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TRAINING OF THE ATHLETES WITH USE OF HYPOXIC CONDITIONS

Introduction. *High performance mountain training as a means of improving the functionality of the athletes and sports results in all sports-related display of endurance athletes, proven by many researchers in the field of sports physiology.*

Purpose. *Analyze and summarize the literature on the issues connected with training of the athletes with use of hypoxic conditions.*

Methods. *Analysis of special scientific and methodical literature, which considers the physiological mechanisms of the athletes adaptation to hypoxia.*

Results. *Generalization of the results of many studies on the problem of human adaptation to high-altitude hypoxia, possible to distinguish between a number of coordinated adaptive mechanisms: 1) mechanisms, mobilization of which can provide sufficient oxygen to the organism, despite the deficiency in the medium: hyperventilation; hyperfunction of heart, enabling the movement of the lungs to the tissues of an increased amount of blood; 2) polycythemia corresponding increase oxygen capacity; 3) the mechanisms that make possible a sufficient supply of oxygen to the brain, heart and other vital organs, despite the hypoxemia, namely the expansion of arteries and capillaries of the brain, heart, etc .; 4) decrease the diffusion distance for oxygen between the capillary wall and the mitochondria of cells by formation of new capillaries and changes the properties of cell membranes; 5) increasing the ability of cells to dispose the oxygen concentration due to the increase of myoglobin; increasing the ability of cells and tissue disposed of oxygen from the blood to form ATP, despite the lack of oxygen; 6) increase anaerobic resynthesis of ATP by activation of glycolysis.*

Conclusion. *It has been shown that as a result of athletic training and continuous training actions load of hypoxia in the body athlete occur various morphological and functional changes, which determine the state of fitness of the athlete. It is very urgent is the need for continuous improvement all around athlete training.*

Keywords: *athletes, training hypoxic, performance aerobic and anaerobic, morphological and functional changes.*

The posing of the problem. Modern sport is a type of human activity that poses extreme stresses on the body systems and there is always a demand for development of the training tools and methods to extend the functional capabilities of the functional body systems [1, 2].

There have been many advancements in athletics achievements around the world, mainly due to: 1 – a sharp increase in the total amount of training hours; 2 – a sharp increase in the volume of support and especially special training; 3 – increase in the percentage of high intensity load with regards to the total load; 4 – the use of non–traditional means that increase human performance [3-5].

The increase in the volume of high–intensity loads ensures maximum development of the functional breathing system, aerobic and anaerobic capabilities [5, 6], but this possibility is almost exhausted in the modern era of ultra high achievements.

More recentaly, unconventional methods have been used to allow athletes to fully reveal the functional reserves of the organism and to surpass the previous levels of achievements. This is achieved via: 1) use of equipment that allows for a combined development of both physical strength and technique; 2) creation of conditions for use of organisational forms of training, contributing to a more complete development of functional resources and ensuring intense competition and psychological stress in training sessions; 3) adaptation to hypoxia and training in mid–mountain [7-9].

One of the main results of sports training is an increase in the overall physical and specialised working capacities of the athlete to allow them to achieve high sports results. At the same time, certain qualities and abilities, especially physical ones, can be more effectively developed using non–specific means and methods related to general and auxiliary training [2, 3].

At the same time, it has been shown that the successful construction of modern training programs, including the use of non–specific means and conditions, can be ensured only when taking into account the general biological patterns of adaptation and individual approach to the development of various aspects of physiological functions corresponding to a particular athlete's characteristics [2, 10, 11].

A high level of functional readiness for a particular type of activity is not necessarily accompanied by a high level of achievement in other areas. To improve general fitness requires understanding of various factors of efficiency, which is optimal for a particular sport specialization, and taking into account the individuality of the athlete. [2].

Often, the leading factors are defined as power indicators of functions, their economization and effective mobilization. In some cases, only two main mechanisms of increasing the capacity for work are distinguished: an increase in the upper redistribution of the functions of various systems of the organism and the degree of their coordination, in particular motor–visceral interactions. It is emphasized that it is the coordination of the activity of the motor apparatus and visceral systems that plays a key role in the process of long–term adaptation to the changing factors of the external environment and, in particular, to intense muscular activity of a different nature [2, 12, 13].

Thereby, the process of adaptation to the load is defined as improvement and adjustment to the physiological mechanisms of regulation leading to the increase in the ability to use the body's functional reserves. Therefore, the physiological essence of adaptation can be generalized as the achievement of such a level of the organism's state that is characterized by the improvement of the mechanisms of regulation, the increase of physiological reserves and the readiness for their mobilization [2, 9].

Therefore, during the analysis of regulatory mechanisms of adaptation attention is focused on taking into account the sensitivity and stability of the body's reactions to internal environment shifts (homeostatic regulation) and external perturbing factors (for example, functional tests). At the same time, the assessment of adaptation to physical exertion concentrates on the intensity and severity of such reactions.

The high efficiency of high altitude training as a means of increasing the functionality of athletes and results in all sports associated with the manifestation of athletes' endurance has been proved by many researchers working in the field of sports physiology [7, 14-16]. Therefore, studies of the effect of hypoxia on the athlete's body in the face of intense muscular activity have become very important in the modern era of ultra high sports achievements.

Aim of the article is analyze and summarize the literature on issues related to hypoxic exposure in the system of training athletes.

Methods

We preformed analysis of specialised scientific literature, which addresses the problems of hypoxic exposure in the system of training athletes. The information files of the search engines have been analyzed: Google, Yandex (www.yandex.ru) – 20 sites, the Catalog of Russian Resources (www.aha.ru) – 30 sites, Alta Vista (www.alvista.com) – 40 sites.

Results and discussion

Training for hypoxia in sports is achieved through staying in mountainous conditions or simulating similar conditions. At present, several variants of hypoxic training are scientifically founded and introduced into practice. Two types of methods should be distinguished: 1) for mountain conditions (low, medium and high mountains, altitude pressure chamber); 2) for conditions of normal atmospheric pressure [15]. In this case, the method of cyclic hypoxic conditinos is often used, also known as interval hypoxic training [17-21].

