

**NEUROBIOFEEDBACK IN SPORTS MEDICINE: ENHANCING AND CORRECTING  
ADAPTATION CAPABILITIES OF COMBAT SPORTS ATHLETES' NEUROPSYCHOLOGICAL  
STATUS**

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**Abstract:** Neurobiofeedback is a method of functional state correction that is increasingly applied in sports medicine. This study investigates its psychophysiological effects in athletes during training and competitive periods. Research indicates that neurobiofeedback shows promise in sports medicine clinical practice, contributing to enhanced adaptation and improved functional capabilities. Electroencephalographic feedback training focuses on the alpha rhythm, aiming to optimize psycho-emotional states, mitigate anxiety, and regulate functional reserves. The results demonstrate significant improvements in psycho-emotional state stability and recovery indicators in athletes, sustained for up to one year. These findings support the incorporation of neurobiofeedback into sports medicine protocols.

**Keywords:** alpha training, training of optimal functioning, EEG biofeedback, functional state correction, cognitive and emotional state correction

**Annotatsiya:** Neyrobiologik qaytar aloqa – funksional holatni tuzatish usuli bo'lib, sport tibbiyotida tobora keng qo'llanilmoqda. Ushbu tadqiqot sportchilarning mashg'ulot va musobaqa davrida ushbu metodning psixofiziologik ta'sirlarini o'rganadi. Tadqiqot natijalari neyrobiologik qaytar aloqa usulining sport tibbiyotida klinik qo'llanilish istiqbollarini tasdiqlab, sportchilarning moslashish qobiliyatini oshirish va funksional imkoniyatlarini yaxshilashga xizmat qilishini ko'rsatadi. Elektroensefalografik bioqaytar-trening alfa ritmiga qaratilgan

*bo'lib, psixo-emotsional holatni optimallashtirish, tashvish darajasini pasaytirish va funksional zaxiralarni boshqarishga yordam beradi. Natijalar shuni ko'rsatadiki, sportchilarda psixo-emotsional holat barqarorligi va tiklanish ko'rsatkichlari sezilarli darajada yaxshilanadi va ushbu ta'sir bir yilgacha saqlanib qoladi. Ushbu topilmalar sport tibbiyoti protokollariga neyrobiologik qaytar aloqani kiritish zarurligini qo'llab-quvvatlaydi.*

***Kalit so'zlar:*** *alfa-trening, optimal faoliyat mashg'uloti, EEG bioqaytar aloqa, funksional holatni tuzatish, kognitiv va emosional holatni tuzatish.*

***Аннотация:*** *Нейробиологическая обратная связь – это метод коррекции функционального состояния, который все шире применяется в спортивной медицине. В данном исследовании изучаются его психофизиологические эффекты у спортсменов в периоды тренировок и соревнований. Результаты исследований подтверждают перспективность применения нейробиологической обратной связи в клинической практике спортивной медицины, способствуя повышению адаптационных возможностей и улучшению функциональных способностей. Электроэнцефалографический фидбек-тренинг направлен на альфа-ритм, с целью оптимизации психоэмоционального состояния, снижения тревожности и регуляции функциональных резервов. Данные показывают значительное улучшение стабильности психоэмоционального состояния и показателей восстановления у спортсменов, сохраняющееся до одного года. Эти результаты подтверждают необходимость включения нейробиологической обратной связи в протоколы спортивной медицины.*

***Ключевые слова:*** *альфа-тренинг, тренировка оптимального функционирования, ЭЭГ-биообратная связь, коррекция функционального состояния, коррекция когнитивного и эмоционального состояния.*

In recent years, there has been a tendency to increase loads in all types of sport activity. This tendency leads to dysfunction of neuron control systems, which in turn entails a significant decrease in physical performance and, as a result, contributes to the formation of negative changes in the vegetative functions of the human body [9,13]. In addition, modern

sports lead to an increase in spectacle, which provokes a tendency towards injuries and autonomic dysfunctions, especially of the nervous and cardiovascular systems [5].

