THE COMBAT SPORTS OF KYOKUSHIN KARATE, KICKBOXING, KUDO, AND MUAY THAI**

### **Biomechanical analysis of a lower limb kick at thigh level – gedan mawashi (low kick)**

Figure 4 illustrates the sequence of movements in the lower limb kick at thigh level – gedan mawashi.



**Figure 4.** *Movement sequence in the lower limb kick gedan mawashi (low kick)*



**Figure 5.** *Point trajectory of the kinematic chain in the lower limb kick at thigh level – gedan mawashi.*

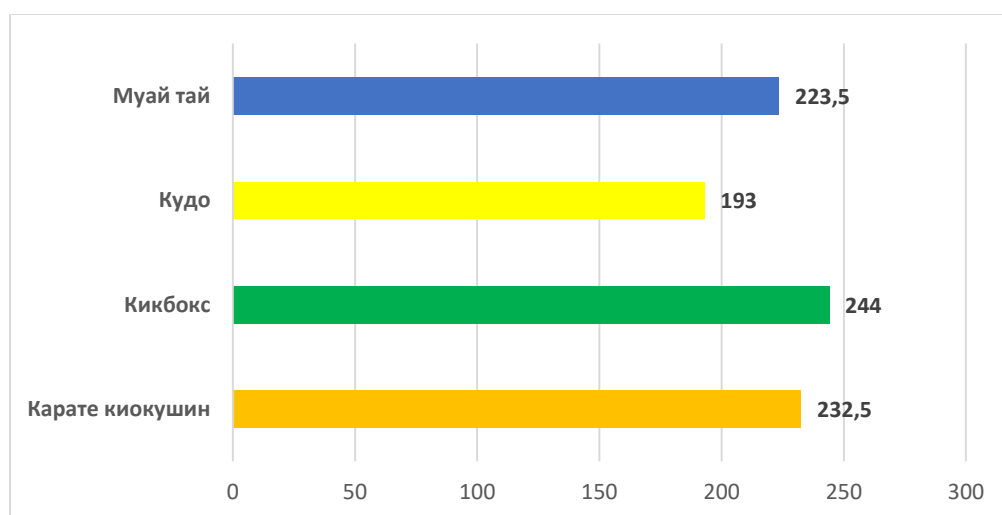
The movement begins with a rotation of the pelvis, followed by extension at the hip and knee joints. The mass of the leg and the angular velocity of the pelvis play a crucial role in generating kinetic energy. The support reaction from the standing leg provides a base for the transmission of momentum.

The trajectory follows the circular arc of the kick, with the greatest range observed in the final phase of the kick. At this point, the impact between the body and the target results in the transfer of accumulated force and momentum.

## VARIATION ANALYSIS BASED ON SPORTS

The average force value of the analyzed strikes, measured in franklins, was  $54,996 \pm 29,827.4$  F; the average kinetic energy was  $252 \pm 82$  J, and the average strike power was  $31,391 \pm 15,190.9$  W. For all three strength-related indicators, the coefficient of variation indicated high dispersion and significant heterogeneity in the sample. The skewness coefficients for the measured force indicators show asymmetrical distributions. In contrast, the kurtosis for force and kinetic energy suggests the sample has a sharp peak, whereas for power, it has a flatter peak.

Since some indicators were found to deviate from a normal distribution, medians will also be used for comparison, as they provide more informative insights. Figure 6 compares the medians of the kinetic energy released during strikes in combat sports, measured in joules (J).



**Figure 6.** *Kinetic energy of the strikes in the different combat sports*

From the data presented in Figure 6, we observe that kickboxing athletes achieved the highest kinetic energy values, 244 J. The lowest values were recorded by Kudo athletes – 193 J.

The differences between the values for Kyokushin karate and Muay Thai athletes were 9 J.

## **CORRELATION ANALYSIS BASED ON SPORTS**

There was a very strong correlation between force and power among the analyzed athletes. As the power generated during a strike increased, so did the force. The explained variance is 96.43%, and the uncertainty coefficient is 3.57%. A moderate positive relationship is observed between kinetic energy and force, indicating that as the force produced in a strike increases, so does the kinetic energy associated with it. The coefficient of determination is 11.02%, with an unexplained variance of 88.98%. For other measured indicators, such as kinetic energy, no correlation is observed with the first two indicators.

Correlation dependencies in kickboxing: A very strong correlation exists between force and power ( $r = 0.977$ ) among the analyzed subjects. As the generated strike force increases, so does the power. The coefficient of determination is 95.45%, and the uncertainty coefficient is 4.55%. No correlation is observed between kinetic energy and the other two variables.

