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CORRECTION OF FUNCTIONAL SYSTEMS AND SELF-REGULATION OF ATHLETES USING INNOVATIVE METHODS OF BIOFEEDBACK. LITERATURE REVIEW

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ABSTRACT

Maintaining the health of athletes is one of the urgent problems in sports medicine, ensuring high readiness for competitions, as well as success in winning. One of the modern methods that finds development as innovative techniques is the biofeedback method, which provides the possibility of regulating and controlling the physiological and functional state of an athlete. This review of the literature presents the main mechanisms and theories of functional systems that underlie the biofeedback session. The review also presents the possibilities of using the technique taking into account the obtained parameters of the functional activity of bioelectric potentials of the brain, neuromyographic studies.

KEYWORDS: *Biofeedback, athletes, sports medicine, electroencephalography, electroneurography, functional activity of the nervous system.*

Trends in professional activity in recent years are associated with a steady increase in workloads in almost all types of professional human activity. The consequence of this is a disruption in the work of regulatory mechanisms, which significantly reduces the level of physical performance and can lead to various adverse vegetative changes in the state of health. The problem of ensuring the effective training of athletes in extreme conditions of activity and the creation of functional prerequisites for maintaining health is becoming more and more urgent. One of the ways to solve this problem is to use effective modern and physiologically sound technologies while using a rational system of complex diagnostics and correction of the functional state. This approach allows expanding the range of compensatory capabilities of the body against the background of the maximum volume and intensity of professional and psycho-emotional stress. Ensuring optimal adaptation to muscle loads can become one of the conditions for maintaining the level of health and improving the quality of professional skills. Undoubtedly, this problem is of particular importance in the modern conditions of human professional activity. This is reflected in a number of works related to the concept of the criticality of loads both in sports and in other areas of professional activity.

Along with traditional approaches, various sports have accumulated extensive experience in using a number of non-traditional means in the system of sports training (middle mountains, pressure chamber, hypoxic and hyperthermic effects, special breathing exercises, biofeedback methods, active self-regulation and relaxation techniques, etc.). At the same time, it should be notedthat recently, among non-traditional means of influencing the functional state of the human body, close attention has been paid to muscle relaxation techniques, which are characterized by such features as safety of exposure, relative ease of achieving the effect, and low financial costs. Relaxation, according to a number of authors[5,6,9], is also considered as an alternative or addition to the correction of the functional state. Therefore, it is often presented as a means of preventing, correcting and eliminating emotional stress. According to the researchers, besides, it is one of the leading methods in a number of methods that allow achieving the necessary changes in the functional state of the body.

In physiology, relaxation is understood as an active process of reducing muscle tone, as well as reducing the degree of psycho-emotional stress. Naturally, all the changes that characterize relaxation processes cannot be reduced to this. Thus, the relaxation of the respiratory muscles significantly changes the state of the respiratory system. During relaxation, a trophotropic state occurs,

the level of anxiety, psychological and physiological response to stress decreases. In addition, relaxation is accompanied by a significant decrease in afferent and efferent impulses, which is confirmed by electroencephalogram data.

As a result, we can say that the introduction into practice of relaxation methods aimed at preventing, correcting and eliminating negative psycho-emotional states can help increase the adaptive capabilities of the body.

Relaxation methods have found application in the correction of a number of pathological conditions, in the treatment of hypertension, to relieve acute and chronic pain conditions, including in sports activities. The state of relaxation is at the heart of meditative techniques. Meditation and relaxation exercises have a wide range of applications, often used in transcendental medicine. There is no doubt that the listed effects of the use of relaxation methods are of great importance in sports activities. In this regard, it is necessary to note such relaxation techniques as biofeedback, functional music, and aromatherapy that have been developing recently and having an objective impact on the functional state of the body of athletes. We also note that all the most effective methods of psychoregulation, self-regulation and autotraining, used in the special psychological training of athletes, and the latest health technologies are based on relaxation.

A functional system is a combination of processes and mechanisms, which, being formed dynamically depending on the created situation, inevitably leads to the final adaptive effect, useful for the body inthis situation.[1] It follows from the definition that a functional system can be formed from such subsystems and mechanisms that may be very distant anatomically. This means that the structural scheme of a functional system and the direction of its activity are determined not by a physiological organ, not by the anatomical proximity of the elements, but by the dynamics of association with the target function of obtaining a useful final adaptive effect.

