

COMPLIANCE OF THE RESISTANCE CAPACITY OF ELITE ATHLETES
FROM DIFFERENT TYPES OF COMBAT SPORTS WITH THE COMPETITIVE
DEMANDS OF MIXED MARTIAL ARTS

ВІДПОВІДНІСТЬ РІВНЯ РЕЗИСТЕНТНОСТІ КВАЛІФІКОВАНИХ
СПОРТСМЕНІВ З РІЗНИХ ВИДІВ ЄДИНОБОРСТВ ЗМАГАЛЬНИМ
НАВАНТАЖЕННЯМ MIXED MARTIAL ARTS

Savenko A.¹, Chernozub A.², Aloshyna A.³

¹ Admiral Makarov National University of Shipbuilding, Mykolaiv, Ukraine

^{2,3} Lesya Ukrainka Volyn National University, Lutsk, Ukraine

² The Scientific Research Center of Modern Kinesiology, Ukraine

¹ ORCID: 0000-0002-3124-2673

² ORCID: 0000-0001-6293-8422

³ ORCID: 0000-0001-6517-1984

DOI <https://doi.org/10.32782/2522-1795.2025.19.3.13>

Abstracts

Purpose. To determine the matching of resistance capacity of elite athletes practicing judo, Muay Thai, Greco-Roman wrestling, and boxing, to the loads that are similar in intensity and duration to those encountered in competitive Mixed Martial Arts (MMA).

Material and Methods. 90 elite male athletes were examined (33 candidates for the Master of Sport and 57 Masters of Sport), aged 15–16 years. Five groups of athletes were formed: judokas, Muay Thai fighters, boxers, MMA athletes, and Greco-Roman wrestlers. Two test loads were proposed. During Test Load 1, participants performed alternating exercises for 3 minutes, a hanging leg raise on a horizontal bar with legs held straight at a 90° angle, followed by push-ups with full arm flexion and extension. During Test Load 2, each group performed the most powerful and technically demanding combination of movements specific to their respective combat sport for 20 seconds. Heart rate variability (HRV) spectral analysis indices were used to evaluate the athletes' resistance to the test loads. Assessment included both the basal HRV parameters (VLF, LF, HF, LF/HF) and the changes these parameters exhibited following the test loads.

Results. Test Load 1 led to a shift in autonomic balance toward parasympathetic regulation, accompanied by an increase in central regulatory activity, in the examined groups of boxers, Greco-Roman wrestlers, and MMA fighters. In the Muay Thai group, a similar training load resulted in enhanced vagal influence on the sinoatrial node alongside diminished central regulation of sinus rhythm. In comparison with baseline HRV, the Muay Thai and MMA athletes demonstrated reduced central regulation before Test Load 1 and one hour after recovery. Following Test Load 2, Muay Thai boxers and Greco-Roman wrestlers exhibited a shift in autonomic balance toward parasympathetic regulation, along with an increase in central regulatory activity. The boxer and MMA groups showed increased vagal influence on the sinoatrial node in response to Test Load 2, which reflected the technical elements of their respective combat sports, reflecting heightened parasympathetic activity.

Conclusions. The results indicate that in 75% of elite athletes from various combat sports, the level of physiological resistance is insufficient to effectively implement short-term adaptation mechanisms during competitive MMA loads. A shift of autonomic balance toward parasympathetic activity, even when accompanied by reduced cardiac regulatory tension, does not necessarily indicate effective short-term adaptation. Additional monitoring of changes in the central regulation of sinus rhythm provides insight into whether the stressor intensity aligns with the individual's functional capacity, allowing for timely interventions to prevent possible adaptive failure.

Key words: combat sports, resistance, test loads, spectral heart rate analysis, adaptation, elite athletes.

Мета. Визначити відповідність рівня резистентності організму кваліфікованих спортсменів з дзюдо, тайландського боксу, греко-римської боротьби та боксу навантаженням, які за інтенсивністю та тривалістю подібні до змагальних в Mixed Martial Arts (MMA).

Матеріал і методи. Обстежено 90 кваліфікованих спортсменів-чоловіків (33 кандидати в майстри спорту та 57 майстрів спорту) віком 15–16 років. Сформовано 5 груп спортсменів: дзюдоїсти, тайландські боксери, боксери, бійці ММА та борці греко-римського стилю. Запропоновано два тестові навантаження: № 1 (протягом 3 хв виконували по чергово вис на поперечині з утриманням прямих ніг під кутом 90° та згинання та розгинання рук в упорі лежачи); № 2 (протягом 20 с кожна з груп виконувала найбільш потужну та складну комбінацію технічних елементів зі свого виду єдиноборств). Для визначення рівня резистентності обстежених спортсменів до тестових навантажень використовували показники спектрального аналізу варіабельності серцевого ритму (BCP). Оцінювали базальний рівень показників BCP (VLF, LF, HF, LF/HF) та зміну їх параметрів у відповідь на задані тестові навантаження.

