# Influence of psychoemotional stress on the functional state of the neuromuscular system and the efficiency of sensorimotor activity of highly skilled athletes

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**Purpose:** assessment of the influence of the level of psychoemotional stress and the effectiveness of mental self-regulation on the functional state of the neuromuscular system and the effectiveness of the sensorimotor activity of highly skilled athletes specializing in complex co-ordination sports (on the example of diving).

**Material & Methods:** study involved 14 high-class athletes (master of sport, international master of sport, honored master of sports) at the age of 15–30 years. To determine the psychophysiological properties of the nervous system of athletes, the diagnostic complex "Diagnost-1" are used. Electroneuromyography was performed on the neurodiagnostic complex "Nicolet Viking Select". For a differentiated assessment of the level of stress, the emotional state of the respondents and also for assessing the effectiveness of mental self-regulation, a technique to select colors was used.

**Result:** interrelation between the effectiveness of mental self-regulation and adaptability, the intensity of existing stress, emotional stability and vegetative balance with electroneuromyographic characteristics, strength and functional mobility of nervous processes, the accuracy of reaction to a moving object and the ratio of the reactions of lead and lag, the efficiency of sensorimotor activity are identified.

**Conclusion:** revealed interrelation of the effectiveness of mental self-regulation and adaptability, intensity of existing stress, emotional stability and vegetative balance with typological properties of the higher parts of the central nervous system and electroneuromyographic characteristics of athletes can have prognostic value and be used to optimize the sports development of promising young people.

**Keywords:** efficiency of sensorimotor activity, electroneuromyography, highly skilled athletes, diving.

## Introduction

A special place in the formation of reliability and effectiveness in sports belongs to the adaptive capabilities of the athlete. Degree of expression of adaptive reactions to the action of external stimuli is one of the main criteria of physical and mental health of an athlete [22] and depends both on the functional reserves of the organism, and on the preliminary adaptation of the athlete's organism to the acting stimulus. Adaptability determines the ability of an athlete to maintain the necessary performance for a long period of time with high efficiency and rapid recovery, which ensures the reliability of achieving high results in sports [8; 29; 30].

It is well known that the formation of a long-term adaptation of the athlete's body to physical loads of different directions leads primarily to improving the effectiveness of sports activities. Physiological adaptation is specific for different types of training loads, typical for different sports. In order to achieve a specific physiological adaptation, the training program must ensure the workload of precisely those physiological systems that are crucial for achieving optimal results in this sport [24; 27].

As the factors determining the psychological adaptability and success of athletes' performances regardless of sports specialization, some authors singled out: high motivation for achievement, adaptive abilities, an internal locus of control,

organization, commitment, perseverance [3; 4; 11; 35]. Their severity differs among representatives of different sports. For example, in artistic sports the most important psychological qualities that determine adaptation to competition are: plasticity, emotionality, mobility of nervous processes, emotional stability, low internality in the field of failures. In martial arts positively affect the adaptation to the competition: the power of excitement, aggressiveness in combination with mental stability, the desire for «struggle» and domination [11]. It is known that the unique variants of adaptation in the sport of higher achievements are best overcome by individuals with a mosaic type of functional asymmetry of the brain [12].

Thus, the problem of adapting to strained physical loads with different types of energy supply depending on the individual characteristics of athletes remains one of the topical problems of biology and medicine, psychology and physiology of sports [20; 21; 26].

One of the methods for predicting the reliability and success of sports activities is to monitor the functional state of the central nervous system of athletes in conjunction with their individual and typological characteristics [6; 14; 18; 31]. To evaluate the functional state of the neuromuscular apparatus of athletes, the application of electroneuromographic (ENMG) study with determination of parameters of the H-reflex, which is a monosynaptic reflex response that is diverted from the muscle (in this case soleus muscle of the leg) under conditions of electri-

cal stimulation of its low-threshold sensitive fibers that make up the mixed nerve [1; 9; 10].

