

Specialized nutrition for athletes: evaluation of ergogenic action using the principles of evidence-based medicine

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Abstract

The aim is to form a balanced position regarding the ergogenic characteristics of new sports food products in the modern practice of training highly qualified athletes on the basis of clinical-experimental evaluation of the effectiveness of special purpose real food additives.

Materials and methods. Studies were carried out on laboratory animals (36 Wistar rats at the age of 3 months weighing 150–200 g and 16 Svetlogorsk mini-pigs) as well as on 102 high-qualified representatives of cyclic sports (all men aged 19–26) – members of national teams such as swimming (25), cross-country athletics (53), and skiing (24). As a control group, we studied 25 athletes of the same gender (all men), age and qualifications who received a placebo (starch capsules) for a long time during exercise. Placebo-controlled studies have been conducted on laboratory animals and athletes in compliance with the principles of bioethics.

Results. It has been established that in the experiment the application of a new specialized food product MioActiv has a positive effect on the physical performance of animals and delays the onset of fatigue, which significantly exceeds the corresponding characteristics in the placebo group. Athletes also showed an increase in speed when passing competitive distances by 18.7–21.4% ($p < 0,05$), as well as a significant increase in mental endurance indicators ($p < 0,05$). The approbation of the innovative pre-workout pharmacological nutrient complex Pre-Fuse also showed the high efficacy and safety of this product with a positive effect of increasing the performance and endurance of animals, as well as the parameters of mental performance of athletes in the main groups, in contrast to the data in the placebo control groups.

Conclusions. An analysis of the prescription components of new types of ergogenic sports nutrition and the presented results of preclinical and clinical studies conducted on the basis of the evidence-based medicine paradigm regarding the effectiveness of specialized products indicate the complex action of these funds on various aspects of both physical and mental performance. From the materials presented in the article, it can be seen that specialized sports nutrition products of an ergogenic orientation can provide significant assistance in increasing sports results.

Keywords

sport, ergogenic functional nutrition, new dietary supplements, preclinical studies of working capacity parameters, evidence-based medicine

Introduction

The problem of nutrition and supplements to it in the form of dietary supplements (often called “sports nutrition”) is one of the components of improving the processes of adaptation to physical activity, accelerating recovery and stimulating physical work capacity, and, consequently, increasing the effectiveness of competitive activity, maintaining the health of athletes and prolonging their sports career. This dietary supplement system, the use of specialized products and the use of ergogenic drugs is based on the plan of building the training process itself and is closely related to it (Logan et al. 2015; Gunina 2016; Platonov 2017).

In this regard, we are talking not only and not so much about the regular diet of athletes specialized in various sports events, which have different needs for the main macro- and micronutrients in the dynamics of the training process, but about the necessary dietary supplements that optimize the athlete’s metabolism, taking into account the volume and intensity of the load (Oleynik et al. 2008; Thomas et al. 2016). Among the latter, special products occupy an honourable place, thanks to which not only proteins, fats, carbohydrates, vitamins and minerals enter the body of an athlete, but also special ingredients with biological activity that have the ability to directly affect the metabolic pathways responsible for stimulating physical and mental work capacity. Such products are rightfully classified now as ergogenic (Aleksandr and Larisa 2018).

The main sports nutrition specialized products also contain compositions of pharmaconutrients - natural (or identical to natural) biologically active substances (BAS), intended for direct intake with food or inclusion in food products in order to enrich the diet with BAS and their complexes. These are substances of plant, animal, and mineral origin that improve competitive form, increase physical strength, endurance, attention concentration and work capacity, acting milder than medicinal preparations, and have far fewer side effects (Rosenbloom 2015).

As for the use of such specialized products for sports nutrition, before the beginning of 2018 there was a need for their use in sports as an additional or intermediate means between drugs and methods of ergogenic dietetics (Rosenbloom 2015). According to the modern point of view (Burke 2017; Aleksandr and Larisa 2018; Garthe and Maughan 2018) and the provisions of the International Olympic Committee Consensus on the use of dietary supplements by elite athletes (Maughan et al. 2018), sports nutrition in all its diversity serves as one of the most significant factors of direct and indirect stimulation of work capacity, while maintaining the health of athletes and prolonging sports longevity.

