The relationship between the functional status of regulatory mechanisms and the effectiveness of technical and tactical operations in boxers

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Abstract
Objective of the study – is to analyze the interrelationships between psychophysiological parameters and characteristics of heart rate variability, which affect the effectiveness of technical and tactical actions of boxers during competitions.
Methods and structure of the study. The study involved boxers aged 18 to 20 years, among whom there were 15 men and 10 women. To assess the functional state, the Varikard 2.52 hardware and software package was used, which was used to record statistical and spectral indicators of heart rate variability. The assessment of the functional state of the central nervous system was carried out using the UPFT-1/30 "Psychophysiologist" psychophysiological testing device.
Results and conclusions. The results of the study showed that the percentage of effective punches in female boxers is inversely proportional to the stability of the reaction in a simple visual-motor reaction, tremometry indicators and the stress index of heart rate variability. In male boxers, the effectiveness of punches is associated with indicators of simple visual-motor reaction, reaction stability, and VLF-wave values reflecting the level of stress on the athlete's body.

Keywords: *heart rate variability, efficiency, technical and tactical actions, boxers, central nervous system, effective strokes, reaction stability.*

Introduction. Heart rate variability (HRV) is an important indicator of the regulation of the autonomic nervous system and is associated with the level of stress and adaptation of the body. In athletes, high HRV may indicate a better ability to recover and mental stability, which, in turn, affects their sensorimotor reactions and overall success in striking martial arts. In order to identify the main factors contributing to the success of technical and tactical actions, which were evaluated in relation to all completed strikes to those counted, a factor analysis of HRV indicators and psychophysiological parameters reflecting the state of regulatory systems was carried out.

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Methods and structure of the study. The study involved boxers aged 18-20: 15 men and 10 women. The functional state of the regulation systems was studied according to the statistical and spectral characteristics of HRV [1] using the Varikard 2.52 hardware and software complex. Cardio intervals were recorded for 5 minutes in a sitting position. The functional state of the central nervous system was determined using the UPFT-1/30 "Psychophysiologist" psychophysiological testing device. The indicators of the time of simple visual-motor reaction (PMR) were studied: 30 values were taken into account, the number of errors (the number of missed stimuli or anticipatory reactions). The reaction time (PMR, ms) and the stability of the response (SKO-PMR) were evaluated. Complex visual-motor reaction (SPMR, ms) was studied based on the analysis of reaction time and stability (SKO-SPMR, ms). The subject was presented with a random

green and red color. The number of errors out of the 35 stimuli presented was taken into account: "no" to the green light, "yes" to the red light. Tremometry (co–ordination) is a method for determining the accuracy of movement reproduction. Measuring tremor is of diagnostic importance for assessing the level of emotional excitability and coordination of movements. The tremor value was estimated during the movement of a special probe in the maze in the form of a winding slot. The width of the slot is 6 mm, the length of its trajectory is 20 cm. Tremometry parameters were evaluated taking into account the time and quality of the task.

The results of the study and their discussion. Each factor combines features that strongly correlate with each other. The suitability of factor analysis according to the Bartlett test is significant ($p < 0.05$). The Varimax initial rotation method was applied, which made it possible to trace a clear factor structure and identify variables marked by correlation coefficients of more than 0.50 with one factor or another. The correlation was considered strong if the coefficient was more than 0.70. The results of calculations of these boxers are presented in Tables 1, 2. Factor loads, the value of which is less than 0.50, are not indicated.

Factor 1 is a general factor, with a variance of 52.7%, which determines the proportion of the influence of these parameters on the functional state of regulatory systems and the psychophysiological status that affect the success of the fight of women specializing in boxing. This factor includes tremometry values (an increase in task completion time has a close inverse relationship with combat success); stability of a simple visual-motor reaction (feedback); and stress index (feedback).