The success in numerous sports associated with endurance is determined by the condition that arises when the body's tissues are not sufficiently supplied with oxygen and the effectiveness of the processes of adaptation to this state. Athletes of cyclic sports are faced wiith the problem of hypoxia when performing at medium, long and super long distances. Lack of oxygen significantly affects the quality of performances in such sports as figure skating, rhythmic gymnastics and others.

In sports games, mainly at the end of half times, periods or matches, mistakes made by players become too frequent and unexplained. However, these errors can be explained by oxygen starvation of working muscles and depression of CNS players. Therefore, the main focus of training athletes in many sports is on development of the training regimes aimed at improving the structure of the body and providing oxygen delivery to working muscles [15, 22, 23].

Adaptation of the athlete to the conditions of high altitude hypoxia is a complex integral reaction, in which virtually all the functional systems of the body are involved. At the same time, integrated and coordinated reorganization of functions at the subcellular, cellular, organ, systemic and organism levels is possible only through the reorganization of the function of systems regulating integral physiological reactions [7, 24].

It is obvious that such adaptation is impossible without an adequate restructuring of the nervous and endocrine systems that provide fine regulation of the physiological dispatches of various systems [25]. Immediately after moving to the mountains, the compensatory protective mechanisms are mobilized in the athlete's body. The main adaptation reactions are: increased pulmonary ventilation; increased cardiac output; increase in hemoglobin; increase in the number of red blood cells; increase in erythrocytes 2,3–diphosphoglycerate (DPG) contributing to the removal of oxygen from hemoglobin; increase in the amount of myoglobin facilitating the consumption of oxygen; increase in the size and quantity of mitochondria; increase in the number of oxidative enzymes [7, 17]. Noticeable changes in the activity of various body systems are already observed from an altitude of 1000–1200 m above sea level.

In particular, at an altitude of 1000 m VO2max is 96–98% of the maximum level recorded at the sea level. With an increase in altitude, VO2 max systematically decreases by 0.7–1.0% for every 100 m. At an altitude of 2500 m, aerobic power is reduced by 10–12%, 3500 m – by 18–20% from the level recorded at the sea level. At the summit of Mount Everest, the IPC level is only 7–10% of the maximum at the sea level. Staring at an altitude of 1500 m, a rise of every 1,000 m leads to a 9.2% reduction in oxygen consumption [26].

For people, who are not adapted to mountain conditions, the heart rate at rest and, especially, when carrying out regular tasks can increase already at an altitude of 800–1000m above sea level. Compensatory reactions are manifested clearly when performing regular tasks. This is evidenced by the dynamics of increasing lactate concentration in the blood when performing regular tasks at different heights. If a regular task at an altitude of 1500 m leads to an increase in lactate by only 30% compared to the data obtained in the plain, then at an altitude of 3000–3500 m it reaches 170–240% [7, 17].

Adaptation to the medium– and high–mountain conditions happens in phases. There are short–term and long–term adaptive reactions of functional systems and mechanisms that are of primary importance for the sport of high achievements.

In the first phase (immediate adaptive reactions) hypoxic conditions lead to the development of hypoxemia, which causes disruption of homeostasis and a number of related reactions. First of all, the functions of the systems responsible for oxygen transport and its distribution in the body are activated: hyperventilation of the lungs, an increase in cardiac output, expansion of the vessels of the brain and heart, narrowing of the vessels of the abdominal cavity organs and muscles, etc. [13, 27]. In addition, in the first phase of adaptation to hypoxic conditions, there is an increase in cardiac reactions and an increase in pulmonary arterial pressure as a result of spasm of pulmonary arterioles, which provides locan redistribution of blood and reduction of arterial hypoxemia [28].

Along with the increase in pulmonary arterial pressure, there is a significant increase in heart rate and cardiac output, which is especially pronounced for the first days of stay in the mountains. At an altitude of 2000–2500 m, the heart rate rises by 4–6 bpm, and the cardiac output by 0.3–0.4 l / min1. At an altitude of 3000–4000 m, these changes can reach respectively 8–10 bpm and 0.6–0.8 l / min [7].

After several days of stay in mountain conditions, the cardiac output returns to that at the sea level, which is a consequence of the increased ability of the muscles to utilize oxygen from the blood manifesting itself in an increase in the arteriovenous oxygen difference [10]. The volume of circulating blood also increases: during the first days of stay in the mountains – as a result of reflex ejection from the depot and redistribution of blood, and after the first few days – as a result of increased hematopoiesis [7].

In parallel with hemodynamic reactions, pronounced changes in external respiration and gas exchange occur. The increase in pulmonary ventilation is noted already at an altitude of about 1000 m, mainly due to a slight increase in the depth of breathing. Physical loads make this reaction much more pronounced: standard loads at an altitude of 900–1200 m above sea level lead to a significant increase in comparison with the plain conditions of pulmonary ventilation due to both depth and respiration rates. The increase in pulmonary and alveolar ventilation leads to an increase in pO_2 in the alveoli, which increases the saturation of the arterial blood with oxygen. With an increase of an altitude the reactions are clearly pronounced even among athletes trained and adapted to the conditions of the mountains (Table 1).

Table 1

Indicators of the oxygen transportation system in trained men with maximum aerobic work at sea level and after 2 weeks of stay in the mountains (Bulatova MM, 2008)

Variables	Sea level	Height, m	
		2300	4000
O2 partial pressure, mmHg:			
in the inspired air	144	112	87
in the alveolar air	120	95	72
in the arterial blood	107	80	55
The difference between alveolar air and arterial blood	13	15	17
External respiration:			
pulmonary ventilation, l/min, BTPS	165	175	200
O2 ventilation equivalent	33	39	57
Blood:			
blood volume, l	6,42	6,19	5,77
volume O2 content			
in the arterial blood, %	15,5	16,8	13,5
in the mixed venous blood, %	1,8	1,8	1,8
Circulation:			
cardiac output, n × min^{-1}	34,2	31,0	27,5
heart rate, bpm. × min^{-1}	190	180	170
systolic volume, ml	180	172	162
oxygen pulse, ml O2 × min^{-1}	27	24	18

The maximum aerobic capacity in the initial phase of adaptation is significantly reduced and then remains low, despite a rapid and significant increase in hemoglobin concentration. This is explained by two factors: 1) an increase in hemoglobin concentration is accompanied by a decrease in the total volume of circulating blood due to a decrease in the volume of plasma, which causes a decrease in the systolic volume; 2) the decrease in the maximum heart rate in the mountainous conditions does not allow raising the level of maximum oxygen consumption, despite the possibility of normalizing the volume of blood plasma after 3–4 weeks of stay in the mountains [13].