Результати. Встановлено, що серед обстежених груп боксерів, борців греко-римського стилю та бійців ММА після тестового навантаження № 1 спостерігаємо зміщення вегетативного балансу в бік парасимпатичної регуляції та одночасне посилення центрального контуру. Виявлено, що лише у групі тайландських боксерів у відповідь на подібні навантаження відбулося посилення вагусного впливу на синусовий вузол і послаблення центрального контуру регуляції синусового ритму. Досліджено, що порівняно з базальним рівнем BCP до початку тестового навантаження № 1 та після години відпочинку лише в групах тайландських боксерів та бійців ММА спостерігаємо послаблення центрального контуру. Після тестового навантаження № 2 у тайландських боксерів та борців греко-римського стилю виявили зміщення вегетативного балансу в бік парасимпатичної регуляції та одночасне посилення центрального контуру регуляції. Виявлено, що лише серед груп боксерів та бійців ММА у відповідь на тестове навантаження № 2, які за змістом та структурою ідентичні їх видам єдиноборств, посилюють вагусний вплив на синусовий вузол унаслідок підвищення парасимпатичної активності.

Висновки. Отримані результати свідчать, що у 75 % кваліфікованих спортсменів з різних видів єдиноборств рівень резистентності організму не дає змоги ефективно реалізувати механізми короткочасної адаптації під час навантажень ММА, наближених до змагальних. Зміщення вегетативного балансу в бік парасимпатичної активності у спортсменів на тлі зниження напруження регуляції ритму серця не завжди свідчить про ефективну реалізацію процесів короткочасної адаптації. Додатковий контроль за напрямком зміни центрального контуру регуляції синусового ритму дає можливість оцінити адекватність величини стресового подразника функціональним можливостям, щоб вчасно протидіяти можливим проявам зриву адаптації.

Ключові слова: єдиноборства, резистентність, тестові навантаження, спектральний аналіз ритму серця, адаптації, кваліфіковані спортсмени.

Introduction. At the current stage of mixed martial arts development, the issue of identifying fighters capable of delivering high-profile and dynamic performances remains one of the most debated topics among a wide range of scholars and practitioners [3; 8]. Efforts to find effective ways to address this issue are being undertaken not only by MMA tournament organizers but also by several interdisciplinary teams composed of leading experts in this sport. The core problem lies in the fact that most current MMA athletes were formerly elite athletes in combat sports [2; 12].

Consequently, the structure and content of training systems, whether functional, strength-oriented, or technical-tactical, in Muay Thai, judo, sambo, and other combat sports differ significantly from the classical approach in MMA [7; 16]. As a result, during fights, especially when facing opponents with entirely different technical arsenals, athletes often experience

a lack of sufficient adaptive reserves needed to accomplish tactical tasks effectively [9; 15]. The high level of resistance developed over years of training and competition in a single combat sport may prove inadequate under the demands of an MMA bout [3; 11; 12].

Mixed martial arts training systems incorporate a wide range of test protocols designed to evaluate athletes' functional capacities [4; 10]. However, in most cases, the selection of test loads depends on the coaching staff of MMA clubs, who are often representatives of entirely different types of combat sports [5; 11]. Among researchers, there is an ongoing discussion regarding the need to develop a clear mechanism for defining criteria to assess the required level of adaptive reserves in athletes from other combat sports who compete in MMA bouts [13; 15].

To address this challenge in practice, researchers employ a range of physiological and biochemical methods to evaluate adaptive and com-

pensatory mechanisms during both training and competition [1; 4; 16]. Nevertheless, the task of determining effective strategies for optimizing training loads in these athletes, regarding their individual resistance levels, demands further study.

Purpose. To determine the matching of resistance capacity of elite athletes practicing judo, Muay Thai, Greco-Roman wrestling, and boxing, to the loads that are similar in intensity and duration to those encountered in competitive Mixed Martial Arts (MMA).

Material and Methods. The study involved 90 elite male athletes (33 Candidates for the Master of Sport and 57 Masters of Sport), aged 15–16 years, representing various combat sports. In accordance with the research aim and objectives, the participants were divided into five groups: judokas ($n = 16$), Muay Thai fighters ($n = 18$), boxers ($n = 16$), MMA athletes ($n = 22$), and Greco-Roman wrestlers ($n = 18$). A distinguishing feature of these athletes is that all of them have actively trained in MMA and participated in MMA competitions over the past year.

The study was conducted in 2025 at the branches of the Research Center for Modern Kinesiology “KINEZUS” (Mykolaiv, Odesa, and Chernivtsi, Ukraine). The Bioethics Committee of Lesya Ukrainka Volyn National University, Ukraine, approved the research design. After being informed about the risks and benefits of the study, all participants signed a written informed consent form, prepared in accordance with the ethical standards of the Declaration of Helsinki.

Test Loads. To assess the functional capacities of the study participants and, accordingly, the level of resistance of their physiological systems to various intensity, volume, and duration loads, two test protocols were proposed.

Test Load 1 was specifically designed to differ structurally and contextually from competitive MMA conditions, yet match them in duration. The magnitude of the proposed stressor was intended to differ from the typical training loads associated with the type of combat sports in which athletes had previously achieved their qualifications.