Factor 2 with a variance of 17.4% signals the role of overexertion and stress in percussive martial arts. The IC – HRV centralization index reflects the ratio of activity of the central and autonomous circuits of heart rate regulation. IC is the ratio of the sum of high frequency waves to low frequency waves. This indicator reflects the degree of predominance of activity of the central regulatory circuit over the autonomous one. An increase in the index may indicate a strain on regulatory systems. Consistently high IC can be a marker of chronic stress or overexertion. With an increase in IC, the time of complex reaction to a visual stimulus increases, which negatively affects the implementation of technical and tactical actions in percussive martial arts.

Factor 3, with a variance of 11.4%, reflects the lability and mobility of nervous processes and includes the values of simple and choice reactions. The analysis revealed some differences in the factors, their distribution and content in men and women. Factor 1 is a general factor with a variance of 58.0%. The success factor of the battle is related to the indicators of simple reaction and reaction stability (feedback) and HRV – VLF values. In sports, VLF analysis helps to assess the long-term adaptive processes that occur in an athlete's body in response to physical activity. This indicator is used to assess the state of the autonomic nervous system and the overall stress load on the body associated with vasomotor activity and thermoregulation.

A decrease in VLF may indicate a lack of recovery after intense exertion or chronic fatigue. An increase in VLF at rest may indicate excessive activation of humoral mechanisms, for example, under stress. Trained athletes usually have an optimal level of VLF at rest. Too low or too high VLF may indicate that the training process needs to be adjusted. During intense physical exertion, VLF may decrease, which is associated with a switch in regulation to the sympathetic nervous system. After the end of training and the body's transition to a resting state, a gradual recovery of the VLF component of the general heart rate spectrum is observed [2]. VLF values are determined by the level of physical fitness, the formation of sport-specific adaptations

Table 1. Results of factor analysis of female boxers (n=10)

Indicators	Factor 1 – technical and tactical activities	Factor 2 – overexertion and stress	Factor 3 – lability and mobility of nervous processes
Tremometry test time, ms	0.910		
Successful strikes, %	-0.894		
SKO-PZMR, ms	0.620		
SI	0.610		
IC		0.907	
SPMR, ms		0.545	0.538
PMR, ms			0.571
The variance is 81.5%	52,7	17,4	11,4

Table 1. Results of factor analysis of female boxers (n=10)

Indicators	Factor 1 – technical and tacti-cal activities	Factor 2 – lability and mobility of nervous pro-cesses	Factor 3 – recovery and long-term adaptation to stress
Successful strikes, %	-0,822		
PMR, ms	0.740		
VLF, мс²	0.715		0.570
SKO-PZMR, ms	0.686		0.564
SKO-PZMR, ms		0.974	
SPMR, ms		0.756	
SI			0.873
HF, мс²			-0.629
The variance is 80.9%	58,0%	12,9%	10,1%

for this sport [2] and the current state of the athlete. Professional athletes may have lower VLF scores than untrained people, which is associated with higher autonomic regulation.

Factor 2-12.9% – lability and mobility of nervous processes (SPMR ms, SKO-SPMR, ms) – time and stability of a complex reaction.

Factor 3-10.1% – recovery and long-term adaptation to stress – includes HRV indicators (VLF mc2, SI, HF MC2) associated with humoral regulation mechanisms and activation of parasympathetic influences, stress index. HF waves are a key indicator of parasympathetic regulation, which is responsible for recovery processes and a decrease in the activity of the sympathetic nervous system. When VLF and HF are activated, the stress index (SI) decreases and the stability of the simple reaction improves (SKO-PMR, ms). The values of VLF and SKO-PMR also determine the success of a boxer's fight, as they are included in the general factor 1.

Conclusions. A simple sensorimotor reaction is the basic value of CNS readiness, reflecting the lability of nervous processes [3] and determines the success of combat in boxing. The percentage of success-ful strokes in men and women has a close relationship with time and the stability of a simple visual-motor reaction. The success rate of strokes in women is determined by resistance to stress and the level of emotional excitability. In men, the success of combat is related to the processes of long-term adaptation and the level of VLF influences.

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