Peculiarities of adaptive changes of qualified athletes to middle mountain conditions

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Abstract

Purpose: to study the peculiarities of adaptive changes in high-class athletes to the effect of significant physical loads in middle mountain conditions.

Material & Methods: determination of the level of urea and the concentration of hemoglobin in the blood was carried out using a biochemical analyzer "Diaglobal" (Germany) using ready-made kits of reagents from the same company.

Results: the article discusses the ways to improve the efficiency of training process management in athletics (race walking) and modern pentathlon, based on the use of biochemical control over the development of adaptation in various climatic conditions of the body of highly qualified athletes under the influence of training and control-competitive activities.

Conclusions: the reaction to the load of the blood system on the hemoglobin in the second microcycle of modern pentathletes showed an unwillingness to perform these loads, due to the fact that most athletes perform training loads at this height for the first time, while in athletes engaged in race walking in the second microcycle adaptive polycythemia was developing. This ensures the formation of sustainable adaptation, which allows you to perform the planned program of training loads. A blood test of race walking athletes showed that the concentration of urea, which was determined before exercise at rest, gradually increased within normal limits, and characterized the tolerability of training loads.

Анотація

Людмила Станкевич, Юлія Хмельницька, Наталія Вдовенко, Галина Россоха, Валентина Єфанова. Особливості адаптаційних змін кваліфікованих спортсменів до умов середньогір'я. Мета: дослідити особливості адаптаційних змін спортсменів високого класу на дію значних фізичних завантажень в умовах середньогір'я. **Матеріал і методи:** визначення рівня сечовини та концентрації гемоглобіну в крові проводились за допомогою біохімічного аналізатора «Diaglobal» (Німеччина) з використанням готових наборів реактивів цієї ж фірми. **Результати:** у статті розглянуто напрями підвищення ефективності управління тренувальним процесом в легкій атлетиці (спортивна ходьба) та сучасному п'ятиборстві, що засновані на використанні біохімічного контролю за розвитком адаптації в різних кліматичних умовах організму спортсменів високої кваліфікації під впливом тренувальної і контрольно-змагальної діяльності. **Висновки:** реакція на навантаження системи крові за показником гемоглобіну у другому мікроциклі спортсменів сучасного п'ятиборства свідчила про неготовність виконувати дані навантаження, що пов'язано з тим, що більшість спортсменів вперше проводять тренувальні навантаження на такій висоті, тоді як у спортсменів спортивної ходьби в другому мікроциклі розвивалась адаптаційна поліцитемія. Це забезпечує формування стійкої адаптації, що в свою чергу дозволяє виконувати заплановану програму тренувальних навантажень. Дослідження крові спортсменів спортивної ходьби засвідчило, що концентрація сечовини, яку визначали до навантаження в стані спокою, поступово збільшувалася в межах норми, і характеризувала переносимість тренувальних навантажень.

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Introduction

The issues of building sports training belong to the category of the most difficult problems in the conditions of modern sports. Despite the fact that at present the main provisions of the organization of the training process have been studied and sufficiently substantiated, a number of issues remain unexplored (Platonov, 2015; Mujika et al., 2019). These include the planning of training loads in special climatic and geographical conditions (mountains).

The growth of sports results and competition in the world sports arena put forward new, increased requirements for optimizing the process of sports training and competitive activity based on an objective assessment of different aspects of preparedness and functional capabilities of the athl etes body (Suslov et al., 2001; Platonov, 2015). The current situation requires specialists to develop priority areas that allow them to unlock the reserves for achieving high sports results (Maydanyuk et al., 2017; Zemtsova et al., 2020). Particularly acute is the problem associated with the use of modern approaches that allow to increase physical performance and recovery processes, to monitor the condition of the athlete and their level of preparedness (Płoszczyca et al., 2018; Kropta et al., 2020).

Achieving significant sports results, in turn, requires great efforts of the physical and mental strength of athletes (Saunders et al., 2009; Platonov, 2015). In order to increase the efficiency of the adaptation process to intense training and competitive loads, additional activities are often used, one of which is training in mountainous areas (Wilber, 2001; Billaut et al., 2012; Chapman et al., 2016; Flaherty et al., 2016).