The modern task of sports medicine is associated with preventive approaches to the emerging risks of maladaptation and deterioration of athletes' health. That is why there is an increasing need to optimize the effectiveness of preparatory measures for people involved in sports in extreme conditions and to develop algorithms that allow maintaining optimal health [7,15].

One of the ways to solve this problem is to include modern, highly effective and physiologically acceptable technologies with the simultaneous use of an effective multicomponent system for diagnostic and optimizing the functional states of the athlete's body. This approach is aimed at increasing the adaptive potential of the body in response to maximum psycho-emotional and sport stress [2,11].

As it's known, achieving acceptable compensatory reactions to physical stress can serve as a basis for maintaining health and increasing the effectiveness of professional activity of athletes. Undoubtedly, this issue is of particular importance in the context of modern sport activity. This problem is the subject of a number of scientific papers devoted to the study of critical loads in sports and other types of professional activity [1,12].

In this regard, the most pressing topic is determining the level of functional state and the use of preventive approaches to correcting the training process in martial arts.

Although the leading system that support of high results in martial arts is the oxygen transport system, it is important to note the role of the central nervous system (CNS), which coordinates of motor functions performed at high speed, requiring increased excitability, lability and mobility of nervous processes [12].

Numerous scientific publications cover studies devoted to the study of the influence of psychophysiological reactions on the functional capabilities of the autonomic nervous system (ANS) under extreme loads. In martial arts, where high results inevitably require high psycho-emotional and static loads, as well as constant control of body weight, there is a high probability of disruption of the adaptive and regulatory processes of the ANS at both

segmental and suprasedgmental levels [4,9]. According to some authors, functional stress and overstrain of autonomic regulation during training can occur due to low compensatory mechanisms, which is considered a borderline state between optimal and pathological conditions. Although the tension of the autonomic nervous system with sympathetic tone is a necessary component for the implementation of the technical and tactical qualities of an athlete in competition conditions [15].

The effectiveness of therapeutic and health-improving biofeedback measures has been demonstrated for a wide range of psychosomatic disorders, as well as for optimizing psychoemotional stress. Significant optimization of autonomic activity has been shown with multicomponent therapy using transcranial electrical stimulation and biofeedback techniques in individuals involved in cyclic and acyclic sports. It is worth noting that the potential of biofeedback therapy in relation to autonomic activity remains insufficiently studied [14].

Biofeedback (BFB) in medicine still faces resistance and persistent rejection, which has led to limited widespread implementation and scientific substantiation of innovative methods using computers and software to study specific neuro- and psychophysiological parameters of human systems, limited mainly to laboratory studies [13]. Despite this, scientists continue to work in this direction, noting the positive results achieved with the help of algorithms and methods based on the principles of biological feedback, which are aimed at optimizing the paths of self-regulation, compensatory capabilities and physiological activity in pathological conditions, and in sports - with high physical loads and active training [8,10].

The application of BFB systems for controlling specific electroencephalographic (EEG) rhythms, individual wave strengths, and spatial arrangement of EEG properties is considered an essential method for investigating the relationships between elements and rhythms of EEG, their role in forming internal connections, performing selective motor activities, and managing psychophysiological responses. Neuro-bio-management based on BFB principles represents a rapidly progressing experimental, technical, and practical field within healthcare, providing effective control in both professional and sport medicine [10,14]. Even though numerous studies exist in this area, the issue of the duration and effectiveness of EEG training combined with BFB procedures during singular neuro-bio-management sessions still remains under-researched.

**Purpose:** To enhance the neuropsychological status correction of combat sports athletes through biological feedback therapy.

### Materials and Methods

The study was conducted at the Republican Scientific-Practical Center for Sports Medicine. The research is based on data from the examination of 136 combat sports athletes, including 85 men (62.5%) and 51 women (37.5%). The average age was  $25.5 \pm 2.6$  years, with a range from 18 to 33 years.