Thus, specialized nutrition products for athletes today belong to the field of research in sports nutritionology, which is a relatively new synthetic, but very actively progressing in recent years, independent direction of clinical and experimental pharmacology and dietetics (Van Loon and Tipton 2013; Aleksandr and Larisa 2018), which has already formed as a separate science. The objectives of sports nutritionology include the development, study and practical implementation of sports nutrition products to increase adaptation to high-intensity physical loads, accelerate recovery and maintain the health of athletes. One of its main tasks is to identify and correct of factors that limit physical work capacity of athletes. Within this framework, the methods of nutritional support of physical activity should take into account specialization and skills of athletes, their gender and age characteristics and should be applied on the training period and the direction of the load (Fry et al. 2018). Due to the improvement and tightening of doping control, it is absolutely necessary that the well-known and widely used products and supplements in sports specialty sports nutrition, as well as future new products, do not contain substances included in the WADA Prohibited List, while it has a pronounced ergogenic effect (Burke 2017; Aleksandr and Larisa 2018). By the beginning of the 21st century, elite sport has turned into a complex socio-political and cultural phenomenon that captures hundreds of millions of people around the world in its sphere of influence. With the development of mass-media communications, and especially the Internet, anyone can take part in elite sports competitions. Several large layers of emotionally and financially involved people have formed around elite sports in society. Therefore, everything related to elite sports should be considered not only as technical, medico-biological, psychological or pedagogical issues, but also as a cumulative phenomenon that covers almost all aspects of society. In many respects, the solution of scientific and practical problems of maintaining the health and physical capabilities of athletes requires team doctors, coaches, and sports medicine organize extensive knowledge and understanding of the limits of applicability of various medical technologies to athletes, objective (based on the results of serious scientific studies, preferably with a high level of evidence rather than on the impressions of athletes and coaches, manufacture advertising and rumours circulating in sports and close to sports environment) assessment of the potential and real efficiency of various biologically active components, prospects and safety of various new scientific research and innovative solutions for sport (Burke 2017; Aleksandr and Larisa 2018).

In the process of training and competitive activity, athletes experience a sharp increase in the consumption of energy and plastic resources, which can lead to a decrease work capacity and the efficiency of recovery processes. This requires the creation of new principles in the development of sports nutrition for elite sport, including components with a pronounced ergogenic biological effect (Fry et al. 2018; Larisa and Alexander 2018). Based on modern views on the optimal nutrition of athletes, that is, the concepts of functional nutrition optimal dietary nutrition (Karkishchenko et al. 2014; Close et al. 2016; Abbey et al. 2017; Shustov et al. 2017), and the agreed position of the American Academy of Nutrition and Dietetics (Gretchen and Heather 2014), efficient sports nutrition should be focused on the main, ergogenic, regulatory components of nutrition, as well as on correctors of the functional state and pathological processes.

Ergogenic sports nutrition products are of particular interest to athletes and coaches, as they are the source of hopes for higher athletic performance. Ergogenic pharmac nutrients are highly specialized components of sports nutrition aimed at mobilizing the body's energy potential (Abel et al. 2005; Louise et al. 2019) and are directly related to improving the competitive result. The list of ergogenic sports nutrition products includes energy and lipotropic means, vitamin and mineral complexes, pre- and post-training complexes, sports drinks of various actions, etc. (Baltazar-Martins et al. 2019). This group of specialized nutrition products is the key and includes such ingredients as caffeine and caffeine-containing products (coffee, tea, chocolate, maté, guarana, Gotu Kola), ginseng, polylactate, inosine, coenzyme Q10, honey products, ribose, dimethylaminoethanol (Ahmad et al. 2017; Aleksandr and Larisa 2018).