The level of functional capabilities of the body cannot be obtained only by increasing the volume and intensity of physical activity, even with the improvement of training methods. A constant increase in the volume of loads can negatively affect the functional state and health of athletes, the growth of sports results and lead to a state of overtraining (Terrados, 1992; Platonov, 2015; Stankevich et al., 2018).

Therefore, it is necessary to look for additional opportunities to create a foundation for the formation of a greater influence on the functioning of various body systems in order to increase the effectiveness of training and competitive activities. Pedagogical and medical-biological studies show the effectiveness of the mid-mountain factor in the system of means for improving the functional and metabolic capabilities of the body of representatives of different sports (Suslov & Gippenreyter, 2001; Rusko et al., 2004; Platonov, 2015). Experimental materials obtained as a result of studies in the mountains, as well as under conditions of artificial hypoxia, have demonstrated their effectiveness in terms of the effect on the body of athletes of various specializations.

Thus, the effectiveness of mountain training, as a means of increasing the functional capabilities of athletes and sports results, in all sports related to the manifestation of endurance athletes, has now been completely proven (Suslov & Gippenreyter, 2001; Wilhite et al., 2013; Chapman et al., 2016). However, interest in the conditions of middle and high mountains is constantly growing due to the expansion of the number of competitions held in mountain conditions (Rusko et al., 2004; Maydanyuk et al., 2017). Therefore, the study of the mechanisms of adaptation to physical loads in the mountains requires an extremely special attitude to planning the intensity of exercise, the total amount of training work and control of recovery processes.

Especially important in mid-mountain training is the correct ratio between the volume and intensity of training work aimed at increasing the aerobic potential of athletes. Significant volumes of high-intensity work can shift work to the zone of anaerobic metabolism, lead to excessive fatigue and a significant overstrain of functional systems and a decrease in the volume of training effects. Low intensity does not provide sufficient incentives to increase the level of adaptation and, moreover, may adversely affect the manifestation of special endurance, sports technique and other important components of preparedness (Suslov & Gippenreyter, 2001; Platonov, 2015).

In order to effectively manage the training process under such conditions, it is necessary to select indicators that adequately reflect the rational intensity of training and the speed of recovery processes after heavy loads, the effectiveness of the functioning of various physiological systems both in the body as a whole and at the cellular and subcellular levels of athletes preparation in mountainous conditions.

Communication with scientific plans, topics. The study was carried out within the framework of scientific topics: “Control and correction of the metabolism of qualified athletes during intense physical loads” (state registration number 0120U103004) and “The influence of endogenous and exogenous factors on the course of adaptive reactions of the body to physical loads of varying intensity” (state registration number 012U108187).

Purpose of the study is to investigate the features of adaptive changes in high-class athletes to the effect of significant physical loads to the middle mountain conditions

Material and Methods of the research

Participants

The studies involved athletes specializing in race walking 10 people (m) and athletes of modern pentathlon 11 people (m), aged 19-25 years, experience in sports 6-15 years, qualifications of the Master of Sports, Honored Master of Sports.

Methods

Biochemical methods were used to study the features of adaptive changes in high-class athletes to the effect of significant physical exertion to the conditions of middle mountains, namely, to determine the content of hemoglobin and the level of urea in the blood of athletes. The studies were carried out both at rest and in dynamics after physical exertion and during the recovery period. Studies of the content of hemoglobin and urea were carried out using a biochemical analyzer “Diaglobal” (Germany) using standard sets of reagents from the same company.

Procedure

Athletes were at a specially preparatory stage of the preparatory period of the annual training cycle. The duration of the training camp in the mountains of Erzurum (Turkey) 1900 m (race walking) and Velingrad (Bulgaria) sports complex “Belmeken” 2000 m (modern pentathlon) was 21 days (3 microcycles). The studies were carried out during three microcycles.