Test Load 1 consisted of two exercises: a hanging leg raise on a horizontal bar with legs held straight at a 90° angle (parallel to the floor), and push-ups with controlled tempo (2 seconds for the concentric phase and 4 seconds for the eccentric phase). Each exercise was performed until a noticeable change in technique or body position occurred, indicating muscle fatigue caused by the depletion of energy reserves in the working muscles. The exercises were performed alternately for a total duration of 3 minutes. The number of sets (i.e., transitions between exercises) depended solely on the individual adaptive reserves of each athlete’s body. The rationale for selecting these specific exercises in Test Load 1 was based on their ability to simultaneously recruit a large number of muscle groups (both synergists and stabilizing muscles). Effective execution of this test requires a sufficiently high level of intramuscular coordination, as well as reserves of creatine phosphate and muscle glycogen in the working muscles [4; 12].

Test Load 2 was designed to simulate the types of physiological demands that occur during offensive phases in MMA bouts. Participants performed, for 20 seconds, their most powerful and simultaneously most impactful combination of technical elements specific to the combat sport they practiced before MMA. The choice of a 20-second duration was based on the observation that most powerful attacks or counterattacks in MMA, judo, Muay Thai, and other combat sports typically do not exceed this time interval [15].

It is important to note that MMA integrates a broad spectrum of strikes, throws, and other technical elements drawn from various modern combat sports [13; 16]. Judokas performed a series of two throws, *Ippon Seoi Nage* and *Tsuri Goshi*, within the given time, executing them at maximum speed and force. Greco-Roman wrestlers performed the *Suplex* exercise over 20 seconds in a relay format, with four athletes of identical weight class alternating continuously. Boxers, Muay Thai fighters, and MMA athletes executed all strikes on a 90-kg punching bag, applying maximal force and speed while maintaining proper technique.

Thus, boxers performed alternating *Cross* and *Hook* punches, which are specific to their type of combat sport. Muay Thai fighters used a series of high-intensity, energy-demanding strikes, including *low kicks*, *jumping knee strikes*, and *elbow strikes*. MMA athletes (who had trained exclusively in mixed martial arts for several years) employed alternating *reverse side kick* and *roundhouse kick* during the test period.

Heart Rate Variability. To assess changes in spectral indicators of heart rate variability (HRV), the Polar V800 heart rate monitor was used, which was worn on the athlete's wrist during the study. An accompanying H10 chest sensor, positioned at the solar plexus, recorded RR intervals (intervals between consecutive heartbeats) both at rest and after the test loads. The device is manufactured by Polar Electro Oy, Finland.

Data processing and protocol generation were carried out using Polar Flow software and Kubios HRV Standard 3.5.0. During the analysis of HRV spectral power, the following frequency bands were identified: very low frequency (VLF, %), low frequency (LF, %), and high frequency (HF, %). The LF/HF ratio was calculated as an indicator of autonomic balance.

According to the standard protocol for HRV assessment, participants from all groups were required to lie quietly with their eyes closed in a calm environment for 30–40 minutes before the start of the study. RR interval signals were recorded in a seated position at rest (baseline) and after exposure to the test load. Following established HRV methodology [10], RR interval recordings were required to last at least 5 minutes.

Bioimpedance Analysis. For comparative analysis of baseline body composition parameters, a non-invasive bioimpedance method was used. This biophysical technique measures the electrical resistance of muscle, fat, bone tissues, and body fluids within a specified frequency range [5; 12]. Using specialized software for Windows 10, the collected data were processed to determine body composition indices, including: fat mass (FM, kg, %), fat-free mass (FFM, kg), and active cellular mass (ACM, kg, %). Measurements were performed using the diag-

nostic hardware-software system KM-AR-01, “Diamant-AST” configuration (VYUSK. 941118.001 PE).

Baseline bioimpedance measurements for athletes in all groups were conducted following the standard instruction manual [4] before the application of test loads. According to the equipment protocol, each participant had to stabilize their stress state for 5–6 minutes while lying on a bench before the measurement. Using the bioimpedance analyzer in combination with a laptop and specialized electrodes, a standard four-pole electrode placement was applied at the ankle and wrist joints. The measurements were conducted in single-session mode using a probing current at frequencies of 28 and 115 kHz.

Organization of the Study. The study was conducted in multiple stages throughout 2025.

In the first stage, the baseline level of adaptive reserves was assessed in athletes from various combat sports who decided to train and compete in MMA. The study involved 90 qualified athletes aged 15–16 years, including judokas, boxers, Muay Thai fighters, MMA athletes, and Greco-Roman wrestlers.

To monitor the participants' resistance to loads that did not fully correspond to the competitive conditions of most combat sports, Test Load 1 was developed. Baseline functional capacities and the manifestation of short-term adaptation or potential compensatory responses to this physical stressor were evaluated using HRV spectral analysis indicators.

At this stage, we conducted a comparative analysis of baseline body composition parameters – fat mass (FM), fat-free mass (FFM), and active cellular mass (ACM) – in the elite athletes from different combat sports. Assessment of baseline bioimpedance parameters provided a clearer understanding of the general characteristics of how training activities influence adaptation processes.

In the second stage, a comparative analysis was first conducted on the baseline spectral analysis parameters observed in participants from all groups before performing Test Load 1 and Test Load 2. One important organizational consideration during this stage was determining the min-

imum interval between the two test protocols. Based on the results of several studies, a rest period of 60 minutes was implemented between the tests, which was sufficient to partially restore energy reserves.