Evaluating the ergogenic effects of the biologically active components of functional sports nutrition used, one should take into account, which bioenergetic parameters they preferentially affect. It is important to determine whether these effects are mainly of alacto-anaerobic, or glycolytic-anaerobic, or aerobic, and in what parameter of these bioenergetic properties they are mainly manifested – power, capacity or efficiency of anaerobic and aerobic energy conversion, and what belongs to the basic principles of using ergogenic means in the practice of training athletes (Gunina 2016).

Modern specialized sports nutrition products (functional sports nutrition products) should contain innovative components with a proven positive effect on work capacity or functional state of athletes. An important element of modern functional nutrition products is the inclusion in their composition of natural health-promoting pharmacological nutrients of regulatory or prophylactic effect (adaptogens and tonic, biogenic stimulants, medicinal plants, plant immunomodulators, sources of vitamins and microelements), the effectiveness of which is confirmed by results obtained with application of the principles of modern evidence-based medicine (Gleeson 2016; Berron et al. 2017; Baltazar-Martins et al. 2019; Hariharan and Dharmaraj 2020).

The analysis of possible approaches to the functional nutrition of athletes made it possible to single out two fundamentally different directions: the creation of the widest in composition complexes and the creation of specialized products narrow in composition and specialized in action. At the same time, a third compromise approach is also possible, which involves the combination of specialized pharmacological nutrients into complexes of “vector” action. Various pre- and post-training complexes can serve as an example of the third direction (products of “vector” ergotropic action). It should be noted that at present, the role of specialized sports nutrition and ergogenic supplements, which are a reasonable alternative to banned doping substances and manipulations, has drastically increased (Aleksandr and Larisa 2018; Dmitriev and Gunina 2020).

Unfortunately, the currently valid documents regulating the circulation of specialized food products, including sports, at best confirm their safety (in terms of the maximum content of pharmacological nutrients and the possible level of bacterial contamination), but do not confirm their effectiveness at the level of preclinical biomedical and pedagogical research (Fry et al. 2018; Larisa and Alexander 2018). Therefore, the relevance of publications on this topic in the field of sports science and its constituent disciplines, which are closely related to the field of medical knowledge (sports medicine, sports pharmacology) remains extremely high.

The aim of this work is to form a reasoned position regarding the ergogenic characteristics of sports nutrition products in the modern practice of training high-level athletes based on the assessment of the effectiveness of real food additives for special purposes.

Methods and materials of study

The study was of an experimental and clinical nature and included the study of the features of the influence of specialized sports nutrition products on the working capacity and endurance using the example of laboratory animals, as well as persons under constant influence of intensive long-term physical and psycho-emotional loads – 102 qualified representatives of cyclic sports events (males aged 19–26 years), such as swimming (25), track and field running events (53), cross country skiing (24) who are members of national teams.

The increase in working capacity was assessed by improving the results of the competition at the simulated competition distances. The psychological state of athletes was assessed according to the level of mental endurance, concentration of attention, speed of simple and complex motor reactions, as described in several works (Vysochina et al. 2019; Vysochina 2021). 25 athletes of the corresponding gender (all men), age and skills, who received placebo (starch capsules) in the dynamics of the load acted as placebo control subjects. Thus, a total of 127 athletes took part in the study.

As experimental animals, we used male Wistar rats (total 36, 18 animals per test product) 3 months old weighing 150–200 g and Svetlogorsk mini-pigs (total 16, 8 animals per test product). They were kept in standard vivarium conditions on a standard diet (Stefanov 2002). The animals of the main groups received the studied products intragastrically in an equal equivalent amount corresponding to the conversion per 1 kg of athlete's body weight; the control used a placebo in the form of a 3% glucose solution; all main and control groups included the same number of animals. The standard methods for assessing work capacity and modeling fatigue of laboratory animals were used: a kinesiohydrodynamic study (speed characteristics, work capacity, endurance, fatigue of animals), forced swimming test on rats with a load of 7% of body weight (assessment of non-specific endurance under conditions of combined stress exposure), rotarod test (general endurance and coordination of motor skills of animals), as well as mini-pig treadmill running test A modified technique of multiple presentation of a standard swimming test was used to study the work capacity of animals under fatigue conditions (Karkishchenko et al. 2016). The psychological state of animals in the dynamics of the study was evaluated by special tests described in the article (Karkishchenko et al. 2015).