Electroencephalographic examination was performed on the BFBSLAB hardware-software complex. To register EEG signals, for the first channel, the sensor was connected to port A of the device, and for the second channel, the sensor was connected to port B.

The assessment of neuropsychological status was conducted using the following scales: the Asthenic State Scale, Kerdo Index, Hospital Anxiety and Depression Scale (HADS), and the Psychological Stress Scale PSM-25. Express diagnostics of asthenic state were conducted using the Asthenic State Scale, consisting of 30 questions. Interpretation of results: up to 50 points – no asthenia; 51-75 points – mild asthenia; 76-100 points – moderate asthenia; 101-120 points – severe asthenia.

The Kerdo Vegetative Index evaluates the functional activity of the autonomic nervous system (ANS), specifically the balance between sympathetic and parasympathetic activity. Values between +16 to +30 indicate predominance of sympathetic activity, while values above 30 indicate pronounced sympathetic dominance. Values from -16 to -30 indicate predominance of parasympathetic activity, and values below -30 signify pronounced parasympathetic dominance; values between -15 and +15 indicate balanced activity [10].

The Hospital Anxiety and Depression Scale (HADS) which used for primary detection of depression and anxiety in general medical practice. This assessment is conducted through a questionnaire consisting of 14 items, with response options including: "all the time," "often," "sometimes," "never" [14].

The PSM-25 scale by Lemyr-Tessier-Fillion is used to calculate the structure of phenomenological experiences of stress. Values above 155 are interpreted as high stress

impact, indicating decompensation and psychological discomfort; values between 155 and 100 indicate moderate stress, whereas values below 99 represent low stress levels, suggesting a high adaptive capacity to received loads [5].

The effectiveness of neuropsychological status correction for combat sports athletes using BFB therapy was assessed in two groups. The main group included 60 athletes, comprising 26 women and 34 men. The comparison group consisted of 76 athletes who did not undergo BFB therapy.

The foundation of optimal functioning (OF) training is based on the concept of self-regulation. The goal of the training is to teach individuals to modulate their psychophysiological state quickly (within minutes or even seconds) to match the most appropriate state for the current task. Since OF training was developed for professionals, such as athletes, military personnel, and other individuals requiring high levels of attention and decision-making in time-constrained and emergency situations, one of the primary components is beta-enhancing training. Increasing EEG activity in the beta range of 15-20 Hz in frontal regions correlates with the activation of cognitive functions, attention, and memory. This is accompanied by a reduction in theta and low-frequency alpha activity. Another variant of beta training involves theta/beta ratio training, where individuals are trained to optimize the transition into combat readiness and enhanced focus during tasks.

The second component of the training is relaxation training. This phase aims at quickly transitioning from a state of tension to a status where optimal replenishment of bodily resources necessary for achieving set goals is achieved. Relaxation components may include alpha-enhancing or myographic training.

EEG background recording was conducted at different intervals: before the start of therapy, immediately after completing therapy, and 90 days after therapy completion.

For statistical processing, the software "Statistica 12" with ANOVA dispersion analysis was used. All participants gave their consent to participate in the study in accordance with the ethical standards of the Declaration of Helsinki.

**Results:**

The mental status of combat sports athletes, assessed using the HADS scale, was characterized in 86.7% of the main group and 86.8% of the comparison group as having subclinical manifestations of anxiety and depression. Clinical manifestations of anxiety/depression were noted in 10.0% and 10.5% of cases, respectively, while in only 3.3% and 2.7% of cases, respectively, anxiety and depressive symptoms were absent.

On the psychological stress scale, 78.3% and 78.9% of athletes, respectively, show low levels of stress, indicating adaptation to workload (Mihailescu et al., 2021). In addition, 26.7% and 27.6% exhibit an average level of stress, which indicates a state of maladaptation and mental discomfort, necessitating the application of a wide range of methods to reduce neuropsychological tension, psychological unloading, and changes in thinking and lifestyle [6,8].