**Relationship of research with scientific programs, plans, themes.** In carrying out complex biological research with the participation of athletes in accordance with the principles of bioethics, the theory and methodology of sports training and reserve capabilities of athletes developed by the Research Institute NUPESU "Programs for a comprehensive biological study of the features of athletes' functional capabilities," as well as the health care legislation of Ukraine and the Helsinki Declaration of 2000, the European Society Directive 86/609 on the participation of people in biomedical research [32].

The work was carried out in accordance with the state budget research theme 2.2п «Technology prediction of the economic development in the instants of the resettlement» (State Registration No. 0117U002385) of the Ministry of Education and Science of Ukraine.

**Purpose of the study:** assessment of the influence of the level of psychoemotional stress and the effectiveness of mental self-regulation on the functional state of the neuromuscular system and the effectiveness of the sensorimotor activity of highly skilled athletes specializing in complex co-ordination sports (on the example of diving).

## Material and Methods of the research

The study involved 14 high-class athletes (MS, MSIG, HMS) at the age of 15–30 years (sport – diving). To determine the psycho-physiological properties of the nervous system of athletes, the diagnostic complex "Diagnost-1" [14; 17; 19; 20; 31]. Electroneuromyographic study was performed on the neurodiagnostic complex Nicolet Viking Select (USA-Germany). A technique was used to determine the rate of conduction of a nerve impulse along the motor fibers of various nerves of the upper and lower extremities, as well as the H-reflexometry [1; 9; 10].

When examining the upper extremities, tested athlete was in a sitting position; his arms were freely placed on the couch. Electrical stimulation of the median nerve (*n.medianus)* was performed in the wrist and elbow joint area with the registration of the M-response (direct muscle response to irritation of motor nerve fibers) from the muscle that leads the thumb (*m.abductor pollicis brevis)*; stimulation of the ulnar nerve (*n.ulnaris*) in the region of the wrist and elbow joint with the registration of M-responses from the muscle that leads the little finger (*m.abductor digiti minimi).*

When examining the lower limbs, the athlete was lying on his stomach, his feet freely hanging from the couch. H-reflex soleus muscle (*m.soleus*) was caused by bipolar percutaneous stimulation of the tibial nerve (*n.tibialis*) in the popliteal fossa. In determining the rate of nerve impulse conduction through the motor fibers of the tibial nerve (*n.tibialis*), stimulation was conducted in the popliteal fossa and the posterior region from the medial epicondyle and M-responses were recorded from the muscle of the short flexor of the fingers (*m.flexor hallucis brevis).* For recording electromyographic signals using a pair of standard surface electrodes with interelectrode distance 20 mm.

Following ENMG parameters were analyzed: $P_H$ and $P_M$ (thresholds for the appearance of the H-response and the M-response), $P_H/P_M$ (ratio of the thresholds for the occurrence of H- and M-responses), $H_{maks}$ and $M_{maks}$ (amplitude of the maximum H-response and maximum M-response), $H_{maks}/M_{maks}$ (ratio of the amplitudes of the maximum H- and M-responses in %). Values of impulse conduction velocities were also obtained (ICV) of motor fibers of the tibial, median and ulnar nerves. Indicators for the right limb (RC) and left limb (LC).

To determine the level of existing stress in athletes, M. Luscher's test was used [2; 5; 23; 28]. Stress level indicator (SL) in the range 0–4 points was characterized by low SL, 5–8 points – average and 9–12 points – high level of stress [15; 16]. Integrative index of emotional stability by the M. Lusher test (ES) was calculated by the method proposed in the methods of investigating the functional state of operators [16]. So, 3 points were assigned to the athlete if he is emotionally stable, 2 points – in case of lack of emotional stability and 1 point – when there is an alarm, signs of emotional instability. Valnefer coefficient (VC) – an index of the total deviation from the autologous norm, was used to assess the harmony and internal optimality of the neuropsychic state of athletes [16]. Minimum values of VC are an indicator of adaptability, well-developed mechanisms of self-regulation, lack of signs of fatigue, emotional tension and intrapersonal conflicts. Based on the values of VC, the contingent of the subjects was divided into individuals with a high level of self-regulation and adaptability (VC is 1–10 c.u.), with an average level of self-regulation and adaptability (VC is 11–20 c.u.), with signs of fatigue and a decrease in the level of self-regulation and adaptability (VC more 20 c.u.).