The limitation of the maximum level of oxygen consumption is also largely determined by the development of myocardial hypoxia, which is the main cause of a decrease in cardiac output and an increase in the load on the respiratory muscles, which requires additional oxygen [29].

One of the most acute initial reactions mountain conditiona is an increase in the number of erythrocytes and hemoglobin (polycythemia). The intensity of this reaction is determined by the altitude, the rate of ascent to the mountains and the individual characteristics [24]. A few hours after the ascent, an increase in the concentration of erythrocytes due to a decrease in the volume of blood plasma is observed because of the increased fluid losses caused by low humidity.

Reticulocytosis begins the day after the ascent to the mountains, which is a consequence of the increased activity of the bone marrow. On the second day of stay in the mountains, the erythrocytes from the blood depots decay the formation of erythropoietin takes place, a hormone that stimulates the formation of hemoglobin and the production of erythrocytes. In addition, lack of oxygen in itself stimulates the release of erythropoietin [10]. The maximum release of erythropoietin is achieved after 24–48 hours of stay in the mountains and then stabilizes at a new level [30]. At very high altitudes, a significant increase in erythrocyte mass can increase the blood viscosity so much that it will limit cardiac output [31].

Along with the above–described changes in the body systems that perform the oxygen transport function, activation of the adrenergic and pituitary–adrenal systems develops in the first phase of the stay in the mountains. This nonspecific component of adaptation plays a role in the mobilization of external respiration and circulation, but at the same time it manifests a pronounced catabolic effect, i.e. negative nitrogen balance, loss of body weight, atrophy of adipose tissue, etc. [7, 13].

In addition, acute hypoxia, limiting the resynthesis of ATP in the mitochondria, causes a direct depression of the functions of a number of body systems, primarily the higher functions of the brain, which is manifested by impaired intellectual and motor activity [7].

The above–described combination of system mobilization constitutes a syndrome that characterizes the first phase of an urgent but in many respects unstable adaptation to mountain conditions [25].

In the first days of stay at medium altitudes, when performing standard physical activities, an increase in anaerobic glycolysis and an increase in the level of lactate in blood and muscle tissue were noted [32]. Two to three weeks after being in the mountains, the intensity of glycolysis and the formation of lactate under the same loads decreases and approaches the conditions at the sea level. Simultaneously, an increase in free fatty acids in muscle tissue is observed [33] and metabolic regulation of energy supply processes is improved [26].

In this transitional phase, sufficiently pronounced and stable structural and functional changes in the athlete’s body are also observed. In particular, the adaptive polycythemia develops and the oxygen capacity of the blood increases; the respiratory surface of the lungs increases as well as the power of adrenergic regulation of the heart, the concentration of myoglobin, the capacity of the coronary bed increases, etc. [7].

The second phase of adaption (long–term adaptation reactions) is associated with the formation of a stable adaptation, a specific manifestation of which is an increase in the capacity and, at the same time, the more efficient utilisation of the respiratory and cardiovascular systems, the growth of the respiratory surface of the lungs and the power of the respiratory musculature and increase in the oxygen utilization rate from the inhaled air. There is an increase in the mass of the heart and the capacity of the coronary bed, an increase in myoglobin concentration and the number of mitochondria in the myocardium, an increase in the power supply capacity, etc. [7, 17]. It is important to take into account that adaptation in all phases is faster and more effective for people who have experience in mountain and artificial hypoxic training [3].

Biopsy studies have made it possible to establish the basic reactions characteristic of the stable adaptation of muscle tissue. Just a 4–5 weeks stay in the highlands leads to pronounced changes in the muscles of the participants of the alpine climbing: decrease in the area of the muscles and the area of the BS fibers, and especially the MC fibers and increase in the number of capillaries per 1 mm2 of muscle tissue [10]. This promotes the extraction of oxygen from the blood by working muscles. This adaptation reaction manifests itself for a fairly long time after returning from the mountains, facilitating the transport of oxygen to the muscle tissue. Athletes, who specialize in sports of speed–strength types, should know that in the mountains there is a certain degree of risk of reducing muscle mass [7, 13].

An important manifestation of sustainable adaptation is the significant economization of body functions. There are two independent adaptaions. The first is due to the economization of functions due to an increase in the functional reserve of the heart, an increase in the oxygen capacity of blood and the ability of tissues to utilize oxygen, etc. The second adaptaion is due to a decrease in the basic metabolism and use of oxygen by tissues, as well as a decrease in the consumption of oxygen by the heart, Highlander–Aboriginal, but inherent in the inhabitants of the plains, adapted to mountain hypoxia [7, 34].

In the transitional and third (stable) adaptation phases, the response of the circulatory system to hypoxia decreases as other adaptive mechanisms develop: erythropoiesis strengthening, shifting the hemoglobin dissociation curve to the right, increasing ATP synthesis, increasing the activity of respiratory enzymes in tissues, increasing tissue vascularization, increasing the permeability of peripheral capillaries, and increasing the density of capillaries and mitochondria in skeletal muscles [7].

The stay of the inhabitants of the plains in the mid–mountain and high mountains conditions leads to an increase in the number of erythrocytes and the concentration of hemoglobin, which underlies the substantial improvement in the supply of oxygen to tissues [35]. The oxygen capacity of the blood increases with increasing altitude. At sea level, it is 17–18.5%, at an altitude of 1850–2000m – 20–22%, at an altitude of 3500–4000 m – 25–27.5% [25]. The dissociation curve of oxyhemoglobin shifts to the right, which is primarily due to a decrease in the affinity of hemoglobin to oxygen with a decrease in the pH of the blood. Oxygen from oxyhemoglobin is released more easily, and despite the reduced oxygen gradient between arterial blood and tissues, oxygen content in tissues rises [36]. A few weeks of stay at an altitude of 4000–4500 m can cause an increase in these indicators to a level characteristic of permanent inhabitants of the areas located at an altitude of 3000–3500 m above sea level [37].