Based on the provisions of the theory of functional systems P.K. Anokhin[2,3], when using biofeedback (hereinafter - BFB) to control the functional state of athletes should take into account the following[4]:

Biofeedback should be focused on a useful adaptive result, taking into account its entry into the functional systems of the body and its athlete's foresight;

When organizing biofeedback, it is necessary to take into account the parameterization of the result in the functional system, i.e., receptors must be formed at the appropriate hierarchical level to evaluate the useful result;

It is necessary to take into account several feedbacks available in the functional system, which differ in temporal characteristics, modality and signal power depending on the level and parameters of the acceptor of the result of the action (physical, cognitive, emotional, etc.)

Assessment of the adequacy of the use of biofeedback in the management of the functional state of athletes can be carried out using a cybernetic model that takes into account the parameters of regulated functional systems, with a check of the model's compliance with the behavior under study.

Based on the theory of functional systems P.K. Anokhin and workprof. EAT. Umryukhin[4], we note the most important provisions in the analysisBiofeedback in the tasks of managing the functional state of athletes:

1. The activity of athletes is organized by functional systems
In order to obtain a result useful for an athlete in accordance with the objective function of this result and the algorithms of activity performed.
The parameters must be obtained, known and estimated usingbody receptors and external information messages.

2. The functional systems of athletes are organized hierarchically, andthe result of the activity of individual functional systems, integrating, leads to the performance of the target function at a higher hierarchical level.

3. In a functional system, when considering one level of hierarchy there are several feedback loops:
- Feedback from the need, on the basis of which the dominant motivation is formed;
– Feedback from the result parameters that satisfies the originalneed;
- Feedback from the acceptor of the result of the action to the afferent synthesis;
– Feedback from executive actions to the acceptor of resultsactions, etc.

The use of biofeedback methods leads to a change in the structure of functional systems. In some cases, structural changes occur at the level of an already formed functional system, when the physiological (psychophysiological) parameter introduced into the biofeedback circuit directly is associated with a useful result for the athlete, and when, on this basis, another reinforcing circuit of the return afferentationis formed at the conscious level. In addition, there is an expansion of the receptor field through the use of visual, sound or tactile channels for the perception of information by athletes. In other cases, a new functional system is formed.[5,6] It is assumed that a change in the structure of an existing functional system or the formation of a new one is due both to the target function of a particular BFB method and to the individual characteristics and level of training of an athlete (patient). When using the BFB

method, athletes can form new functional systems for the self-regulation of certain psychophysiological (physiological) parameters and functional states (behavioral reactions), while in some cases such functional systems cannot be formed in any other way.

Several types of biofeedback are known: sound, tactile, visual (visual). The choice of the type, modality and parameters of biofeedback is determined by the problem statement and the conditions for biofeedback. Tactile and sound biofeedback can be used to control the functional state of athletes, if the algorithms of its activity require intensive loading of the visual analyzer. Visual BFB has become the most widespread, and a number of authors have demonstrated its advantages over other types of BFB organization.[7,8] A polyfunctional (multi-parameter) biofeedback, in contrast to a monoparametric one, implies the possibility of simultaneous control over several physiological systems, which is preferable for a number of tasks.[9,10] This is due to the fact that the multiple adaptive responses aimed at maintaining homeostasis are a good example of the complex interactions and control systems that an organism possesses, constantly and simultaneously integrating and controlling multiple systems of physiological responses. BFB methods belong to promising areas of modern medicine and psychophysiology. Significant experience has been accumulated in the application of the method for the problems of diagnostics, rehabilitation and prevention of diseases. As a diagnostic method, this method allows dynamic testing of the regulatory properties of biosystems by strengthening existing or creating artificial information links between individual functional systems in the mechanisms of homeostasis and adaptation. In the tasks of rehabilitation, the method allows accelerating the restoration of impaired functions, mobilizing and expanding the body's reserve capabilities, improving the nervous regulation of functions and functional interaction between the physiological systems of the body. This method is fundamentally different from others: it is focused on the rehabilitation of the body's control systems and contributes to the achievement of not only medical, but also social rehabilitation. It is necessary to know that adaptive biofeedback has practically no contraindications. It is also important that biofeedback can be successfully applied even to children from 5–7 years of age with psychomotor developmental delay, with a significant reduction in the use of pharmacological agents. At present, functional biofeedback is of particular importance as an effective preventive measure aimed at increasing the adaptive capabilities of a person and his stress resistance, optimizing the psycho-emotional sphere.

One of the key provisions of the concept of bioadaptive animations in virtual reality systems is the use of the semantic biofeedback method, which is the development of the classical biofeedback method, the transition to the next, higher hierarchical level. When organizing semantic biofeedback, it is supposed to use not psychophysiological (physiological) parameters (as in the classical ways of organizing biofeedback), but integral indicators, such as the functional state or behavioral response of the operator.[9,18] The functional states (behavioral response) of the operator of athletes can be interpreted using various data, such as the analysis of physiological (psychophysiological), psychological parameters, control of the correctness and effectiveness of the implementation of activity algorithms, analysis of the situation in the internal circuit of the “man-machine” system and the interaction of this system with external environment. Taking into account these features, a new way of organizing BFB of a higher hierarchical level is proposed, which is classified as a way of organizing semantic BFB.