Lusher's test also allowed us to indirectly judge the sympathetic or parasympathetic dominance of activity in the autonomic nervous system of the subjects [16; 34]. For this purpose, the coefficient of vegetative balance of K. Shipos (KS). Value of KS>1 is interpreted as ergotropic dominance (sympathotonia), KS<1 as trophotropic dominance (vagotonia), KS=1 – as vegetative balance, respectively.

Statistical processing of data was carried out using nonparametric statistics. The results were processed by statistical analysis using the computer program STATISTICA 6.0.

## Results of the research and their discussion

Of particular interest are studies of the psychophysiological reliability of the athlete, based on the ideas of B. F. Lomov [13] that characterizes the reliability, above all, the potential reserves of the person, and the effectiveness of professional activity – mainly the presence of certain properties [29, 30].

In this study, an attempt was made to identify the criteria for assessing the potential reserves of athletes in complex co-ordinated sports by analyzing the interrelationships between the effectiveness of mental self-regulation and adaptability of athletes, as well as the relationship between the level of existing stress, emotional stability, vegetative regulation with electroneuromyographic and psychophysiological characteristics.

Overall, 78,57% of athletes with high (21,43%) and medium (57,14%) levels of self-regulation and adaptability were identified among the surveyed sportsmen (Valnefer coef-

ficient from 1 to 20 c.u.), which indicates that most of the athletes – surveyed are sthenic, balanced, have no signs of fatigue, emotional tension and intrapersonal conflicts. At the same time, 21,43% of athletes were identified (Valnefer coefficient more than 20 c.u.) with a low level of self-regulation and adaptability, signs of fatigue and heightened emotional tension.

As you know, a special place in the formation of reliability in sports belongs to the nonspecific reaction of the body to various stress factors: cold, hunger, fatigue, rapid movement, lack of oxygen, blood loss, pain, uncertainty of the situation, and extreme significance of events for the individual – that is, resistance to stress. On the impact of stress factors, the body responds not only with the appropriate protective reaction, but also with a universal process – an adaptation syndrome, that is, mobilization of the organism's capabilities [3; 5; 7; 29; 33; 35].

According to the results of M. Lusher's test, it was revealed that the level of existing stress was low or absent – in 64,29% of the surveyed athletes, average LS – in 28,57% of athletes, high LS – in 7,14% of athletes. Authors admit that it is the athletes with a high level of existing stress that can primarily constitute a risk group for the development of occupational stress [33].

According to the results of the studies, 71.43% of the surveyed athletes had a high (28,57%) and average (42,86%) emotional stability, while 28,57% of the athletes were emotionally unstable.

In addition, the Lusher test allowed indirectly to judge the sympathetic or parasympathetic dominance in the autonomic nervous system of the examined athletes [16; 23]. According to the results of the conducted studies, 57,14% of the examined athletes demonstrated the predominance of sympathetic regulation (sympathotonia), 28,57% – the predominance of parasympathetic regulation and 14,29% – were normotonics. Thus, the surveyed athletes had more pronounced ergotrope dominance.

Correlation analysis of the obtained data showed that the Valnefer coefficient in the examined athletes was not related to age and sports experience. Ratio of the vegetative balance of Shipos criterionwas significantly correlated according to the Spearman criterion with sports experience (respectively $r_s=0,55$, $p<0,05$). Same criterion establishes an inverse correlation between the age of athletes and the coefficient of assessing the intensity of existing stress($r_s=-0,68$, $p<0,05$), as well as a direct correlation – between age and the indicator of emotional stability ($r_s=0,80$, $p<0,05$). Thus, the increase in sports experience (and, therefore, for athletes of high class – improving sports skills) was associated with an increase in the dominance of sympathetic regulation in the autonomic nervous system. With age, in the examined observed athletes decrease in the level of stress, increased stress resistance and increased emotional stability.