In Kudo, there is also a strong correlation between power and force ( $r = 0.990$ ), suggesting that increasing the striking force will also increase the power output. The explained variance is 98%, and the unexplained variance is 2%. No such correlation is observed with kinetic energy. A strong relationship is also seen between weight and height among the analyzed Kudo athletes.

Correlation dependencies in Muay Thai: A very strong correlation exists between power and force ( $r = 0.985$ ). We can conclude that increasing the applied force in Muay Thai strikes also leads to increased power. The coefficient of determination is 97%, and the uncertainty coefficient is 3%. Again, no such relationship is seen with kinetic energy. There is a correlation between height and weight, as well as between weight and age, among the studied athletes.

## **DISPERSION ANALYSIS BASED ON SPORTS**

Tracking the effect of strike force application across various combat sports necessitates a comparison among the four disciplines—Kyokushin Karate, Kickboxing, Muay Thai, and Kudo. Due to the smaller sample sizes of elite athletes in some sports and the non-normal distribution of the data, a non-parametric method for multiple comparisons—the Kruskal-Wallis test—was applied. Comparing all four combat sports simultaneously will help identify differences in the levels of applied force and provide some recommendations for its improvement.

### **U-Criterion of Mann-Whitney for the Kick Technique Mawashi Geri Chudan**

Given the specifics and characteristics of non-parametric dispersion analysis, additional pairwise comparisons using the Mann-Whitney U test were conducted to uncover differences between groups. A key feature here is that each group is compared individually against each of the others.

For the Mawashi Geri technique, differences were found only in the kinetic energy produced during the strike. The result  $U = 543.500$  (sig.  $< 0.05$ ) confirms a significant difference in kinetic energy between kickboxing and Kudo athletes. When comparing kickboxing and Kyokushin Karate, the Mawashi Geri technique again showed differences only in kinetic energy, with no significant differences in force or power, confirmed by sig.  $> 0.05$ .

A comparison of kickboxing and Muay Thai athletes revealed no statistically significant difference in kinetic energy. However, the force and power of the technique did differ significantly, as confirmed by sig.  $< 0.05$ .

The comparison between the sports of Kyokushin Karate and Muay Thai revealed that the athletes differ significantly in the execution of the mawashi geri technique. The observed differences are present in all three measured indicators, as confirmed by sig.  $< 0.05$ .

The comparison between Kyokushin Karate and Kudo showed that the execution of the mawashi geri technique does not differ across the three studied indicators between athletes of the two combat sports. This may be due to the similar execution of the technique in both Kyokushin Karate and Kudo, as well as the comparable training programs followed by elite athletes in these sports. The mawashi geri kick shows differences in all three studied indicators among elite athletes in Kudo and Muay Thai.

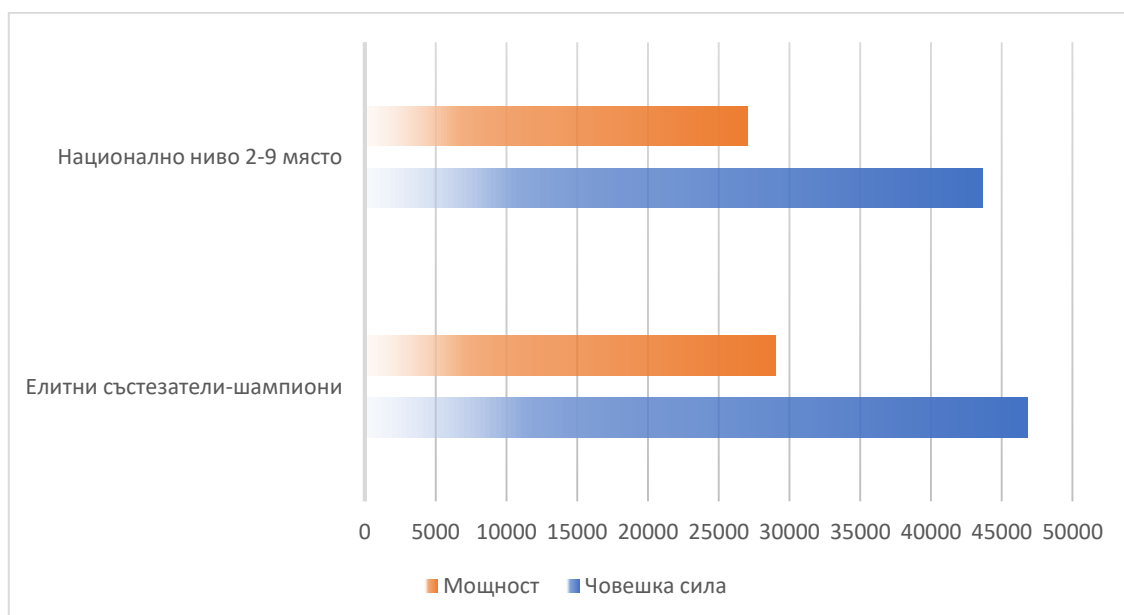
### **VARIATION ANALYSIS OF THE GROUP “ELITE ATHLETES” AND THE GROUP “NATIONAL LEVEL” ATHLETES**