Among the factors that ensure an increase in working capacity and maximum oxygen consumption as a result of stay and training in the mountains, vascularization and the associated increase in capillary blood flow in the muscles are among the most important [13].

Similar changes occur in the brain, which has the highest sensitivity to lack of oxygen. Long stay in the mountains leads to a significant increase in the number and extent of cerebral capillaries, contributing to increased blood supply to the brain [7].

The adaptive reactions of respiratory function and gas exchange in the second and third stages are as follows: breathing becomes less frequent and deeper than the reactions noted in the first phase of adaptation. 1–minute breathing volume also decreases somewhat, but does not exceed the normal rate; Respiratory alkalosis is eliminated; there is an increase in chest excursion and there is a steady increase in all pulmonary volumes and capacities, as well as in the proportion of alveolar ventilation in the 1–minute respiration volume [26].

Stable adaptation to hypoxia is also associated with significant changes in the capabilities of the central and peripheral parts of the nervous system. At the level of the higher sections of the nervous system, this manifests itself in increasing brain resistance to excessive stimuli, conflict situations, increasing the stability of conditioned reflexes, accelerating the transition of short–term memory to long–term memory [7].

At the level of vegetative regulation, stable adaptation is manifested, for example, in the increase in the power of adrenergic regulation of the heart, expressed in hypertrophy of sympathetic neurons [38], an increase in the number of sympathetic fibers in the myocardium, as well as an increase in intensity and a decrease in the duration of inotropic response of the heart to noradrenaline [39]. This phenomenon is combined with a decrease in the myogenic tone of the vessels and a decrease of their reaction to noradrenaline [25].

Such changes in adrenergic regulation of the heart and vascular bed provide a situation in which the increase in cardiac output during behavioral reactions is, firstlu, more quickly realized and completed, and secondly, accompanied by a smaller increase in blood pressure, i.e. in general, it is more economical [7].

Training in mountain conditions helps to increase the body efficiency. Just 5–8 hours of active load during the first three days of stay at an altitude of 2500 m lead to an increase in the oxygen capacity of the blood, as well as the diffusion of oxygen into muscle tissue [40, 41]. This is clearly evident in the analysis of the heart rate when performing standard test programs on different days of training in the mountains. In the first 3–4 days of the acclimatization period, the heart rate is increased by 3–8% compared to the conditions of the plain.

By the end of the first week, the acclimatization process is completed and the heart rate is set at a level close to that noted in the plain conditions. However, after a week of training, despite the increase in the speed of movement, athletes have a decrease in heart rate, and ventilation and oxygen consumption [7, 42]. The fact that training in mid–mountain conditions is a powerful factor in increasing the efficiency of the functioning of the body of athletes is evidenced by data on a reliable decrease in the oxygen cost of passing the marathon distance with standard speed after a 12–week training in the mountains [43].

The generalization of the results of numerous studies carried out on the problem of human adaptation to the conditions of high altitude hypoxia made it possible to single out a number of coordinated adaptive mechanisms: 1) mechanisms whose mobilization can ensure sufficient supply of oxygen to the body despite its deficiency in the environment: hyperventilation; hyperfunction of the heart, providing movement of an increased amount of blood from the lungs to the tissues; 2) polycythemia and a corresponding increase in the oxygen capacity of the blood; 3) mechanisms that make possible the sufficient supply of oxygen to the brain, heart and other vital organs, despite hypoxemia, namely: the expansion of the arteries and capillaries of the brain, heart, etc.; 4) reduction of the diffusion distance for oxygen between the capillary wall and mitochondria of cells due to the formation of new capillaries and changes in the properties of cell membranes; 5) increase in the ability of cells to utilize oxygen due to the increase in myoglobin concentration; increase the ability of cells and tissues to utilize oxygen from the blood and form ATP, despite the lack of oxygen; 6) an increase in the anaerobic resynthesis of ATP due to the activation of glycolysis, evaluated by many researchers as an essential mechanism of adaptation [25].

Incorrectly constructed training in mid–mountain and high–mountain conditions (ultra–high loads, irrational alternation of work and rest, etc.) can lead to excessive stress, in which summation of the effects of mountain hypoxia and hypoxia load can lead to reactions characteristic of chronic mountain sickness [7].

Especially the risk of mountain sickness increases with excessive physical loads in high altitude conditions at an altitude of 2500–3000 m and more [44, 45]. It should not be thought that a high level of adaptation of athletes to mountain conditions and their frequent stay in the mountains are a powerful preventative against the occurrence of mountain sickness. The disease can also occur in high–qualified athletes with extensive training in the middle and high mountains, as they tend to begin intensive training without the necessary preliminary adaptation [40, 46].

Prevention of mountain sickness is facilitated by preliminary artificial hypoxic training, stay in the pressure chamber and stepwise ascent to the highlands. To eliminate the symptoms of mountain sickness, it is possible to use special medicine (according to the doctor's indications) or move to a lower altitude.

It should be noted that the time needed to achieve sustainable adaptation is determined by many factors. Other things being equal, adaptation occurs more quickly in people who are regularly under conditions of artificial or natural hypoxia. Athletes, adapted to the endurance load, adapt to the mid–mountain and high–mountain conditions faster than those who are not physically active.

Increasing the altitude (within certain limits) stimulates adaptive reactions and accelerates the adaptation process; The process of adaptation is much faster for people who are physically active [47]. To achieve the maximum values of the volume of circulating blood and the mass of circulating erythrocytes at an altitude of 3200 m, about 40 days are necessary without special training [48]. However, depending on the factors listed above, this period can be reduced by a factor of 1.5–2.