To evaluate the athletes' level of resistance under conditions similar to offensive phases in MMA bouts, Test Load 2 was developed. The combinations of strikes and throws used in this test consisted of the most powerful technical elements in each athlete's respective combat sport and, accordingly, could vary in energy expenditure. This variability was carefully considered when summarizing the results. The study examined the characteristic changes in heart rate spectral analysis parameters in athletes from all five groups in response to the acute load of Test Load 2. The acquired data were subjected to comparative analysis, followed by appropriate statistical processing.

Statistical Analysis. IBM SPSS Statistics 27 (StatSoft Inc., USA) was used for statistical analysis of the study results. G*Power 3.1.9.6 was applied to estimate the minimum sample size needed for sufficient statistical power. Non-parametric methods were applied for statistical analysis. Median (Me) and interquartile range (IQR) were calculated. The Kruskal-Wallis test was used to compare baseline parameters between the groups at the start of the study, and the Wilcoxon signed-rank test was applied for comparisons between two dependent samples.

Results. Table 1 presents the baseline body composition data for elite-level athletes who moved into MMA after long-term involvement in other combat sports disciplines.

A comparative analysis of the bioimpedance results indicates that, despite nearly identical levels of qualification, age, and weight categories among the examined athletes, the measured body composition parameters show significant differences. The highest body fat percentages were observed in the groups of athletes who practiced Muay Thai (FM = 26.4%) and boxing (FM = 24.7%). In contrast, the lowest body fat percentages were recorded in the judokas and MMA fighters (FM = 15.4%).

The highest fat-free mass (FFM) values were found among judokas (FFM = 65.2 kg) and

Greco-Roman wrestlers (FFM = 65.1 kg), while the lowest FFM was observed in the Muay Thai group (FFM = 58.9 kg). These results indicate that the highest active cellular mass (ACM) values (54–55%) were present in the groups of judokas, Greco-Roman wrestlers, and MMA athletes.

Thus, the results indicate that among the examined athlete groups, judokas and Greco-Roman wrestlers demonstrated the highest fat-free mass (FFM) and active cellular mass (ACM, %) alongside the lowest body fat percentage (FM, %). These findings suggest that these two groups exhibited the most optimal body composition parameters before the test loads.

Table 2 shows the results of heart rate spectral analysis for elite athletes from all five groups during Test Load 1. HRV parameters were recorded both at rest (baseline) and after the test.

The baseline HRV results before Test Load 1 demonstrate that the autonomic balance in Muay Thai fighters and Greco-Roman wrestlers was significantly shifted toward sympathetic regulation. These HRV characteristics indicate high cardiac regulatory system tension, which may reflect the specific nature of their training regimens. In contrast, the judokas and MMA fighters exhibited a shift in autonomic balance toward parasympathetic regulation (LF/HF < 1). Interestingly, in Muay Thai and MMA athletes, despite substantial differences in their baseline cardiac regulatory system tension, there was a simultaneous increase in central sinus rhythm regulation (VLF > 22%). This suggests that prior training or competitive loads may have exceeded the athletes' resistance capacity, leading to pronounced signs of both functional and potentially non-functional overstrain [10; 14].

The HRV results in response to Test Load 1 demonstrate a diverse pattern of spectral parameter changes among the examined athlete groups. In judokas, the stressor induced a decrease in sympathetic tone (HF –6.1%) and parasympathetic tone (LF –58.1%), accompanied by an increase in the central regulatory component (VLF +64.1%). At the same time, cardiac regulatory system tension increased, as reflected by a 5.7-fold rise in LF/HF.

Table 1

Bioimpedance parameters of participants from the examined groups who were qualified athletes in other combat sports before commencing competitive MMA activity (Me, IQR), n = 90

Groups of athletes	Body composition parameters					
	FM, kg	FM, %	FFM, kg	ACM, kg	ACM, %	BMI, a.u.
Judokas, n = 16	11.80 (0.87)	15.40 (1.13)	65.20 (4.41)	41.60 (2.53)	54.00 (3.07)	23.50 (1.42)
Muay Thai fighters, n = 18	21.10 (1.65)	26.40 (1.23)	58.90 (4.22)	38.80 (2.49)	48.00 (3.02)	27.70 (1.11)
Boxers, n = 16	20.00 (1.03)	24.70 (1.15)	61.00 (3.71)	40.30 (2.65)	50.00 (3.28)	28.00 (1.44)
MMA athletes, n = 22	10.80 (0.98)	15.40 (1.01)	59.20 (3.28)	38.20 (2.18)	55.00 (2.66)	22.10 (1.32)
Greco-Roman wrestlers, n = 18	12.90 (1.16)	16.60 (1.09)	65.10 (3.74)	41.90 (2.41)	54.00 (2.48)	22.80 (1.17)

Table 2

Changes in HRV spectral analysis parameters in participants from the examined groups in response to acute Test Load 1 (median, IQR), n = 90