Summary Values for the "Champions" Group for the Six Studied Strikes. We determine the average values for force – **56,629±30,318.9** Franklin units (F), kinetic energy – **252±72.9** J, and power – **32,299±15,682.8** W. Notably, there is a wide range in kinetic energy values, from a minimum of 120 J to a maximum of 484.3 J, resulting in a range of 364.3 J. Of the 16 individuals studied in this group, all successfully performed all six techniques. The coefficient of variation for force is 53.5%, indicating a highly heterogeneous sample with significant dispersion of values. For kinetic energy, the coefficient of variation (V) is 29.9%, indicating that the sample is reasonably homogeneous. For power, the coefficient of variation is 48.5%, suggesting again that the dispersion is large and the sample is quite heterogeneous.

Summary Average Values for Force in the "National Level" Group of Competitors. For force, the average value is **53,130** F. With a standard deviation of 29,324.9 and a coefficient of variation of 55.1%, we can conclude that the sample is highly heterogeneous with considerable dispersion of values. For kinetic energy, the average value with standard deviation is **252 ± 91.3** J, and  $V = 36.3\%$ , indicating a highly heterogeneous sample with a large dispersion of values. Remarkably, the maximum achieved kinetic energy in the study was



574.8 J. Once again, the data show that the average power is **30,354 W**, with a coefficient of variation of 48.2% and a standard deviation of 14,632.9, confirming that the sample is highly heterogeneous. Skewness in all three indicators indicates a non-symmetrical distribution, with a sharp peak for force and kinetic energy, and a more rounded peak for power. Figure 7 presents a comparison of the average values of human force and power in strikes among combat sports participants in the “Elite Competitors – Champions” group and the “National Level 2nd to 9th Place” group.



**Figure 7.** *Values of human strength and power when comparing the two groups*

From Figure 7, it is clear that when comparing the indicators of force and power between the two groups, the values are almost identical, with a slight advantage for the "Elite Competitors – Champions" group. The force exerted by the elite competitors is greater than that of the national-level group.

In the strength-related indicators (force, kinetic energy, and power), there is significantly greater dispersion and strong heterogeneity in some sports (especially Kudo and Muay Thai), which indicates varying technical and physical potential in executing strikes.

## **REGULATORY FRAMEWORK FOR EVALUATION OF STRENGTH ABILITIES OF ATHLETES PRACTISING KYOKUSHIN KARATE, KICKBOXING, MUAY THAI, AND KUDO**

To achieve the aim of the dissertation and improve the effectiveness of the strength components in strikes for combat sports, a summarized regulatory framework for assessment has been developed.

Measuring the basic techniques in karate under strength conditions and with instrumental indicators is a novelty for combat sports athletes in Bulgaria.

Two methods have been used to present evaluations of athletic performance: a point-based score (T-score scale) ranging from 0 to 50, and a verbal grade ranging from "Poor" to "Excellent". The best sports performances receive 50 points and a verbal grade of Excellent. As is known from statistics, practically 99.73% of cases fall within a score range of 10 to 40 points.

T-scores are a standardized measure of evaluation, which allows for the comparison of scores across different tests, as well as the averaging of scores from various measurement scales for a given quality, and across different groups of participants.

For each test, the corresponding points for the athlete are assigned based on normative tables. The overall evaluation is obtained by calculating the arithmetic mean of the total points and the number of tests included in the assessment.

**Таблица 1.** *Regulatory Framework for the Evaluation of the Mawashi Geri Chudan Kick, Category 70–80 kg*

	<b>HUMAN STRENGTH</b>	<b>KINETIC ENERGY</b>	<b>POWER</b>
<b>50</b>	135131,55	390,08	74427,67
<b>49</b>	132194,80	383,25	72951,15
<b>48</b>	129258,05	376,42	71474,63