The same factors determine the length of the period during which the achieved level of adaptation is preserved. Athletes well adapted to hypoxic conditions, with a certain training regime and the use of artificial hypoxia sessions are able to maintain the level of reactions achieved in the mountains 30–40 days or more after moving to the conditions of the sea level. With a one–off training g in the mountains, the number of red blood cells, for example, returns to the baseline level after 9–12 days. When hypoxic training is carried out regularly for many months, its effect persists after 40 days or more after the termination of such training. This also applies to such indicators as maximum oxygen consumption, oxygen consumption at the level of anaerobic metabolism, etc. [49].

Moving athletes to the mountains dramatically affects their physical performance and leads to a more pronounced reaction of the body's functional systems to standard loads. For example, a decrease in working capacity under standard loads in hypoxic conditions causes an unequal reaction from the power supply of highly skilled cyclists. In some of them, a sharp decrease in the speed of work at an altitude of 3000 m is accompanied by a significant increase in the concentration of lactate in the blood (up to 6–7 mmol / l). This indicates the need to take into account the individual characteristics of the athlete and, on this basis, the individual approach is needed when planning training in the mountains.

The duration and effectiveness of acclimatization of athletes to the conditions of mountains depends on a large number of factors and can vary within fairly wide limits, depending on the age and qualifications of the athletes, the specifics of the sport, the experience of hypoxic training, and the characteristics of the training process preceding the ascent to the mountains. Of great importance is a full preliminary rest: starting training in the mountains is necessary in a state of complete recovery of the physical and mental capabilities of the athlete after previous training and competitive loads. In the event that mountain training begins in conditions of under–recover, the process of adaptation to hypoxia slows down considerably, therefore, as a rule, 5–7 day–old recover microcycles are planned before moving to the mountains [7, 47].

The process of acclimatization also slows down in the event of the mountain training regime being significanlty different from a training regime at sea level. The acceleration of the accilimatisaion process is facilitated by a variety of aerobic exercises, including non–specific ones [7, 47].

The period of acclimatization varies in a wide range – from 3–5 days and 10–12 hours of active load to 10–12 days of active load. These fluctuations are due to a number of reasons. First, the amount of total mountain training accumulated by athletes who regularly train in the mountains enables them to develop the ability to adapt quickly to new conditions and be able to enter the usual training mode 1.5–2 times faster than athletes of the same qualifications who arrived in the mountains for the first time [50]. Equally important for accelerating the processes of acclimatization is the practice of applying artificial hypoxic training conducted in sea level conditions during the weeks immediately preceding training in the mountains. Two–week of such pre–training in conditions of artificial hypoxia with a total load of 20–30 hours can dramatically accelerate and facilitate the process of acclimatization [7].

There are data indicating the need for much longer acclimatization of athletes specializing in sports requiring endurance [51-53]. If the altitude is 1200–1500 m above sea level, acclimatization requires at least a week, 2000 m – a month. However, the experience of mountain training of high–class athletes indicates that these terms are clearly overstated. Sportsmen of the highest qualification pass the acclimatization period much easier compared to athletes who are significantly inferior to them in their skills, training and competitive experience [7].

Recovery processes for young athletes, as well as for non–adapted adult athletes, are much slower in comparison with older high–qualified athletes who regularly train in mountains [7]. For example, after a standard load, the duration of restorative reactions according to HR, oxygen consumption, oxygen debt repayment in adult athletes adapted to the mountains, is 25–35% shorter compared to older athletes not adapted to mountains, and by 30–45 % – compared with young athletes. Such significant differences are largely due to the different reaction of the athletes of these groups to the respective standard loads. However, even when the athletes are offered absolutely identical loads (increasing the concentration of lactate in the blood to 6.5 mmol / l in all groups), the adapted adult athletes recover by 15–20 and 25–35% faster than the unadapted adults and young athletes, respectively [54].

When it comes to the appropriate altitude at which training should be conducted, it is necessary to take into account the tension existing between the effect of mountain hypoxia on the respiratory, circulatory, blood systems and, in general, the body's ability to provide energy for aerobic and aerobic–anaerobic work and conditions for effective improvement of technical–tactical, speed–strength and special mental components of preparedness. While mountain training can be highly effective for improving the capabilities of the various links in the energy supply system, in relation to the most important components of technical and tactical skill and a number of important components of physical and mental fitness, a significant reduction in the intensity of training and its total volume inevitable in high mountain conditions is a negative factor [7].

Therefore, the choice of optimal altitudes for training in mountain conditions should be determined to a large extent by the specifics of the sport. Experience, as well as results of scientific research show that runners for long distances and marathon runners can periodically train at an altitude of 5300–4000 m. For rowers, swimmers, runners for medium distances and skaters the most appropriate altitude lies in the range of 1600–2200 m. Athletes specializing in speed–power, hard–coordinate and game types, can use bases for mountain training located at altitudes of 1200–1600 m [47, 55, 56].

In practice, training in mountain conditions is most often carried out at altitudes of 2000–2700 m above sea level for at least 2–3 weeks, which allows athletes to achieve high results in competitions held on the plain. Modification of this type of training is a technique that reflects the concept of "living on top – to train below" when athletes are constantly in medium or high mountains, and train at an altitude of 1000 m or less [15, 57].

Continuous stay of athletes who are well acclimatized to mountain conditions at the sea level gradually leads to the disappearance of structural and functional adaptive changes in the body. First of all, there are changes in the respiratory system: breathing adaptation reactions disappear within a few weeks. The changes in the blood system last a little longer – an increased amount of erythrocytes and hemoglobin content, an oxygen capacity of the blood. Increased vascularization of tissues can persist for 2–3 months [25].

The duration of acclimatization at sea level after a stay in the mountains, as well as re–acclimatization to mountain conditions, depends on many factors and can fluctuate widely. For some individuals, the process of readaptation to mountain conditions may not be completed even after 6 months after moving to sea level. For others, at the end of the second month, the main effects of staying in the mountains disappear altogether [7].