**Table 1 Changes in the asthenic state scale indices after neurofeedback**

Scale	Asthenic State	Score						±m
		Nor m (up to 50)		Mild (51-75)		Moder ate (76-100)		
		bs.		bs.		bs.		
Main Group, n=60								
	Initial Data		,0	9	1,7		3,3	5,0±1,5
	After BFB therapy	7	5,0		,0		,0	2,2±1,2
Control Group, n=76								
	Initial Data		1,8	3	9,7	4	8,4	5,8±1,5
	After BFB therapy	3	7,1	2	8,4	1	4,5	8,6±1,3

Upon repeated dynamic examinations, it was established that training promotes the normalization of the functional activities of body systems, reduction in psycho-emotional load, anxiety, and worry. Special psychophysiological tests conducted after training showed an increase in positive attitudes, a desire for active engagement, and overall success. Athletes became calmer, more motivated for success, with increased self-assertion.

Prior to BFB training, the HADS scale scores for athletes were  $34.8 \pm 4.24$ , corresponding to a medium level of anxiety; after BFB training, although remaining in the medium range, there was a tendency toward an 11% increase to  $32.5 \pm 0.7$  ( $p < 0.05$ ). In the comparison group, a non-significant ( $p \geq 0.05$ ) trend was observed for a 7% decrease in anxiety scores (from  $37.3 \pm 6.8$  to  $34.7 \pm 9.5$ ).

**Table 2 HADS scale performance in anxiety and depression - a comparative study before and after therapy**

Anxiety and Depression Scale (HADS)	Score						M $\pm m$
	No		Su		Cli		
	rm		bclinical		nical		
	bs.		bs.		bs.		
Main Group, n=60							
Initial Data		,3	2	6,7		0,0	9 $,5 \pm 0,2$
After BFB therapy	6	3,3		,0		,7	5 $,5 \pm 0,2$
Control Group, n=76							
Initial Data	3	7,1	0	5,8	3	7,1	9 $,3 \pm 0,2$
After BFB therapy	6	1,1	3	9,7		,2	8 $,4 \pm 0,2$

On the psychological stress scale, athletes in the main group showed a decrease in stress levels. In the main group, low stress levels increased from 78.3% to 93.3% (by 15%),

while in the comparison group it increased from 78.9% to 85.5% (by 6.6%). These results are shown in Table 3.

Evidence of the effectiveness of biofeedback correction was demonstrated by a significant increase in maximum tapping frequency – by 19.7% – in the main group compared to 4% in the comparison group ( $p < 0.001$ ), indicating improved mobility of nervous processes and the functional state of the athletes' motor apparatus. Comparative evaluation of nervous system lability scores post-correction revealed a significant ( $p < 0.001$ ) increase in the subgroup using adaptive biofeedback technology – 7 (5; 7.5) (main group) and 6 (5; 7) (comparison group). The increase in nervous system strength in the tapping test with gaming biofeedback was 25.6% in the main group, while no effect was registered with pedagogical correction. These findings suggest a more favorable impact of gaming biofeedback technology on maintaining work pace at a specific level.

**Table 3 Psychological stress reduction following biofeedback therapy**

Psychological Stress Scale	Score						M ±m
	Low		M edium		Hi gh		
	bs.		bs.		bs.		
<b>Main Group, n=60</b>							
Initial Data	7	8,3	3	7,1		,0	8 9,8±1,8
After BFB therapy	0	00,0		,0		,0	6 8,2±1,1
<b>Control Group, n=76</b>							
Initial Data	0	5,8	1	7,6		,6	9 8,5±2,7
After BFB therapy	5	2,4	7	2,4		,3	8 3,4±3,4

BFB therapy contributes to the restoration of psychological and emotional responses of combat athletes, with their occurrence remaining strictly individual and lasting from three to six months. Overcoming self-doubt, emotions, fear, and insecurity is achieved through correctional interventions, which are enhanced through BFB therapy. This method is considered effective and promising not only among the athletic population but also in treating various illnesses.