The study was conducted in accordance with the basic bioethical norms of the Declaration of Helsinki of the World Medical Association on the ethical principles of scientific and medical research, as amended (2000, as amended in 2008), the Universal Declaration on Bioethics and Human Rights (1997), the Council of Europe Convention on Human Rights and Biomedicine (1997). Written consent to participate in the

study was obtained from each athlete.

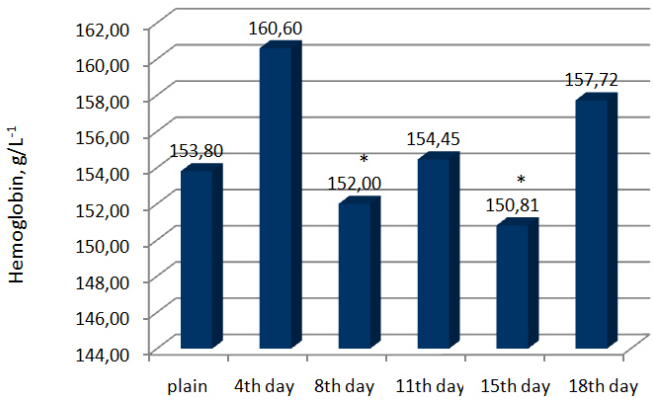
Statistical analysis

Processing of the study results was carried out by methods of mathematical statistics using standard computer programs. Descriptive statistics was used to generalize the quantitative characteristics of the studied components of the preparedness of athletes. On the basis of the initial statistical population, variation series were formed and their parameters were determined, characterizing the totality of information. At the same time, the following numerical characteristics of the sample were calculated: arithmetic mean ($\bar{X}$), standard deviation (S), coefficient of variation (V). The method of averages also included the determination of the error of representativeness, dispersion, and reliability of the results. The subtraction of the statistical significance of discrepancies was assessed by the nonparametric Wilcoxon test.

Results of the research

So, in studies of athletes training for endurance in the middle mountains at an altitude of 2000 m above sea level, after performing the loads of the first and second microcycles, where the volume of loads for race walking athletes was 4-5 hours, and for modern athletes - 5-6 hours per day in the mode of high and moderate intensity, the dynamics of hemoglobin concentration was different.

Studies have shown that on the 4th day of stay in the mountains, modern pentathlon athletes have significant polycythemia compared to the plains (Fig. 1). Along with this, on the 8th and 15th days (Figure 1) of staying in the mountains, athletes have a decrease in hemoglobin concentration by 1,4%, and only on the 18th day adaptive polycythemia develops. This reaction during the transition period indicates the inhibition of hematopoietic functions and increased blood-destroying function and hemolysis with impaired erythrocytes, which indicates the breakdown of erythrocytes. The reason for the decrease in the function of hematopoiesis and the destruction of blood cells is probably uncompensated fatigue, which leads to severe acidosis and impaired neurohumoral regulation of the blood system. And only on the 18th day of stay in the mountains, pentathlon athletes develop adaptive polycythemia, which leads to the formation of fairly stable structural and functional changes in the athlete's body.



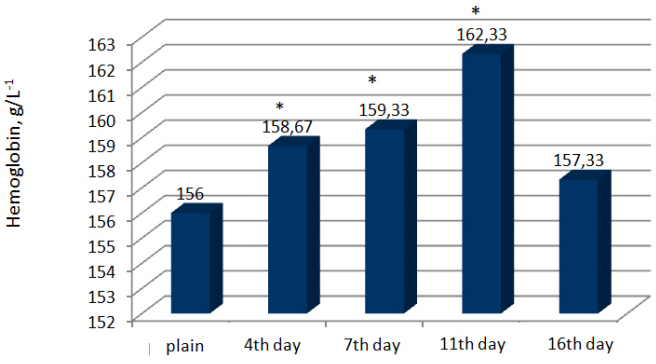
** - p<0,05 in relation to the plain*

Figure 1. Dynamics of blood hemoglobin concentration at an altitude of 2000 m above sea level in modern pentathlon athletes during two microcycles of the preparatory period, (n=11)

In the group of athletes training for endurance (race walking), the hemoglobin concentration gradually increased during the second microcycle (Figure 2). This reaction to the load is characterized by the mobilization of blood from the depot and redistribution in the blood system, which provides an expansion of adaptive capabilities, an increase in the power of this system and resistance to the load.