47	126321,30	369,59	69998,11
46	123384,55	362,76	68521,59
45	120447,80	355,93	67045,07
44	117511,05	349,10	65568,55
43	114574,30	342,27	64092,03
42	111637,55	335,44	62615,51
41	108700,80	328,61	61138,99
40	105764,05	321,78	59662,47
39	102827,30	314,95	58185,95
38	99890,55	308,12	56709,43
37	96953,80	301,29	55232,91
36	94017,05	294,46	53756,39
35	91080,30	287,63	52279,87
34	88143,55	280,80	50803,35
33	85206,80	273,97	49326,83
32	82270,05	267,14	47850,31
31	79333,30	260,31	46373,79
30	76396,55	253,48	44897,27
29	73459,80	246,65	43420,75
28	70523,05	239,82	41944,23
27	67586,30	232,99	40467,71
26	64649,55	226,16	38991,19
25	<b>61712,80</b>	<b>219,33</b>	<b>37514,67</b>
24	59290,05	212,36	36140,45
23	56867,30	205,39	34766,23
22	54444,55	198,42	33392,01
21	52021,80	191,45	32017,79
20	49599,05	184,48	30643,57
19	47176,30	177,51	29269,35
18	44753,55	170,54	27895,13
17	42330,80	163,57	26520,91
16	39908,05	156,60	25146,69

15	37485,30	149,63	23772,47
14	35062,55	142,66	22398,25
13	32639,80	135,69	21024,03
12	30217,05	128,72	19649,81
11	27794,30	121,75	18275,59
10	25371,55	114,78	16901,37
9	22948,80	107,81	15527,15
8	20526,05	100,84	14152,93
7	18103,30	93,87	12778,71
6	15680,55	86,90	11404,49
5	13257,80	79,93	10030,27
4	10835,05	72,96	8656,05
3	8412,30	65,99	7281,83
2	5989,55	59,02	5907,61
1	3566,80	52,05	4533,39
0	1144,05	45,08	3159,17
<b>Verbal evaluation of the results</b>			
<b>Excellent – 6</b>	over 111 637,55	over 335,44	over 62 615,51
<b>Very good – 5</b>	from 111 637,55 to 88 143,55	from 335,44 to 280,80	from 62 615,51 to 50 803,35
<b>Good – 4</b>	from 88 143,54 to 39 908,05	from 280,79 to 156,60	from 50 803,34 to 25 146,69
<b>Average – 3</b>	from 39 908,04 to 20 526,05	from 156,59 to 100,84	from 25 146,68 to 14 152,93
<b>Poor – 2</b>	below 20 526,05	below 100,84	below 14 152,93

## CONCLUSIONS

1. The analysis of survey data collected from elite combat sports athletes shows a clear trend regarding the effectiveness of specific training tools in improving technical skill, endurance, and strike force. It is noted that the regular and methodically organized use of these tools leads to movement automation, improvement of "signature techniques," and increased confidence during competitions. The survey reveals the strong practical value of an integrated approach to physical and technical training in combat sports, emphasizing the need for a systematic, phase-oriented training process.
2. The biomechanical analysis shows that an effective strike depends on the synergy between joints, with rotational body movements being the primary generators of energy. In upper limb strikes (hook punch) and lower limb strikes (gedan mawashi – “low kick”), peak linear and horizontal velocities are observed in the final phase, which confirms that proper sequencing and timing are crucial for strike power.
3. It was established that combat sports significantly differ in the strength characteristics of their strikes. The highest force and power values are observed among kickboxing and Kyokushin karate athletes, particularly in lower limb techniques. More noticeable differences are seen in upper limb strikes, which show greater variation compared to lower limb strikes.
4. The use of instrumented methodology enables the objective and standardized measurement of strike strength characteristics, thereby significantly enhancing the accuracy of strength assessment in combat sports.
5. The developed regulatory framework, featuring a T-score scale and verbal evaluations, enables comparison among athletes from different combat

disciplines. It serves as a foundation for scientifically grounded management of the training process.

6. Improvement in strike force is a prerequisite for greater success in competitions of various levels and for achieving higher athletic performance.

## **RECOMMENDATIONS**

1. Emphasize individualized physical preparation focused on developing strike power, using effective methods proven by elite combat sports athletes, including means such as punching bags, focus mitts, and shadow boxing with dumbbells.
2. Utilize biomechanical and video analysis to identify and correct technical inaccuracies in striking movements, particularly in the training process. It is beneficial to apply specialized exercises that aim to improve the kinetic chain by enhancing synchronization between body segments.
3. Emphasize the optimal use of ground reaction force as a means of transferring energy through the body to the striking limb.
4. Athletes with lower strike force should be included in training programs focused on developing explosive strength and power, given the proven strong correlation between force and power.
5. Measure and monitor strike force throughout different training phases using statistical tools (U-test, variance, and correlations) and apply the T-score scale and verbal evaluations to manage the training process more objectively.

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