Research shows a significant role of neurofeedback courses in shaping psychophysiological states in athletes. Among athletes who successfully underwent EEG-BFB training, more pronounced psychophysiological changes were observed compared to those who completed the training unsatisfactorily. Significant effects of this method were achieved in reducing psychological stress and anxiety, as well as improving cognitive abilities (creativity and intelligence quotient). Gradual reduction in psychological stress was observed six months after the training, and even a year later, parameters such as originality index and non-verbal creativity were sustained, with a slight decrease in personal anxiety.

## Discussion

The aim of this study was to identify ways to improve the effectiveness of correction of the neuropsychological status of martial artists using biofeedback. To solve this problem, complex methods for assessing neuropsychophysiological states were used.

This study confirms that neurofeedback, particularly alpha training, effectively enhances psychophysiological states in athletes. The sustained improvements in anxiety, recovery, and functional reserves highlight its potential as a valuable tool in sports medicine.

The observed increases in alpha rhythm amplitude align with previous findings that associate alpha activity with relaxation and focused attention. Research in sports medicine has consistently demonstrated that higher alpha amplitudes are associated with reduced stress and better regulation of emotional states, which are crucial for optimal athletic performance [10,15].

Moreover, the reduction in asthenic symptoms supports the hypothesis that neurofeedback stabilizes emotional states and optimizes energy regulation. This aligns with

existing literature suggesting that neurofeedback enhances autonomic nervous system regulation, which is vital for athletes managing physical and mental fatigue [10].

It appears that, in line with the opinions of numerous authors, mechanisms of self-regulation and recovery of physiological and mental components developed through neurofeedback have a positive impact and enhance neuronal plasticity in motor areas of the brain cortex [3]. This facilitates optimized responses from cortical-subcortical structures, manifesting in improved psychophysiological parameters. Such findings are consistent with research in neuroplasticity, which shows that targeted neurofeedback training can lead to structural and functional changes in the brain, enhancing motor and cognitive functions [12,14].

Confirming these results, it can be emphasized and agreed with the opinion of most authors and researchers studying BFB therapy, where the mechanism primarily lies in the ability to train the brain in attention concentration, enhancing the relationship between high-frequency rhythms and the slower parts of the spectrum. Additionally, it allows the acquisition of skills in effective transitions between states of attention, relaxation, and rest, which correspond to an increase in EEG alpha rhythm oscillations and a decrease in high-frequency activity.

The study and evaluation of psychophysiological activity parameters and neurophysiological regulation before and after EEG-BFB training sessions will allow for determining the necessary number, duration, and frequency of sessions, along with the development of neurofeedback protocols that facilitate brain activity control and regulation programming for sport [3,7].

Future research should prioritize longitudinal studies to better understand the long-term impact of neurofeedback interventions on both psychological and physical well-being. By tracking athletes over a more extended timeframe, insights into the persistence and durability of neurofeedback benefits can be obtained [14]. Expanding the scope of research to include a diverse range of sports disciplines and varying levels of athletes, from amateur to professional, would provide a more holistic understanding of neurobiofeedback's effectiveness. Additionally, direct investigations into how neurofeedback influences specific performance outcomes—such as endurance, speed, and precision—are essential. This would

enhance the evidence base and offer a more comprehensive view of its impact on athletic performance.

## Conclusion

Neurobiofeedback emerges as a promising intervention in sports medicine, delivering sustained psychophysiological benefits. By enhancing alpha rhythm activity, neurofeedback promotes emotional stability, reduces anxiety, and supports functional recovery. Integrating neurofeedback into training regimens offers athletes a competitive edge while safeguarding their mental health. Its application not only enhances athletic performance but also helps manage psychological challenges, ensuring holistic well-being.

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