When adapting to physical loads in such conditions, the metabolism in the body of athletes changes, which leads to the appearance in various tissues and biological fluids of individual metabolites (metabolic products), reflecting functional and metabolic changes that can serve as a control over the functional state of the athlete, and be used for correction of training loads and recovery.

The dynamics of urea content in the blood carries very important information about the direction of metabolic processes occurring in the body during muscle activity. The need for such control in sports is obvious, since it ensures compliance with all the rules for building a rational training process, and also justifies the use of nutritional factors and pharmacological agents. Such timely control also prevents the development of negative consequences of exposure to inadequate physical loads for the body, which takes place in modern sports.



** - p<0,05 in relation to the plain*

Figure 2. Dynamics of blood hemoglobin concentration at an altitude of 1900 m in athletes trained for endurance (race walking) during two microcycles of the preparatory period, (n=10)

The studied indicator of urea in the blood indicates the state of balance of anabolism and catabolism of proteins, and therefore, at rest, it may indicate the tolerance of physical exertion, and immediately after them, the contribution of proteins to the energy supply of muscle activity.

The data obtained indicate that in the first days of stay in the mountains, the concentration of blood urea (Figure 3) in athletes of the modern pentathlon was 6,14 and 6,98 mmol l^{-1}, which indicates a non-recovery caused by preloads on the plain. And only from 8 to 15 days, the level of urea in the blood of athletes, which determined before the load at rest, gradually increased, which indicated a slight under-recovery, those. The incompleteness of the recovery processes of previous workouts, such a growth dynamics of this indicator leads to supercompensation, which ensures an increase in the content of glycogen and protein in skeletal muscles, resulting in an increase in the functionality of the body.

A study of the blood of race walking athletes testified (Figure 4) that the concentration of urea, determined before the load at rest, gradually increased within the normal range, and characterized the tolerance of training loads.

A characteristic feature of the dynamics of the results obtained is that the recovery period after the end of muscu-

lar work is always associated with the intense activity of the body, which is characterized not only by ensuring a decrease in work shifts, but also by filling the body's energy resources and restoring working capacity.

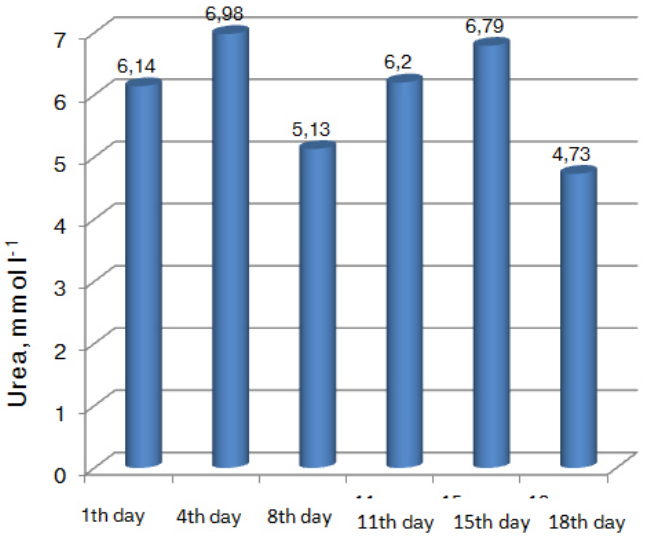
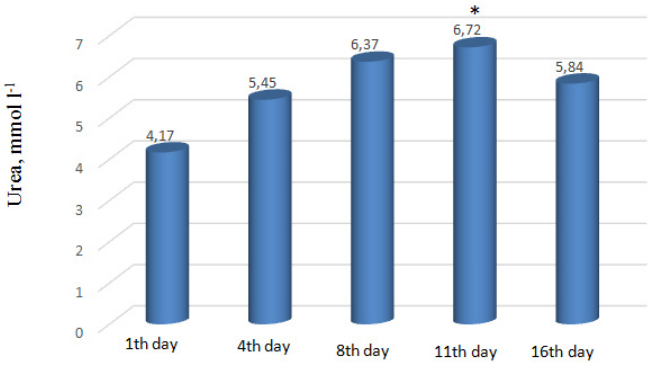