Groups of athletes	Heart rate variability spectral analysis parameters			
	VLF, %	LF, %	HF, %	LF/HF
<i>Before Test Load 1, at rest (baseline level)</i>				
Judokas, n = 16	6.34 (0.21)	26.50 (1.33)	67.15 (4.28)	0.39 (0.07)
Muay Thai fighters, n = 18	22.87 (1.35)	62.58 (2.08)	14.54 (1.18)	4.30 (0.32)
Boxers, n = 16	6.63 (0.28)	67.39 (3.33)	25.98 (1.97)	2.59 (0.15)
MMA athletes, n = 22	27.52 (1.25)	33.89 (1.73)	38.56 (2.03)	0.87 (0.05)
Greco-Roman wrestlers, n = 18	5.06 (1.15)	77.05 (4.55)	17.87 (1.28)	4.31 (0.26)
<i>After Test Load 1</i>				
Judokas, n = 16	70.47 (5.47)*	20.45 (0.43)*	9.08 (0.19)*	2.25 (0.14)*
Muay Thai fighters, n = 18	9.15 (0.54)*	72.45 (3.89)*	18.38 (1.15)	3.94 (0.22)
Boxers, n = 16	14.40 (1.02)*	22.31 (1.34)*	63.17 (2.87)*	0.35 (0.02)*
MMA athletes, n = 22	23.47 (1.15)*	20.84 (1.36)*	55.55 (2.43)*	0.37 (0.02)*
Greco-Roman wrestlers, n = 18	47.36 (2.38)*	16.99 (1.04)*	35.62 (1.62)*	0.47 (0.02)*

Note: *p < .05 – compared with baseline values (at rest)

In Greco-Roman wrestlers, autonomic balance shifted toward parasympathetic regulation (LF/HF reduced by 89.1%), resulting from an increase in HF (+17.7%) and a decrease in LF (–60.1%) after Test Load 1. Simultaneously, VLF in this group increased by 42.3% compared to the baseline (rest). A similar pattern of

HRV spectral changes was observed in boxers (LF/HF –86.4%; LF –45.1%; HF +37.2%; VLF +7.7%) and MMA fighters (LF/HF –57.4%; LF –13.0%; HF +16.9%).

During Test Load 1, the Muay Thai group had a classical physiological response to a load, despite the load being markedly different from

their usual training and competitive activities. Specifically, there was an increase in sympathetic activity (LF +9.8%), a strengthening of parasympathetic tone (HF +3.8%), and a decrease in cardiac regulatory tension (LF/HF -8.4%).

Figure 1 presents a comparative analysis of changes in baseline HRV spectral parameters in

study participants, observed before Test Load 1 and after one hour of recovery. The primary aim of this analysis was to assess the athletes' capacity for functional readaptation following loads to which their resistance levels were low.