Animal studies were carried out in compliance with the provisions of bioethics (procedures related to the maintenance, care and use of animals in experiments were carried out in accordance with the requirements of the Directive of the European Parliament and the Council of the European Union for the Protection of Animals Used for Scientific Purposes (EU Directive 2010). Athletes participated in the study on the effectiveness of innovative specialized sports nutrition products only after they provided "Voluntary informed consent".

Tested products

The MioAktiv product is a dry concentrate for the preparation of instant protein drinks, which includes high absorbable animal proteins that are native to the amino acid spectrum (milk cheese proteins, whey proteins, calf plasma proteins, poultry protein hydrolyzate), medium-chain triglycerides, lecithin, mineral-organic forms of macro- and microelements (heme iron, organic iodine in the form of iodinated milk whey proteins, biogenic calcium from eggshell, amino acid chelates of magnesium, zinc, cobalt, manganese and copper), an ergogenic component of carnosine, which binds intracellular lactate in muscles, succinic acid, lecithin (phosphatidylcholine), choline, dietary fibers, etc. They combine a variety of useful substances: easily digestible carbohydrates (glucose, fructose, sucrose); organic acids (malic, citric, tartaric); vitamins C, A, P, etc.; mineral salts of potassium, calcium, phosphorus, etc.; flavonoids, pectin, tanning, coloring, aromatic as well as other substances useful for the athlete's body. The MioAktiv protein drink can be used as a replacement for your regular diet

or as a supplement to your basic diet. One serving of a drink was equal to 33 g.

The second product we tested, the Pre-Fuse pre-workout complex, can be formulated to urgently mobilize athletes' functional reserves. It includes caffeine, guarana extracts, green tea, lemongrass, rhodiola, yohimbine, maltodextrin carbohydrates and fructose, succinic and citric acids, creatine, L-carnitine, L-glutamine, aspartic acid, potassium chloride, vitamins A, groups B, as well as C, E, D3, H. The Pre-Fuse pre-workout complex should work after a single dose, therefore, in its pre-clinical evaluation, a single-dose regimen was also used in laboratory animals 1 hour before the test load. In accordance with the instructions for the pre-workout complex, the recommended single dose for a person is 30 g. The bioequivalent dose for rats and mini-pigs constitutes $2.74 \text{ mg} \times \text{kg}^{-1}$ and $0.7 \text{ g} \times \text{kg}^{-1}$, respectively.

Standard mathematical and statistical methods were used to process the results (Greg and Alan 1998; Lang and Sesik 2011). For the calculations, we used a personal computer using the integrated statistical and graphic packages Stat Plus 2005, Statgraphics, Microsoft Excel XP, Statistica 6.0 (StatSoft), as well as the GraphPadInStat (GraphPad Software, USA) licensed program. When processing the sample data, the following were calculated: the arithmetic mean value M , standard deviation S . The assessment of compliance of the indicators with the law of normal distribution was checked using the Shapiro-Wilk criterion. Since the samples were found not to fit a normal distribution, the Kruskal-Wallis, Wilcoxon and Mann-Whitney criteria (Osipov et al. 2002), as well as the Friedman method (Greg and Alan 1998) were used to further evaluate the differences. The confidence level was set $P = 95\%$ (the probability of an error is 5%, that is, the significance level is $p = 0.05$).

Results

The results of preclinical and clinical studies of the sports nutrition product MioAktiv and the specialized pre-workout complex Pre-Fuse, which were created with all the necessary conditions contributing to safety and high efficiency of these products for athletes under conditions of real training process, can be considered a convincing example of the high margin of safety and effectiveness of ergogenic sports nutrition.

The use of the specialized food MioAktiv in the final swimming test was found to have a positive effect on the physical work capacity of the animals and delay the onset of fatigue. It is noteworthy that these effects persisted in rats and mini-pigs even one week after discontinuation of the intake (study point 28th day) (Fig. 1), which significantly exceeded the corresponding characteristics in the placebo group.