The positive impact of mountain training on the functionality of athletes and their athletic performance is not immediately apparent after returning from the mountains. Perhaps this is due to the need to adapt the muscular system, that is the training of muscles in new (with higher atmospheric pressure) conditions [15]. A certain period of re–acclimatization is required, the duration of which depends on the individual characteristics of the athlete's body. Approximately 50–60% of athletes in the first few days (no more than 3–4) are able to show high results and demonstrate high performance in special tests. After this, a fairly long phase (5–6 days) of reducing the functional capacity of the athletes' organism may occur. In the remaining 40–50% of athletes, this phase occurs immediately after returning to the sea level conditions, which can last up to 6–8 days or more [8]. During this time, participation in important competitions, exercises with extreme loads and exercises of a special–preparatory character, which demands the maximum capacity of the athletes' organism, are not recommended [7].

After the end of the phase of reduced functionality, a lagged effect of mountain training manifests itself, which depending on an individual can develop over the next 8–12 days. The maximum values of oxygen consumption are usually recorded 3–4 weeks after returning to sea level conditions [13]. Depending on the features of the construction of the training process during these days, the peak of the functional capabilities and performance of athletes falls on 20–25 days after returning from the mountains [8].

After 30–35 days after returning from the mountains, the first signs of de–daptation are noted, which primarily affect the functions of blood circulation, breathing, blood, the system of oxygen utilization by tissues, etc. [8]. It is noted that the more pronounced the effect of the mountain preparation is, the earlier signs of deadaptation appear [7].

The timing of deadaptation and the intensity of the weakening of the functional and structural rearrangements in the athlete's body, achieved as a result of moutains training largely depend on the specific nature of the sport, the experience of hypoxic training and the nature of the training after returning from the mountains. Athletes who specialize in sports associated with endurance (stray run, cycling (highway), skiing and biathlon) retain the level of adaptation achieved in the mountains 20–40% longer compared to athletes specializing in martial arts or games. Adaptive reactions persist significantly longer (in 1.5–2 times) among athletes using hypoxic training (natural and artificial) regularly, compared with athletes using training in the mountains occasionally. Using training exercises of a hypoxic nature can significantly postpone the process of de–adapting. The same effect follows from the inclusion of artificial hypoxic training in the training process [50, 58].

Conclusions

1. It is shown that as a result of hypoxia training there are various morphological and functional changes that influence the athlete's fitness. At the same time, it is very important to constantly improve all aspects of the athlete's training. Along with the further development of traditional methods for the comprehensive training of athletes, the development and use of non–traditional means and methods aimed at expanding the boundaries of the athlete's body, its aerobic and anaerobic productivity, which largely determine the level of efficiency, is becoming increasingly important.

2. The problem of training and competition of athletes in mountain conditions attracts wide attention of specialists in the field of sports. Modern sport of higher achievements has become a field of activity in which studies of the influence of hypoxia on the athlete's body in the conditions of intense muscular activity are being carried out most intensively. The high efficiency of moutain training as a means of improving the functionality of athletes and results in all sports associated with endurance has been proven by many researchers working in the field of sports physiology. However, much less work has been devoted to the training of non–endurance athletes (power, speed–power, complex coordination sports, martial arts) in mountainous conditions. In addition, insufficient attention is paid to the studying of individual characteristics of adaptation to hypoxic conditions, in particular, characteristics related to the type of central nervous system and vegetative homeostasis.

Література

1. Ільїн В. М. Особливості функціонального і психофізіологічного статусу спортсменів високої кваліфікації з ознаками хронічного стомлення / В. М. Ільїн, Р. С. Жила, Л. І. Черкес, Г. В. Рассоха, К. В. Медвідчук // Спортивна медицина. – 2007. – № 1. – С.42-45.
2. Мищенко В. С. Реактивные свойства кардиореспираторной системы как отражение адаптации к напряженной физической тренировке в спорте / В. С.Мищенко, Е. Н.Лысенко, В. Е.Виноградов. – К.: Науковий світ, 2007. – 351 с.
3. Виноградов В. Е. Стимуляция работоспособности и восстановительных процессов в тренировочной и соревновательной деятельности квалифицированных спортсменов: Монография / В. Е. Виноградов. К.: НПФ «Славутич-Дельфин», 2009. 367 с.
4. Новиков А. А. Система подготовки спортсменов высокой квалификации / А. А.Новиков // Теория и практика физ. культуры. – 2003. - №10. – С.38
5. Платонов В. Н. Система подготовки спортсменов в олимпийском спорте. Общая теория и ее практические приложения / В. Н.Платонов – Киев: Олимпийская литература, 2004. – 808 с.
6. Astrand P. Text book of work Physiology: Physiologcal bases of exercise. Ed.2./ P. Astrand, K. Rodah. – New York: McGrow Hill Book Co., 1977. – 584 p.
7. Булатова М. М. Среднегорье, высокогорье и искусственная гипоксия в системе подготовки спортсменов / М. М. Булатов, В. Н. Платонов // Спортивная медицина. – 2008. – № 1. – С.95-119.
8. Суслов Ф. П. Спортивная тренировка в условиях среднегорья / Ф. П. Суслов, Е. Б. Гиппернрейтер, Ж.К. Холодов. – М.: Советский спорт, 2003. - 2002с.
9. Филиппов М. М. Физиологические механизмы развития и компенсации гипоксии в процессе адаптации к мышечной деятельности: Монография / М. М. Филиппов, Д. Н. Давиденко – СПб. – Киев: БПА, 2010. – 260 с.
10. Уилмор Дж. Х. Физиология спорта / Дж. Х. Уилмор, Д. Л. Костилл. – К.: Олимпийская литература, 2005. – 504 с.
11. Viru A. Adaptation in Sport Training / A. Viru // Times Mirror International Publishers. – London. – 1995. – 320 p.
12. Costill D. L. Handbook of sports medicine and science: Swimming Blackwell Scientific Publications / D. L. Costill, E. W. Maglisco, A. B. Richardson // Oxford, 1992. – 286 p.
13. Saltin B. Exercise and the Environment: Focus on Altitude / B. Saltin // Res. Quarterly Exerc. Sport. – 1996. – Vol. 67. – P. 1-10.