Figure 3. Dynamics of blood urea content in modern pentathlon athletes at an altitude of 2000 m in the preparatory period, (n=11)



** – p < 0,05 compared to the beginning of the mesocycle*

Figure 4. Content of blood urea in athletes trained for endurance (race walking) at an altitude of 2000 m in the preparatory period, (n=10)

Thus, the reaction of the body to the load is defined as three successive phases: load, recovery and supercompensation. Strengthening the process of formation of urea during physical work and an increase in its content in the blood occurs in the later stages of physical work. In the early stages, an increase in the concentration of this substance does not occur. Obviously, this is due to the fact that in the early stages of recovery after a long-term high-intensity muscle load, as well as at the beginning of prolonged muscle work, the urea content does not increase. Therefore, in the practice of biochemical control, this indicator is the most informative in the morning of the next physical activity after the previous day.

Discussion

Human adaptation to high-altitude hypoxia is a complex integral reaction involving various body systems. The most pronounced are changes in the cardiovascular system, hematopoietic apparatus, external respiration, gas exchange and metabolism, which leads to high-altitude hypoxia of sports specialists (Wagner, 2000; Chapman, 2013; Pugliese et al., 2014; Platonov, 2015). It is clear that an integrated and coordinated restructuring of functions at the subcellular, cellular, organ, and system levels is possible only through a restructuring of the functions of systems that regulate integral physiological responses. From this it becomes obvious that adaptation is impossible without an adequate restructuring of the functions of the nervous and endocrine systems, which provide fine regulation of the physiological functions of various systems.

Thus, the restructuring of the athlete's body in mountain conditions is expressed in an increase in pulmonary ventilation, cardiac output, an increase in hemoglobin content, an increase in the number of erythrocytes, an increase in 2,3-diphosphoglycerate in erythrocytes, an increase in the amount of myoglobin in muscles, an increase in the size and number of mitochondria, increased activity of oxidative enzymes (Suslov & Gippenreyter, 2001; Stellingwerff et al., 2019; Płoszczyca et al., 2021).

Features of adaptation of the organism of athletes to mountain conditions require a special approach, which is associated both with individual adaptation and taking into account high-altitude hypoxia of different heights.

So the first reaction to hypoxic conditions leads to the occurrence of hypoxemia (a decrease in the partial pressure (content) of oxygen in the blood) and thereby sharply disrupts the body's homeostasis, causing a number of interrelated processes (Suslov & Gippenreyter, 2001; Płoszczyca et al., 2018). The occurrence of such a state of the body of athletes leads to the activation of a functional system that ensures the transport of oxygen from the environment to the body and its distribution within the body, this is hyperventilation of the lungs, an increase in cardiac output, dilation of the vessels of the brain and heart, narrowing of the vessels of the abdominal organs and muscles.

At the same time, one of the first hemodynamic reactions is an increase in heart rate, an increase in pulmonary blood pressure as a result of spasm of the pulmonary arterioles, which ensures regional redistribution of blood and a decrease in arterial hypoxemia, but after a few days, cardiac output returns to a plain level, which is a consequence of an increase in the ability of muscles to utilize oxygen from the blood, which is expressed in an increase in the arteriovenous oxygen difference.

The period from the 4th to the 16th day of stay in the mountains is associated with the formation of sufficiently pronounced and stable structural and functional changes in the body of athletes. In particular, adaptive polycythemia develops and there is an increase in the oxygen capacity of the blood; a pronounced increase in the respiratory surface of the lungs is detected, the power of the adrenergic regulation of the heart increases, the concentration of myoglobin increases, and the throughput of the coronary bed increases.