From the point of view of psychophysiology, in the course of studying the influence of new specialized products on behavioral characteristics of laboratory animals, an increased tolerance to stress effects and some activation of their spontaneous motor activity as a result of using the MioAktiv product were revealed.

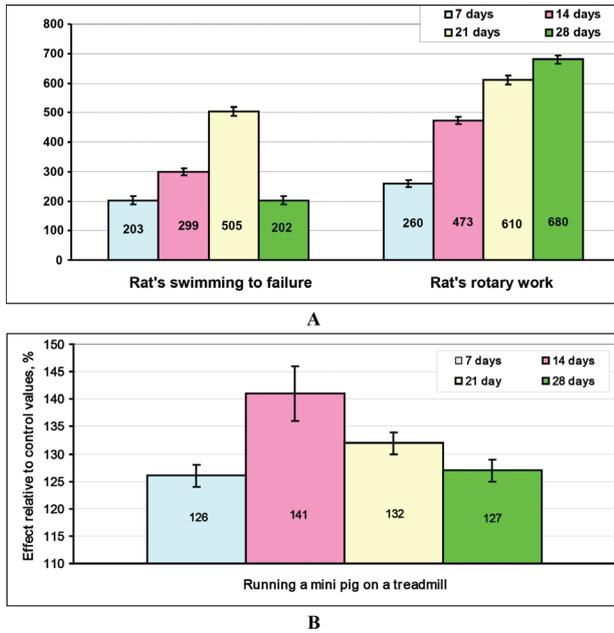


Figure 1. The impact of the MioAktiv product course usage on physical work capacity of laboratory animals during load modeling.

Athletes also show an increase in speed when passing competitive distances (by 21.4%, 18.7% and 19.6% for swimmers, middle distance runners and skiers, respectively $p < 0.05$) as well as increased mental endurance, specialized perception of which is manifested in the sense of speed, strength, speed-power, jumping and other types of endurance were also noted. Besides, there is an increase in the concentration of attention, acceleration of simple and complex motor reactions in combination with the accuracy of movements, improvement of mental processes associated with the predominance of processes of excitation of the nervous system over inhibition of processes under the influence of the tonic effect of the product MyoAktiva and others. All these characteristics reflect a general increase in the mental work capacity of athletes during developing fatigue as the nervous system response to the use of specialized sports nutrition with its ergogenic effects (Vysochina et al. 2019; Vysochina 2021).

The Pre-Fuse pre-workout complex testing has shown the high efficiency and safety of this innovative pharmac-nutrient complex. The results of determining physical work capacity of laboratory animals during multiple-repetition of the swimming test with a load equal to 10% of body weight are presented in Table 1.

A study of the effect of the ergogenic pre-workout complex Pre-Fuse on the duration of physical load performance on mini-pig treadmill running test to exhaustion demonstrated a pronounced positive effect of work capacity and endurance increase one hour after taking this supplement. At the same time, the average running time of the animals increased from 24.0 ± 2.5 minutes to 39.4 ± 5.7 minutes (+64%, $p = 0.04$).

In the study of the spontaneous behavioral activity of laboratory animals, it was shown (Table 2) that the effect

Table 1. Influence of the pre-workout complex Pre-Fuse on the performance indicators of rats on the development of fatigue.

| Group of animals | Period of study | Sample indices ($M \pm \sigma$), s | | | |
|---|-----------------|--------------------------------------|-----------------|---------------|-----------------|
| | | T1 | FI | EI | A |
| control (n = 9) | factor | 115 ± 8 | 0.63 ± 0.04 | 5.2 ± 0.4 | 285 ± 19 |
| | testing | 112 ± 9 | 0.69 ± 0.03 | 3.7 ± 0.2 | 229 ± 13 |
| Pre-Fuse (n = 9) | factor | 117 ± 5 | 0.74 ± 0.03 | 3.7 ± 0.2 | 246 ± 16 |
| | testing | 126 ± 8 | 0.65 ± 0.04 | 4.3 ± 0.3 | 292 ± 24 |
| Intake effect, % of values in placebo-control | | $\uparrow 13$ | $\downarrow 7$ | $\uparrow 19$ | $\uparrow 28^*$ |

Notes: T1 – first swim duration (seconds), FI – fatigue index, EI – endurance index, A – volume of performed work; 1.* – significant differences from control ($p = 0,04$); 2. \uparrow or \downarrow – direction of changes.