Semantic biofeedback is a way of organizing biofeedback, where such integral indicators as a functional state, a person's behavioral response in a specific expedient situation are used as feedback parameters. Managing the functional state of an athlete using semantic BFB allows solving the following tasks[6]:

- Preventive formation of functional systems in the process of technological preparation, ensuring the maintenance of psychophysicalthe human condition necessary for the implementation of activity algorithms;
- Stress relief (relaxation) after the end of the activity or duringtime of technological breaks;
- Operational management of the functional state of the operator and/orathlete directly during the execution of activity algorithms,based on the skill of adaptive state transformation. The theory of functional systems[11,22], which considers a purposeful behavioral act as a systemic dynamic organization unfolding in a certain sequence, has specific key mechanisms that are involved in the construction and implementation of complex adaptive behavior. At the same time, according to P.K. Anokhin[1,2], all functional systems, regardless of the level of their organization and the number of constituent components, have fundamentally the same functional architecture, in which the result is the dominant factor stabilizing the organization of systems. The biofeedback method makes it possible to perform a number of initially involuntary functions of the operator's (patient's) body and bring to the level of consciousness the dynamics of their changes, due to various kinds of influences. The main mechanisms underlying the structure of a behavioral act of any degree of complexity include: afferent synthesis; decision-making stage; formation of an acceptor of the result of an action; the formation of the action itself; multicomponent action; achieving a result; reverse afferentation about the parameters of the achieved result and its comparison with the previously formed model in the acceptor of the result of the action.[11]

The biofeedback methodology has long been and effectively used in sports,many fundamental and applied results have been obtained.[12–15]

Modern professional sport is characterized by progressivean increase in the volume and intensity of physical activity, which leads to the need for widespread use in the training process of various stimulating and restorative, including pharmacological agents.

However, in recent years, the International Olympic Committee, taking care of the health of athletes, tightens the requirements for anti-doping control and prohibits the use of doping. Under these conditions, it is obvious that there is a need to search for new approaches to expand the functionalitybody, increasing the efficiency and endurance of athletes. One of these approaches can be the use of biofeedback and similar methods of self-regulation. For the first time biofeedback was carried out in 1938. E. Jacobsonduring relaxation training using visual control through external feedback of the intensity level of muscle bioelectric activity.[16] In the future, BFB methods received the greatest development. According to the electronic program (EMG-BFB), since the striated muscles are easily amenable to arbitrary (conscious) management and control. On the basis of EMG-BFB, a method of "deep relaxation" was developed in Germany, which has become very popular in the treatment of stress and neuroses. Further studies have shown that the relaxing effect of EMG-BFB significantly increases when it is combined with regulation by electroencephalogram (EEG-BFB), heart rate (HR-BFB), blood pressure (BP-BFB), etc.[17–19] The generalization of the literature data and the results obtained makes it possible to consider the cause-and-effect relationships of the processes and mechanisms that ensure the expansion of the functional capabilities of the body and the increase in physical performance. Any cyclic work is carried out due to the alternating tension and relaxation of the skeletal muscles. Physical performance, or the ability to perform physical work, depends mainly on the level of development of the contractile characteristics of the muscles. And the duration of the work (endurance), ceteris paribus, depends on the economy of spending and the rate of recovery of the body's energy resources during motor activity, which are directly dependent on the functional state of the central nervous system (hereinafter referred to as the CNS) and the rate of voluntary relaxation of the skeletal muscles.