Correlation analysis showed the existence of interrelations between the effectiveness of mental self-regulation and adaptability, the intensity of existing stress, emotional stability and vegetative balance with electroneuromyographic characteristics – speed of conduction of the nerve impulse along the motor fibers of the ulnar nerve and the threshold of the occur-

rence of the H-response (Table 1). Evealed interrelations of the measured parameters can testify to the mutual influence of the functional state of the neuromuscular apparatus and the neuropsychic state of the athletes. The obtained results confirm the well-known paradigm (postulate) that reactivity (including nonspecific reactivity), as well as individual-typological features of the nervous system, temperament, significantly influences the components of mental health and can contribute to the corresponding disorders of the psyche and personality behavior – affective, neurotic, psychosomatic disorders [7; 25; 35].

**Table 1**

**Correlation links (according to Spearman) psychological characteristics of athletes with electroneuromyographic characteristics (n=14), $r_s$**

| Indicators | Correlation links, $r_s$ |
|---|---|
| Valnefer coefficient – speed of the impulse along the ulnar nerve (right arm), $m \cdot s^{-1}$ | 0,58* |
| Indicator of the level of stress – speed of the impulse along the ulnar nerve (right arm), $m \cdot s^{-1}$ | 0,61* |
| Indicator of emotional stability – speed of the impulse along the ulnar nerve (right arm), $m \cdot s^{-1}$ | −0,56* |
| Coefficient of the vegetative balance of K. Shiposh – the threshold of occurrence of the H-response (right leg), mA | 0,54* |

***Note.*** * – $p<0,05$.

Predominance of sympathetic dominance in the functioning of the autonomic nervous system of athletes was associated with large values of thresholds for the appearance of the H-response (values of the stimulatory current needed to obtain the minimal H-response). And such ENMG parameters as the thresholds for the appearance of the M-response, the ratio of the thresholds for the occurrence of H- and M-responses, the amplitude of the maximum H- and M-responses, and the ratio of the amplitudes of the maximum H- and M-responses were not associated with the measured psychological characteristics of athletes.

Correlation analysis of the obtained data revealed the existence of interrelations between the effectiveness of mental self-regulation and adaptability in the examined athletes with the indices of strength and functional mobility of the nervous processes (Table 2), the accuracy of the reaction to the moving object and the ratio of the lead and lag reactions (Table 3). Athletes with the optimal neuropsychic state had a higher functional mobility of the nervous processes, greater strength of the nervous processes and a greater prevalence of advanced reactions in the RMO on the results of three trials.

Coefficient of the intensity of existing stress was related to the indices of the strength of the nervous processes and the efficiency of the sensorimotor activity (see Table 2) and the accuracy of the reaction to the moving object (see Table 3). Stress-resistance of athletes was associated with greater strength of the nervous processes and efficiency of sensorimotor activity, a greater predominance of advanced reactions in the RMO and a smaller number of delayed responses.

Higher the emotional stability of the examined athletes, the greater the effectiveness of sensorimotor activity, determined by the time of minimum exposure of signals in the feedback

**Table 2**
**Correlation (according to Spearman) psychological and psychophysiological characteristics (in feedback and imposed rhythm) among athletes (n=14), $r_s$**

| Indicators | Correlation links, $r_s$ |
|---|---|
| Valnefer coefficient – is an indicator of the functional mobility of the nervous processes (test 5 min) | 0,62* |
| Valnefer coefficient – indicator of the strength of the nervous processes (test 5 min), the number of processed signals in the range of 30–60 s | –0,68** |
| Valnefer coefficient – indicator of the strength of the nervous processes (test 5 min), number of processed signals in the range of 90–120 s | –0,54* |
| Stress level indicator - minimum exposure time of signals (test 5 min), ms | 0,56* |
| Stress level indicator – indicator of the strength of the nervous processes (test 5 min), the number of processed signals in the range of 30–60 s | –0,55* |
| Stress level indicator – показатель силы нервных процессов (тест 5 мин), the number of processed signals in the range of 210–240 s | –0,58* |
| Indicator of emotional stability – minimum exposure time of signals (test 5 min), ms | –0,54* |
| Coefficient of vegetative balance of K. Shipos – indicator of the strength of the nervous processes (test 5 min), number of processed signals in the range of 90–120 s | 0,56* |

*Note.* * – p<0,05; ** – p<0,01.