Both the Muay Thai and MMA groups showed a reduction in autonomic regulation

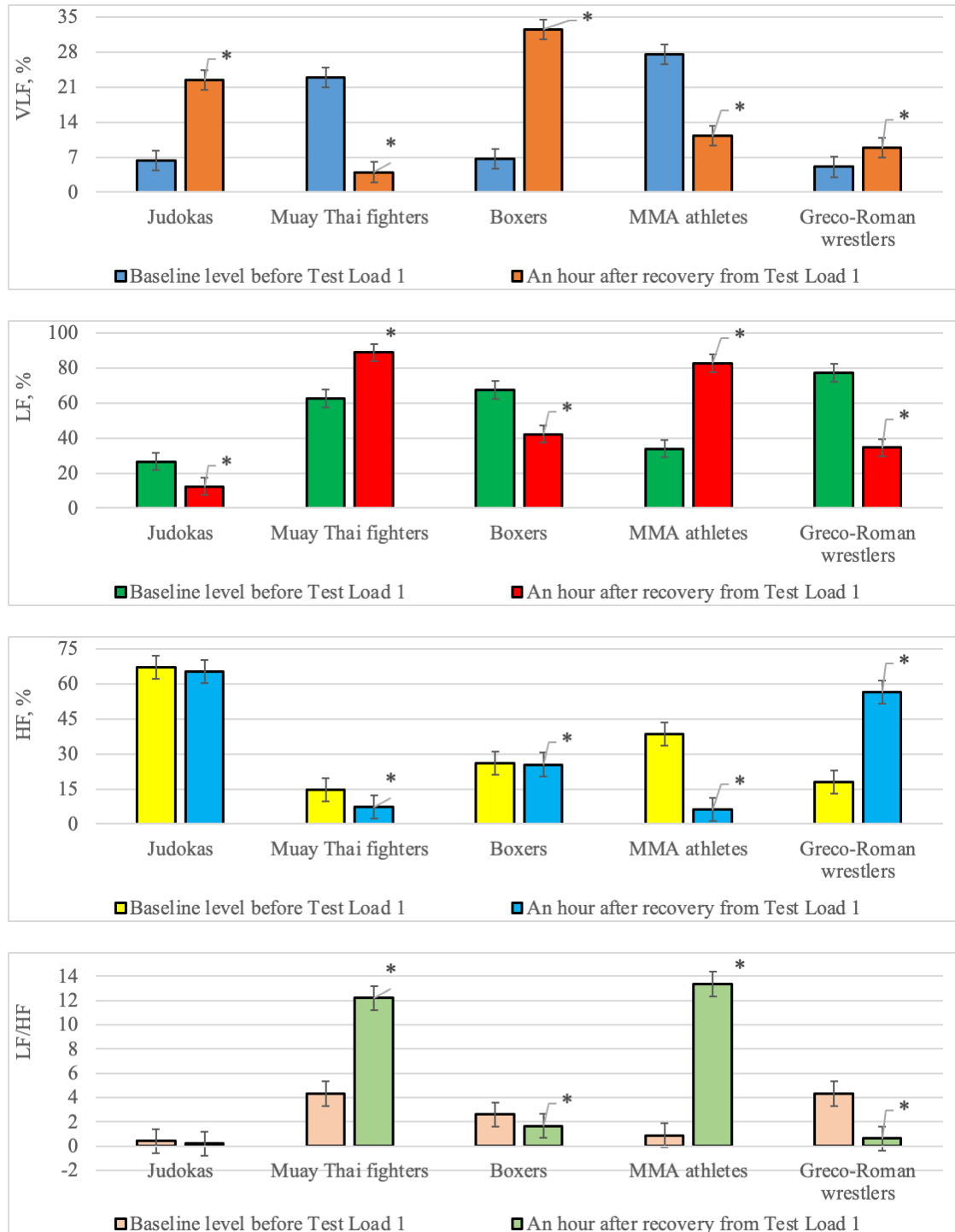


Fig. 1. Comparative analysis of changes in baseline HRV spectral parameters before and one hour after Test Load 1 among study participants, n = 90

influence compared with HRV parameters at rest and after one hour of recovery following Test Load 1. At the same time, there was a weakening of the central regulatory component, indicating an effective readaptation process of the athletes' physiological systems. During this period, there was a significant increase in cardiac regulatory tension, both in the Muay Thai group (2.8-fold) and in the MMA group (15.3-fold).

In contrast, in the groups of qualified judokas, boxers, and Greco-Roman wrestlers, there was a shift of autonomic balance toward sympathetic regulation and a strengthening of the central sinus rhythm regulation. This indicates that for these athletes, Test Load 1 may have acted as an excessively strong stressor, exceeding their physiological resistance and adaptive reserves. Consequently, effective readaptation mechanisms were not observed in these groups within the recovery period.

Table 3 demonstrates changes in HRV spectral parameters in response to acute Test Load 2.

The HRV responses to Test Load 2 showed a notably variable pattern among the athlete

groups. In response to the stressor, there was a simultaneous reduction in parasympathetic activity and sympathetic tone, accompanied by a marked increase in the central regulatory component among Muay Thai fighters (LF –56.9%; HF –2.8%; VLF +59.6%) and Greco-Roman wrestlers (LF –14.9%; HF –22.1%; VLF +37.1%).

In response to Test Load 2, the other athlete groups demonstrated a strengthening of vagal influence on the sinoatrial node, reflected by an increase in HF power and a decrease in LF power. These changes were observed in boxers (LF –2.7%; HF +31.9%; VLF –29.2%; LF/HF –58.7%) and MMA fighters (LF –15.3%; HF +22.4%; VLF –7.1%; LF/HF –82.4%).

Discussion. This study presents one approach to investigating the mismatch between the resistance level of many elite athletes from various combat sports and the competitive loads encountered in MMA [4; 12; 15]. Addressing this issue is challenging due to the absence of an effective system for evaluating whether the adaptive reserves of this population match the stressors

Table 3

Changes in HRV spectral analysis parameters in participants from the examined groups in response to acute Test Load 2 (median, IQR), n = 90

Groups of athletes	Heart rate variability spectral analysis parameters			
	VLF, %	LF, %	HF, %	LF/HF
<i>Before Test Load 2, at rest (baseline level)</i>				
Judokas, n = 16	22.37 (1.32)	12.33 (1.02)	65.21 (3.15)	0.18 (0.01)
Muay Thai fighters, n = 18	3.98 (0.27)	88.73 (4.19)	7.27 (0.44)	12.20 (1.06)
Boxers, n = 16	32.48 (1.85)	42.10 (2.03)	25.41 (1.11)	1.65 (0.02)
MMA athletes, n = 22	11.26 (0.91)	82.55 (3.94)	6.18 (0.31)	13.35 (0.94)
Greco-Roman wrestlers, n = 18	8.85 (0.57)	34.52 (1.26)	56.51 (2.73)	0.61 (0.02)
<i>After Test Load 2</i>				
Judokas, n = 16	26.02 (1.16)	15.81 (1.03)	58.06 (2.16)*	0.27 (0.01)
Muay Thai fighters, n = 18	63.64 (3.06)*	31.83 (1.23)*	4.50 (0.22)	7.07 (0.23)*
Boxers, n = 16	3.29 (0.25)*	39.39 (1.46)	57.32 (2.37)*	0.68 (0.02)*
MMA athletes, n = 22	4.17 (0.11)*	67.18 (3.04)*	28.62 (1.32)*	2.34 (0.13)*
Greco-Roman wrestlers, n = 18	45.93 (2.64)*	19.59 (1.22*)	34.46 (1.83)*	0.56 (0.02)

Note: *p < .05 – compared with baseline values (at rest)

encountered under MMA-like competitive conditions.

The research examined the adaptive-compensatory responses of elite athletes from different combat sports under loads that were unusual for their primary disciplines [5; 12; 16]. The study assessed the effectiveness of readaptation processes in each group after exposure to loads exceeding their resistance capacity. It also evaluated the individual capacity of athletes from different combat sports to implement mechanisms of short-term adaptation under high-intensity loads operating in the creatine-phosphokinase energy mode, following prior depletion of energy reserves.