14. Бойчук Т. В. Оцінка факторів, що впливають на ефективність тренувального процесу у бігунів на середні і довгі дистанції та вплив гіпоксії на функціональний стан організму / Т. В. Бойчук, Д. В. П’ятничук, Е. Й. Лапковський // Науковий часопис національного педагогічного університету ім.. М.П.Драгоманов. серія 15. Теорія та методика навчання: фізична культура і спорт. – Випуск 8. – Л.: НПУ ім.. М.П.Драгоманова, 2010. – С. 134-138.
15. Дмитрук А. И. Гипоксия и с порт: Учебно-методическое пособие / А. И. Дмитрук. – СПб.: 2007 – 44 с.
16. Шпак Т. В. Підготовка велосипедистів високої кваліфікації в умовах середньогір’я / Т. В. Шпак, М.П.Кірієнко // Спортивная медицина. – 2008. – № 1. – С.137-142.
17. Колчинская А. З. Интервальная гипоксическая тренировка в спорте высших достижений / А. З. Колчинская // Спортивная медицина. – 2008. – №1. – С.9-25.
18. Кравченко Ю. В. Імпульсно-періодична гіпоксія як метод прискорення адаптації до умов високогір’я / Ю. В. Кравченко, В. М. Ільїн, О. Л. Євтушенко, В. І. Портниченко, І. О. Яхниця, Л. І. Черкес // Вісник Черкаського університету. – 2007. – Вип. 105. – С. 43-48.
19. Радзієвський П. О. Механізми адаптації до нормобаричної гіпоксії в курсу інтервального гіпоксичного тренування у висококваліфікованих спортсменів / П. О.Радзієвський // Фізіол. журнал. – 2005, №2. – С.90-96.
20. Ровна О. А. Особливості адаптації організму людини до інтервальної нормобаричної гіпоксії в умовах складно-координаційної рухової діяльності. – Автореф. дис...канд.наук. – К., 2011. – 20 с.
21. Цыганова Т. Н. Эффективнгость использования адаптации к гипоксии в курсе интервальной нормобарической тренировки в медицине / Т. Н. Цыганова. – М.; Нальчик: НИИПРУ КБНЦ РАН, 2000. – 186 с.
22. Закусило М. П. Ефективність адаптації – в покращенні стану функціональної системи дихання і підвищення працездатності у висококваліфікованих спортсменів / М. П. Закусило, П. О. Радзіевсський // Наукові записки, Біологія та екологія. – 2002. – Т. 20. С. 47-50.
23. Landby C. The influence of intermittent altitule exposure to 4100 m on exercise capacity and blood variables / C. Landby, T. R. Nielsen, F. Dela, R. Damsgaard // Scand. J. Med. Sci. Sport. – 2005. – Vol. 15, N 3. – P. 182.187.
24. Dempsey J. A. Discussion: Cardiovascular and pulmonary adaptation tp physical activity / J. A. Dempsey, S. K. Powers, N. Gledhill // Exercise, Fitness and Health / C. Bouchard, R. J. Sheppard. T. Stephens, J. R. Sutton. B. D. McPherson (Eds.). – Champaign IL: Human Kinetic Books, 1988. – P.205.
25. Меерсон Ф. З. Адаптация к высотной гипоксии / Ф. З. Меерсон // Физиология адаптационных процессов. – М.: Наука, 1986. – С.224-248.
26. Robergs R. A. Fisiologia do Exercicio / R. A. Robergs, S. O. Roberts. – San Paulo: Phorte Editora, 2002. – 490 p.
27. Sutton J. R. Breathlessness at Altitude / J. R. Sutton, A. Balcomb, K. J. Killian, H. J. Green, P. M. Young, A. Cymerman, J. Reeves, C. S. Houston // Breathlessness, The Cambell Symposium / N.L.Jones, K.J.Killian (Eds.). – Toronto:Boehringer Ingelheim. Inc., 1992. - P. 143-148.
28. Malik A. B. Independent effects of changes in H+ and CO2 concentrations on hypoxic pulmonary vasoconstriction / A. B. Malic, R. S. Kidd // J. Appl. Physiol. – 1973. – Vol. 26, N 3.- P. 318-323.
29. Reeves I. T. Activation of Sympathj-Adrenal System at High Altitude / I. T. Reeves, L. G. Moore, E. E. Wofei, R. S. Maaeo, A. Cymerman, A. I. Long // High-Altitude Medicine / Ed. by G. Ueda, I. T. Reeves, M.Sekiguchi. – Shinshu University Press, 1992. – P. 10-27.
30. Wolfel E. E. Oxygen transport during steady state, submaximal exercise in chronic hypoxia / E. E. Wolfel, B. M. Groves, G. A. Brooks et al. // J. Apll. Physiol. – 1991. – Vol. 70. – P. 1129-1136.
31. Briek F. J. Red cell mass and aerobic performance at sea level / F. J. Briek, N. Gledhill, A. B. Fmese, L. L. Spnet, J. R Sutton., N. L. Jones, C. S. Houston // Hypoxia: Man at Altitude. – Thieme-Stratton-New York, 1982. – P. 43-50.
32. Brooks G. A. Decreased reliance on lactate during exercise after acclimatization to 4,300 mb / G. A. Brooks // J. Appl. Physiol. – 1991. – Vol. 71. – P. 43-50.
33. Green H. J. Altitude acclimatization and energy metabolic adaptations in skeletal muscle during exercise / H. J. Green // J. Apll. Physiol. – 1992. – Vol. 73. – P. 2701-2708.
34. Wilmore J. H. Physiology of sport and exercise / J. H. Wilmore, D. L. Costill. – Champaingn, Illinois: Human Kinetics, 2004. – 726 p.
35. Портниченко В. И. Развитие гипометаболического состояния у высокквалифицированных спортсменов в условиях гипоксии / В. И. Портниченко, В. Н. Ильин, Б. А. Подливаев // Спортивная медицина. – 2008. – № 1. – С. 74-77.
36. Boutellier U. Aerobic performance at altitude: effects of acclimatization and haematocrit with reference to training / U. Boutellier, O. Derias, P. di Prampero, P. Cerretelli // Int. J. Sports Med. – 1990. – N. 11. – P. 21-26.