**Table 3**
**Correlation links (according to Spearman) of psychological and psychophysiological characteristics (reaction to a moving object by the leading hand) among athletes (n=14), $r_s$**

| Indicators | Correlation links, $r_s$ by results of the best samples | by results of the three samples |
|---|---|---|
| Valnefer coefficient – total number of the leading reaction | – | –0,71** |
| Valnefer coefficient – ratio of the total number of lead and lag | – | –0,60* |
| Valnefer coefficient – ratio of total lead and lag | – | –0,58* |
| Stress level indicator – number of lag reactions | 0,54* | – |
| Stress level indicator – ratio of the total number of lead and lag | –0,54* | – |
| Stress level indicator – total number of the leading reaction | – | –0,60* |
| Coefficient of vegetative balance of K. Shipos – total deviation | –0,68** | – |
| Coefficient of vegetative balance of K. Shipos – average deviation | –0,69** | – |
| Coefficient of vegetative balance of K. Shipos – average lead | –0,61* | – |
| Coefficient of vegetative balance of K. Shipos – average lag | –0,54* | – |
| Coefficient of vegetative balance of K. Shipos – total deviation | – | –0,62* |
| Coefficient of vegetative balance of K. Shipos – average deviation | – | –0,62* |
| Coefficient of vegetative balance of K. Shipos – average lead | – | –0,63* |
| Coefficient of vegetative balance of K. Shipos – average lag | – | –0,63* |

*Note.* * – p<0,05, ** – p<0,01.

mode (see Table 2). The predominance of sympathetic dominance in the functioning of the autonomic nervous system of athletes was associated with large values of the strength of the nervous processes (see Table 2) and smaller values of the deviation (lead/lag) in the reaction to the moving object based on the results of the best sample and the results of three samples (see Table 3).

Thus, the specific psychophysiological markers of adaptability can be considered an indicator of the functional mobility of nervous processes, and stress resistance and emotional stability – the effectiveness of sensorimotor activity.

Revealed interrelationships between the effectiveness of mental self-regulation and adaptability, the intensity of existing stress, emotional stability and vegetative balance with the typological properties of the higher sections of the central nervous system and the electroneuromyographic characteristics of athletes may have prognostic value and used for optimization of sports perfection promising young people in this sport.

## Conclusions

1. The interrelationships between the effectiveness of mental self-regulation and adaptability, the intensity of existing stress, emotional stability and vegetative balance with electroneuromyographic characteristics – the speed of the nerve impulse along the motor fibers of the ulnar nerve and the threshold of the occurrence of the H-response.

2. It was revealed that the effectiveness of mental self-regulation and adaptability in the examined athletes was associated with the strength and functional mobility of the nervous processes, the accuracy of the reaction to the moving object and the ratio of the lead/lag reactions.

3. Intensity of the existing stress in the studied group of athletes was associated with the indicators of the strength of the nervous processes, the efficiency of the sensorimotor activity and the accuracy of the reaction to the moving object.

4. Emotionally stable athletes demonstrated higher efficiency of sensorimotor activity.

5. Predominance of sympathetic dominance in the functioning of the autonomic nervous system of athletes was associated with greater strength of the nervous processes and smaller values of the deviations (lead/lag) in the reaction to the moving object.

6. Revealed interrelationships of the effectiveness of mental self-regulation and adaptability, the intensity of existing stress, emotional stability and vegetative balance with the typological properties of the higher parts of the central nervous system and electroneuromyographic characteristics of athletes can have prognostic value and be used to optimize the sports development of promising young people.

**Prospects for further research in this direction.** It is of interest to further study the influence of the level of psychoemotional stress and the effectiveness of mental self-regulation on the functional state of the neuromuscular apparatus and the effectiveness of sensorimotor activity of highly skilled athletes specializing in various sports, with the conduct of a comparative analysis of psychophysiological and electroneuromyographic characteristics.

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