Under the influence of biofeedback EEG, activation of the inhibitory systems of the central nervous system, strengthening of inhibitory control, normalization of the process of muscle relaxation, a significant increase in the rate of formation of the relaxation type of long-term adaptation occur. These positive restructurings activate a chain of interrelated processes that provide economy of functions, reduction of energy costs, increase in the rate of recoveryprocesses and increase physical performance. Strengthening inhibitory control leads to a decrease in psycho-emotional tension and hypertonicity of skeletal muscles, improved regulation andcoordination of movements, inclusion in the work of only the most necessary groups of muscles, i.e. to the practical implementation of the law of "saving active musclemass", which was first described by G.P. Conradi in 1934.[20–26] Itis manifested by a decrease in the content of creatine in the blood after exercise (hereinafter referred to as FN). Increasing the rate of muscle relaxation during cyclic work activates a number of mechanisms. Firstly, the alternating rhythm of antagonist muscle activity is maintained, the resistance from antagonist muscles is reduced and, accordingly, energy consumption is reduced to perform the same physical activity, i.e., efficiency is increased. Secondly, there is a significant increase in blood flow in the working muscles, which increases 14–15 times in the relaxation phase compared to the phase of muscle tension. This is manifested by an increase in the efficiency coefficient of peripheral blood flow. Thirdly, the improvement of blood supply and, accordingly, the access of oxygen to working muscles is accompanied by an increase in the share of aerobic resynthesis of adenosine triphosphoric acid, which is 30–40 times more effective than anaerobic resynthesis. This is manifested in a decrease in the content of lactate in the blood after exercise, an increase in the efficiency factor for the use of glycolysis, and an increase in the rate of recovery processes during exercise.[24,26] The development of biofeedback methodology today has several mandatory components related to the category of strategic, tactical, and, finally, methodological.[20,27]

Area of strategic decisions The main question we need to answer is whether we accept as a general statement that biofeedback is an alternative technology that provides a paradigm shift "doctor (coach) - patient (athlete)", where the last of the object of medical (or coaching) the impact naturally (due to the specifics of the technology) turns into a full-fledged subject of the educational or treatment and rehabilitation process. If this statement does not meet with objections, then biofeedback should become a mandatory attribute of any situation where there is a "teacher-student" scenario.

Tactical activities Tactical activities can be divided into two categories: research and practical. The research component in its most general form should be focused on the analysis of the central mechanisms of effective biocontrol using all intrascopic (intragraphic) methods of studying brain activity at our disposal. First of all, we will talk about positive emission intrascopy, methods of multichannel mapping of the electric fields of the brain. These high technologies are poorly perceived in connection with biofeedback. However, if we agree with the paradigm shift, then the analysis of the central mechanisms of biocontrolshould be carried out using precisely these tools and methods. The practical side of biofeedback today should be improved through: the widespread use of mathematical models that make it possible to predict the development of biofeedback training, attempts to find on their basis some quantitative criteria for the effectiveness of biofeedback; careful analysis of the database of each athlete; scrupulous

comparison of the dynamics of the psychological and physiological status of an athlete in the process of sports training; wide use of game forms of biocontrol and involvement of modern multimedia technologies for their development.

Methodological Improvements Methodological improvements primarily relate to ensuring the further development of biofeedback training with the maximum involvement of the kinesthetic sphere. This problem can be solved with the help of wireless biofeedback systems (using a radio channel, optimizing the procedure and signal detection areas).

Methodological improvements will make it possible to fundamentally expand the scope of biocontrol technology and obtain scientific results.

A technique for developing the skill of self-regulation of athletes using the BFB methodology.

Preparatory period A. The experimenter explains to the subjectthe purpose of the electrodes (sensors) and, in general terms, the essence of the experiment. Within 5–10 minutes, the subject gets used to the conditions of the experimental environment (during subsequent sessions, the duration of period A is reduced).

Period B. Determination of the base level of the managed indicator (ormanaged indicators). Based on the measurements of psychophysiological characteristics during this period, the control criterion (ranges of self-regulation) is determined. Because of its importance, period B may be repeated several times.

Rest period C. The subject gets acquainted with the instructions for adaptivea state transformation that also contains a motivating message that encourages the subject to try to complete the task. In the instructionsit is usually not indicated which strategies are preferable to use to develop the ability to control one's physiological activity. The subject is given the opportunity to find the functional states, expressed in the correct performance of the task, and further consolidate the ability to randomly generate them. The task is formulated in a simple form. For example, for visual biofeedback, it is necessary to combine the images generated on the screen of information display devices, to display the control image beyond the set thresholds, etc. Each subject chooses his preferred self-regulation strategy (for example, muscle relaxation, changing the breathing pattern, etc.).

Self-regulation period D. The subject is presented with a control image consisting of the current value of the psychophysiological parameter and the control criterion obtained in period B. Period D can be interrupted by 2-minute pauses to present rest to the subject and, if necessary, to correct the control criterion.

Period E. Control of the adequacy of the developed skill of adaptive transformation of the athlete's functional state according to the biofeedback method in order to eliminate the so-called placebo effect.

CONCLUSION

This review presents the current state of research and how new technologies and new approaches are being used to solve existing and potential future problems. Real-time BMF is a relatively new area of research, as can be seen in the studies that have been found. With the improvement of biofeedback systems and applications among the sports contingent, they will become a necessary tool for widespread use in training, training and rehabilitation of athletes. This will subsequently allow for the improvement of high performance, providing high functional activity for world-class competitions.

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28.