Table 2. The results of determining spontaneous locomotor activity of animals (group averages, activity structure, % of time from observation period).

| Group of animals | Period of study | HA | VA | Q | GR | SBE |
|---|-----------------|--------------|-----------------|----------------|----------------|-------------------|
| control (n = 9) | factor | 4 | 36 | 5 | 13 | 42 |
| | testing | 3 | 21 | 7 | 20 | 49 |
| Pre-Fuse (n = 9) | factor | 4 | 30 | 10 | 16 | 40 |
| | testing | 6 | 37 | 10 | 18 | 29 |
| Intake effect, % of values in placebo-control | | $\uparrow 3$ | $\uparrow 23^*$ | $\downarrow 2$ | $\downarrow 5$ | $\downarrow 19^*$ |

Notes: HA – horizontal motor activity, VA – vertical activity (postures), Q – quiescent periods, GR – grooming (washing), SBE – systemic behavior elements; 1.* – statistically significant differences from control ($p < 0,05$); 2. \uparrow or \downarrow – direction of changes.

of taking the analyte consists in statistically significant change in the structure of the behavioral activity of animals - an increase of 23% in the vertical activity of animals (which is interpreted as mental and exploratory activity, vigor, stenicity) due to a decrease in the proportion of systemic elements of behavior that are characteristic of animals (and have no meaningful interpretation).

Therefore, the introduction of one dose of the pre-workout complex Pre-Fuse in a single dose, the bioequivalent dose recommended for athletes one hour before physical loads causes a statistically significant ($p = 0.04$) increase in the volume of work performed by both small and large laboratory animals under conditions of fatigue. At the same time, at the level of statistical trends, a higher level of activity of the nervous system is observed without signs of adverse changes in their behavioral activity and emotional state, a decrease in the perception of neurodynamic fatigue by animals and an increase in their endurance ($p = 0.07$).

While testing this pre-workout complex Pre-Fuse on a group of athletes engaged in martial arts (boxing, karate, taekwondo) by the method of formalized state self-assessment, it was shown that its intake is accompanied by an increase in indices of general state, activity, mood, desire to train, readiness for competitions. In addition, all athletes noted an increase in endurance and speed-strength indicators during training.

Discussion

Numerous studies devoted to assessing the state of nutrition and health of a modern person have shown that the majority of the population has traditional nutritional disorders associated with a deficiency of the main macro- and microele-

ments of animal proteins, dietary fiber, vitamins, minerals, polyunsaturated fatty acids of a number of minor food components (Burke 2017; Aleksandr and Larisa 2018; Garthe and Maughan 2018; Dmitriev and Gunina 2020). Chronic nutritional imbalance inevitably leads to the development of foodborne illness, leading to loss of health and work capacity. The lack of basic nutrients in athletes is aggravated by their increased expenditures due to the increased level of metabolic processes during muscle activity, which is usually accompanied by psychoemotional tension (Gonzalez and Miranda-Massari 2014). An effective solution to the correction of nutrition and health is the use of biologically active or dietary supplements, which are successfully used in sports practice to maintain a high level of physical work capacity at the preparatory and competitive periods, and to activate the recovery processes after the end of the competitions (Stellingwerff et al. 2019).

To date, the effectiveness of the use of specialized supplements in the training and competitive process has been shown, which ensure an increase in working capacity and preservation of the body's adaptive reserves. There is currently no doubt that dietary supplements are a common modern strategy for achieving a specific health and quality of life or improving fitness and performance. As concerns elite sports, "advances in the field of nutrition and dietary supplements can help to improve not only the athlete's work capacity parameters and recovery processes, but his/her health and well-being as well" (Gunina 2016; Baltazar-Martins et al. 2019).