The study examined the rationale for using HRV spectral analysis parameters as informative markers for assessing resistance to MMA-related loads relative to the adaptive reserves of elite athletes from other combat sports [6; 14]. Test loads were specifically designed to evaluate the functional capabilities of participants and the resistance of their physiological systems to loads differing in intensity, volume, and duration.

Results indicate that the athletes' responses to the designed test loads simultaneously exhibited short-term adaptation and compensatory reactions. The patterns of change in baseline HRV spectral parameters during readaptation between the two test loads varied substantially among athletes from different combat sports.

These findings provide a scientific basis for developing mechanisms to optimize the training process for elite athletes from various combat sports who choose to compete in MMA. The data also enable the optimization of HRV-based monitoring systems to evaluate the correspondence between athletes' physiological resistance and the magnitude of stressors in MMA, even for athletes transitioning from other combat sports.

In mixed martial arts, insufficient attention has been paid to the growing issue of a mismatch between classic competitive loads and the adaptive reserves of athletes transitioning from other combat sports [2; 10]. Several researchers [13; 16] suggest that one potential solution is for athletes to use the most effective technical arsenal from their primary combat sport during MMA bouts.

However, another problem arises: in most cases, these athletes will face opponents whose fight tactics differ significantly from the classic strategies of their original sport [7; 9; 12]. Consequently, the intensity and volume of loads during competition may also differ substantially, potentially leading to premature depletion of energy reserves, muscular fatigue, and even increased risk of injury [4; 13; 16].

Thus, current scientific literature has not yet identified optimal mechanisms for addressing this problem, particularly when considering the functional capacities and technical mastery of elite athletes who have transitioned to MMA from other combat disciplines.

Among the examined groups of boxers, Greco-Roman wrestlers, and MMA athletes, Test Load 1 induced a shift of autonomic balance toward parasympathetic regulation along with a simultaneous strengthening of the central regulatory component. These findings indicate that, despite a reduction in the tension of cardiac regulatory systems, the applied loads represented a substantial stressor for the athletes' bodies [10; 12].

The response to these loads involved an enhanced vagal influence on the sinoatrial node only in the Muay Thai group. We observed a simultaneous increase in sympathetic activity (LF) and a significant rise in high-frequency power (HF) in this group, accompanied by a weakening of the central component of sinus rhythm regulation. Such combinations of HRV changes in elite athletes under non-standard loads, for which their resistance level is low, indicate a high level of functional capacity and sufficient energy reserves [2; 3; 7].

Both Muay Thai and MMA athletes showed a decline in central regulatory activity relative to baseline HRV, observed immediately before Test Load 1 and after one hour of recovery. Despite a shift of the autonomic balance toward sympathetic regulation, these changes clearly reflect pronounced readaptation processes within the physiological systems of these athlete groups [1; 5; 10].

The results observed in Muay Thai and Greco-Roman wrestlers in response to Test Load 2 demonstrated a shift of autonomic balance toward parasympathetic regulation. Simultaneously, a significant strengthening of the central compo-

ment of sinus rhythm regulation was observed in response to this stressor. Although the tension of cardiac rhythm regulation decreased in these athletes after the load, the overall assessment of HRV parameters indicates activation of compensatory mechanisms [12; 15]. Accordingly, for these athlete groups, the intensity of Test Load 2 represents a high-level stressor, which may potentially lead to adaptive failure [5; 6].

The boxer and MMA groups, in response to Test Load 2, which closely resembled the structure and content of their types of combat sports, demonstrated an enhanced vagal influence on the sinoatrial node due to increased parasympathetic activity. These results indicate a mechanism for the effective practical implementation of short-term adaptive processes in the athletes' bodies under similar stressors [8; 12].

Conclusions. The results indicate that in 75% of elite athletes from various combat sports, the level of physiological resistance is insufficient to implement short-term adaptation mechanisms during competitive MMA loads effectively. Notably, only the Muay Thai and MMA groups exhibited pronounced readaptation processes during recovery periods between exhaustive test loads. The findings highlight the necessity of using all four parameters of HRV spectral analysis as informative markers to assess the level of resistance in elite athletes from different combat sports under MMA competitive demands.

A shift of autonomic balance toward parasympathetic activity, even when accompanied by reduced cardiac regulatory tension, does not necessarily indicate effective short-term adaptation. Additional monitoring of changes in the central regulation of sinus rhythm enables the assessment of stressor intensity relative to functional capacity, allowing for timely interventions to prevent potential adaptive failures.

Acknowledgements. There are no acknowledgements.

Conflict of interest – all authors in this study declare that they have no conflict of interest with any party.

References

1. Addleman, J., Lackey, N., DeBlauw, J., Hajduczek, A. (2024). Heart Rate Variability

Applications in Strength and Conditioning: A Narrative Review. *J Funct Morphol Kinesiol*, 9 (2), 93. <https://doi.org/10.3390/jfmk9020093>.

2. Brockmann, L., & Hunt, K. (2023). Heart rate variability changes with respect to time and exercise intensity during heart-rate-controlled steady-state treadmill running. *Journal of Scientific Reports*, 13, 8515. <https://doi.org/10.1038/s41598-023-35717-0>.

3. Chycki, J., Krzysztofik, M., Sadowska-Krępa, E., Baron-Kaczmarek, D., Zajac, A., Poprzeczki, S., Petr, M. (2024). Acute Hormonal and Inflammatory Responses following Lower and Upper Body Resistance Exercises Performed to Volitional Failure. *International Journal of Molecular Sciences*, 25 (13), 7455. <https://doi.org/10.3390/ijms25137455>.