And from the 16th day of stay in the mountains, a stable adaptation is formed, a concrete manifestation of which is an increase in the power and at the same time the efficiency of the functioning of the apparatus of external respiration and blood circulation, the growth of the respiratory surface of the lungs and the power of the respiratory muscles, the coefficient of oxygen utilization from the inhaled air. There is also an increase in the mass of the heart and the capacity of the coronary bed, an increase in the concentration of myoglobin

and the number of mitochondria in the myocardium, and an increase in the power of the energy supply system.

Myogenic shifts in the morphological nature of the blood depend on the duration, intensity and nature of the work, but they are largely determined by the state of the blood depots, hematopoiesis and blood destruction. So at the beginning of muscle activity and during short work, blood is mobilized from the depot, while the qualitative composition does not change significantly. With a longer physical load, more significant changes occur in the hematopoietic and blood-destroying organs, which is reflected in the composition of blood cells.

Training loads are longer, several hours of moderate intensity lead to an increase in the number of erythrocytes due to more complete mobilization, however, the total content of hemoglobin and its presence in the erythrocyte decreases due to young forms less saturated with hemoglobin. The number of reticulocytes increases due to the strengthening of hematopoietic functions. The composition of red blood cells is rejuvenated, the activity of cellular enzymes increases. This reaction is explained not only by the mobilization of blood from the depot, but also by the strengthening of hematopoietic functions - which has been proven by many authors (Suslov & Gippenreyter, 2001; Płoszczyca et al., 2018; Płoszczyca et al., 2021).

Conclusions

Intense physical activity, as well as special conditions, which are mountains, lead to the destruction of blood erythrocytes and, consequently, to a decrease in hemoglobin concentration, therefore, this indicator can be considered as a factor indicating exercise tolerance, which provides the potential for the passage of oxidative stress in the body. Recovery reactions, that is, the processes of aerobic metabolism. Thus, the reaction to the load of the blood system in terms of hemoglobin in the second microcycle of modern pentathlon athletes indicates the unwillingness to perform these loads, which is due to the fact that most athletes conduct training loads at such a height for the first time. Recovery after this reaction takes longer and requires additional correction of training loads. Sports walking athletes developed adaptive polycythemia in the second microcycle, this reaction provides an increase in the oxygen capacity of the blood, an increase in the respiratory surface of the lungs, an increase in the power of heart regulation, an increase in the conductivity of the coronary bed and an increase in the concentration of myoglobin. This response to this indicator ensures the formation of sustainable adaptation, which allows you to carry out the planned program of training loads.

The value of the urea clearance itself varies depending on the volume and intensity of the work done: as a rule, it increases in the post-work period. Tiring muscular work delays the increase in the intensity of renal excretion of urea. So, during long-term work (5-hour training), at the beginning of the recovery period (during the first six hours), its active accumulation in the blood continues, which leads to the highest concentration. Inhibition of the functioning of the adrenal cortex, accompanied by changes in water-salt metabolism, causes retention of urea in the blood.

It should be noted that the strength component in training has a significant impact on the body's response to urea in the direction of increasing its concentration to the load. In the supercompensation phase, along with various biological processes, the content of glycogen and protein in skeletal muscles increases, as a result of which the functional capabilities of the body increase. This is the most important process of transition of urgent adaptation to long-term one. The severity and duration of the supercompensation phase depend on the magnitude of the preload. At the same time, if significant loads are used during the period of incompleteness of anabolism processes, then, on the contrary, the opposite state may turn out - overwork, overtraining. Since urea is an integral indicator of the course of recovery processes, the assessment of the dynamics of its concentration in the blood has found wide use in the practice of sports training.

In further studies, it is planned to monitor the studies of metabolism in the body of track and field athletes and athletes from other sports at various volumes and intensity of loads in certain climatic and geographical conditions.

Author Contributions
Lyudmyla Stankevych: data collection, input, data analysis, manuscript preparation, statistics; Yuliia Khmelnytska: data interpretation, manuscript preparation, statistics; Nataliia Vdovenko: design, interpretation of data; Halyna Rossokha: design, research planning; Valentyna Yefanova: data interpretation, literature search analysis.

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Conflicts of Interest
The authors declare no conflict of interest.

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