The materials presented in the article show that specialized ergogenic sports nutrition products can significantly assist in improving sports results. Moreover, their effectiveness can be confirmed not only at the level of clinical studies and targeted testing by athletes, but by the methods of preclinical (biomedical) animal studies as well. Thus, it becomes possible to make a reasonable (and comparable) assessment of the efficiency of various ergogenic sports nutrition products in full concordance with the policy of their proven effectiveness (principles and criteria of the evidence-based medicine paradigm adopted in clinical medicine). These are just the kind of products of functional nutrition that should become indispensable for athletes under the conditions of the constantly increasing and psychological loads of modern sports.

The revealed positive effect of the Pre-Fuse supplement can be explained by the pharmacological properties of its constituent components, which ensure the preservation of the ultrastructure and the functioning of mitochondria of skeletal muscle cells and myocardium, an increase in the expression of HIF-1 α , and the activation of mitochondrial-cytosolic energy shunts during work (Aleksandr and Larisa 2018; Dmitriev and Gunina 2020). Under the experimental conditions, it was also found that the components in the initial ratio included in the Pre-Fuse supplement suppress the reactions of oxidative stress and increase the level of reduced equivalents of the thiol-disulfide system of organs and tissues, including skeletal muscle during ischemia, increase the expression of VEGF, at the same

time, they are able to have an endothelioprotective effect, accelerate angiogenesis, improve O₂ transport to working muscles and myocardium during ischemia, hypoxia and physical activity of varying intensity (Shustov et al. 2017).

Conclusion

The research have shown an increase in the resistance of experimental animals to stress and a partial activation of their spontaneous locomotor activity when using the MyoActive product.

For athletes using the MyoActive product, there is a significant ($p < 0.05$) increase in speed when passing competitive distances (by 21.4%, 18.7%, and 19.6%, respectively, for swimmers, middle-distance runners, representatives of cross-country skiing), as well as mental endurance and increased concentration of attention, improvement of mental processes associated with the predominance of the processes of excitation of the nervous system over inhibitory processes.

Study of the effect of the pre-workout ergogenic complex Pre-Fuse on the duration of physical activity in the test of running mini-pigs on the treadmill to failure showed that one hour after taking this supplement, there was a pronounced positive effect of increasing the performance and endurance of animals. At the same time, the average running time of the animals increases from 24.0 ± 2.5 minutes to 39.4 ± 5.7 minutes (+ 64%, $p = 0.04$).

In the study of spontaneous behavioral activity of laboratory animals showed the effect of the pre-training complex Pre-Fuse, consisting mainly of a statistically significant increase in the vertical activity of 23% of animals.

It was found that even a single administration of the Pre-Fuse complex in a single dose, the bioequivalent dose recommended for athletes, causes a statistically significant ($p = 0.04$) increase in the volume of work performed by both small and large laboratory animals under conditions of fatigue.

When using the method of formalized self-assessment of the state in the group of athletes involved in martial arts, it was shown that the use of the Pre-Fuse pre-training complex is accompanied by an increase in the indicators of well-being, activity, mood, desire to train, and readiness for competition.

Prospects for further research lie in the plane of an in-depth study of the mechanisms of the influence of new products of ergogenic nutrition on various aspects of metabolic rearrangements in the body under the influence of physical loads.

The results of the conducted studies are the rationale for the inclusion of the additive in pharmacotherapeutic schemes to stimulate physical performance in athletes of various sports and to modulate various mechanisms of energy supply to muscular activity. This is promising for the medical and biological support of sports training. The data obtained on the increase in the functional capabilities of the organism under the influence of the additive became the basis for supplementing the existing schemes of pharmacological sup-

port of sports activity in order to obtain high results while maintaining the proper quality of life and health of athletes. Our data open up approaches to optimizing the pharmacological modulation of energy metabolism in sports.

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Conflicts of Interest

The authors declare no conflict of interest.

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