4. Chernozub, A., Korobeynikov, G., Mytskan, B., Korobeinikova, L., Cynarski, W. (2018). Modelling mixed martial arts power training needs depending on the predominance of the strike or Wrestling fighting style. *Ido Movement for Culture*, 18 (3), 28–36. <https://doi.org/10.14589/ido.18.3.5>.

5. Chernozub, A., Manolachi, V., Korobeynikov, G., Potop, V., Sherstiuk, L., Manolachi, V., Mihaila, I. (2022). Criteria for assessing the adaptive changes in mixed martial arts (MMA) athletes of strike fighting style in different training load regimes. *PeerJ*, 10, e13827. <https://doi.org/10.7717/peerj.13827>.

6. Chernozub, A., Koval, V., & Derliuk, O. (2025). Adaptive-compensatory reactions of the organism of untrained adolescents with different types of heart rate regulation to power fitness load. *Rehabilitation and Recreation*, 19 (1), 117–126. <https://doi.org/10.32782/2522-1795.2025.19.1.11>.

7. Claiborne, A., Alessio, H., Slattery, E., Hughes, M., Barth, E., Cox, R. (2021). Heart Rate Variability Reflects Similar Cardiac Autonomic Function in Explosive and Aerobically Trained Athletes. *Int J Environ Res Public Health*, 18 (20), 10669. <https://doi.org/10.3390/ijerph182010669>.

8. Finlay, M., Greig, M., Page, R., Bridge, C. (2023). Acute physiological, endocrine, biochemical and performance responses associated with amateur boxing: A systematic review with meta-analysis. *European Journal of Sport Science*, 23 (5), 774–788. <https://doi.org/10.1080/17461391.2022.2063072>.

9. Haller, N., Behringer, M., Reichel, T., Wahl, P., Simon, P., Krüger, K., Zimmer, P.,

Stöggli, T. (2023). Blood-Based Biomarkers for Managing Workload in Athletes: Considerations and Recommendations for Evidence-Based Use of Established Biomarkers. *Sports Med.*, 53 (7), 1315–1333. <https://doi.org/10.1007/s40279-023-01836-x>.

10. Korobeinikova L., Raab M., Korobeynikov G., Pryimakov O., Kerimov F., Chernozub A., Korobeinikova I., Goncharova O. (2024) Comparative analysis of psychophysiological state among in physical active and sedentary persons. *Journal of Physical Education and Sport*, 24 (2), 382–389. <https://doi.org/10.7752/jpes.2024.02046>.

11. Manolachi, V., Chernozub, A., Tsos, A., Potop, V., Kozina, Z., Zoriy, Y., Shtefiuk, I. (2023). Integral method for improving precompetition training of athletes in Mixed Martial Arts. *Journal of Physical Education and Sport*, 23 (6), 1359–1366. <https://doi.org/10.7752/jpes.2023.06166>.

12. Manolachi, V., Chernozub, A., Tsos, A., Syvokhop, E., Marionda, I., Fedorov, S., Shtefiuk, I., Potop, V. (2023). Modeling the correction system of special kick training in Mixed Martial Arts during selection fights. *Journal of Physical Education and Sport*, 23 (8), 2203–2211. <https://doi.org/10.7752/jpes.2023.08252>.

13. Mousavi, E., Sadeghi-Bahmani, D., Khazaie, H., Brühl, A., Stanga, Z., Brand, S. (2023). The Effect of a Modified Mindfulness-Based Stress Reduction (MBSR) Program on

Symptoms of Stress and Depression and on Saliva Cortisol and Serum Creatine Kinase among Male Wrestlers. *Healthcare (Basel)*, 11 (11), 1643. <https://doi.org/10.3390/healthcare11111643>.

14. Schoenfeld, B., Androulakis-Korakakis, P., Piñero, A., Burke, R., Coleman, M., Mohan, A., Escalante, G., Rukstela, A., Campbell, B., Helms, E. (2023). Alterations in Measures of Body Composition, Neuromuscular Performance, Hormonal Levels, Physiological Adaptations, and Psychometric Outcomes during Preparation for Physique Competition: A Systematic Review of Case Studies. *J Funct Morphol Kinesiol*, 8 (2), 59. <https://doi.org/10.3390/jfmk8020059>.

15. Shtefiuk, I., Tsos, A., Chernozub, A., Alosyna, A., Marionda, I., Syvokhop, E., Potop, V. (2024). Developing a training strategy for teenage athletes in mixed martial arts for high-level competitions. *Journal of Physical Education and Sport*, 24 (2), 329–337. <https://doi.org/10.7752/jpes.2024.02039>.

16. Shtefiuk, I., Moseichuk, Y., & Chernozub, A. (2025). Systematization of the recovery of adaptive body reserves in qualified MMA athletes during the short-term period between consecutive competitions. *Rehabilitation and Recreation*, 19 (1), 229–240. <https://doi.org/10.32782/2522-1795.2025.19.1.21>.

Прийнято до публікації: 17.09.2025

Опубліковано: 30.10.2025

Accepted for publication on: 17.09.2025

Published on: 30.10.2025