37. Ferretti G. Oxygen transport system before and after exposure to chronic hypoxia / G. Ferretti, U. Boutellier, D. R. Pendergast et al. // Int. J. Sports Med. – 1990. – N 11. P. 15-21.
38. Бернштейн Н. А. Роль оксигемоглобина в адаптации к гипоксической гипоксии среднегорья / Н. А. Бернштейн // Механизмы адаптации к спортивной деятельности. – М., 1977. – С.14-15.
39. Черкес Л. І. Особливості функціонального стану регуляторних систем організму спортсменів високої кваліфікації в початковій фазі адаптації до умов середньогір'я / Л. І. Черкес // Зб. наук. праць Харківського національного педагогічного університету ім. Г.С. Сковороди. Серія «БІОЛОГІЯ ТА ВАЛЕОЛОГІЯ». Вип. 13. – 2011. – С. 113-120.
40. Пшенникова М. Г. Адаптация к физическим нагрузкам / М. Г. Пшенникова // Физиология адаптационных процессов. – М.: Наука, 1986. – С. 124-221.
41. Колб Дж. Факторы окружающей среды /Дж. Колб // Спортивная медицина. – К.: Олимпийская литература, 2003. – С.265-280.
42. Hacker R. Energiebereitstestellung und Energieumsatz unter Hypoxiebedingungen / R. Hacker, D. Appelt, H. Buhme. – Leipzig, FKS, 1984. – 245 s.
43. Ильин В. Н. Влияние факторов среднегорья на функциональное состояние регуляторных систем организма в тренировочном процессе спортсменов / В. Н. Ильин, В. И. Портниченко, А. Родригес, Л. И. Черкес // Мат. ХІ Міжнародному науковому конгресі "Современный олимпийский спорт и спорт для всех», Мінск, 10-12 жовтня, 2007 р. – С. 86-88
44. Сведенхаг Я. Развитие выносливости в тренировке бегунов на средние и длинные дистанции / Я. Сведенхаг // Наука в олимпийском спорте. – 1995. – № 1. – С. 19-27.
45. Anholm J. D. Radiographic evidence of interstitial pulmonary edema after exercise at altitude / J. D. Anholm, E. N. Milne, F. Stark et al. // J. Appl. Physiol. – 1999. – Vol. 86. – P. 503.509.
46. Montgomery A. B. Incidence of acute mountaine sickness at intermediate altitude / A. B. Montgomery, Y. Mills, Y. M. Luse // YAMA. – 1989. – N 261. – P. 732-726.
47. Shephard R. J. Problems of High Altitude / R. J. Shephard // Endurance in Sport. – Blackwell Sci. Publ., 1992. – P. 471-478.
48. Platonov V. N. Teoria geral del entrenamiento deportivo Olimpico / V. N. Platonov. – Barcelona: Paidotribo, 2002. – 686 p.
49. Миррахимов М. М. Значение красной крови в адаптации организма человека к условиям высокогорья / М. М. Миррахимов, Н. Я. Юсупова, А. Р. Раимжанов // Горы и система крови: Тез. докл. – Фрунзе, 1969. – Т. 56. – С. 77-78.
50. Wolf W. V. Untersuchungen fur biologischen Wirkungsrichtung der Kunstichen und naturlichen Hypoxietrainings im DRSV der DDR / W. V. Wolf, J. Schwalm, S. Buschrov. – Berlin: SHB, 1986. – 305 p.
51. Волков Н. И. Изменение работоспособности спортсменов в условиях среднегорья / Н. И. Волков, Ф. А. Иорданская, Э. А. Матвеева // Теория и практика физической культуры. – 1970. – № 7. – С. 26-31.
52. Loffredo B. M. The ergogenics of hypoxia training in athletes / B. M. Loffredo, J. L. Glazer // Curr. SportsMed. Rep. – 2006. – Vol. 5, N 4. – P. 203-209.
53. Mason S. D. HIF-1alfa in endurance training: suppression of oxidative mttabolism / S. D. Mason, H. Rundgvist, I. Papandreou et al. // Am. J. Physiol. Regul. Integr. Comp.Physiol. – 2007. – Vol. 293, N 5. – P. 2059-2069.
54. Wilber R. L Application of altitude/hypoxic training by elite athletes / R. L. Wilber // Med. Sci. Sports Exerc. – 2007. – Vol. 39, N 9. – P. 1610-1624.
55. Платонов В. Н. Гипоксическая тренировка в спорте / В. Н. Платонов, М. М. Булатова // Hypoxia medical. – М., 1995. – С. 17-23.
56. Палатний Ігор. Порівняльна ефективність тренування бігунів в умовах низькогір'я та рівнинної підготовки. / Ігор Палатний // Молода спортивна наука України: Зб. праць з галузі фізичної культури та спорту. Вип. 7: У 3-х т. – Львів: НВФ «Українські технології», 2003. Т. -3. –С. 180-183.
57. Пятничук Д. В. Побудова тренування бігунів на середні і довгі дистанції в умовах Карпатських гір : метод. реком. / Д. В. Пятничук, Т. В. БойчукТ.В. – Івано-Франківськ, 2011. – 56 с.
58. Nummela A. Acclimatization to altitude and normoxic training improve 400-m running performance at sea level / A. Numella, H. Rusko // J. Sports Sci. -2000. -№3. – P. 441-419.
59. Криворученко Е. В. Вариабельность сердечного ритма в практике спортивной медицины и спортивной подготовки: обзор научной литературы / Е. В. Криворученко // Спортивная медицина. – К.: Олимпийская литература, 2006. – №1. – С.37-46.

References

1. Ilyin, V. M., Zhyla, R. S., Cherkes, L. I., Rassoha, H. V., Medvidchuk, K. V. (2007). Features functional and psychophysiological status of athletes qualifications with symptoms of chronic fatigue. *Sports Medicine,* 1, 42-45 (in Ukr.)
2. Mishchenko, V. S., Lysenko, E. N., Vinogradov, V. E. (2007). *Reactive properties as the cardiorespiratory adaptation to reflection strenuous physical training in sport.* K. Naukova's World (in Ukr.)

3. Vinogradov V. E. (2009). *Stimulation of the health and recovery processes in training and competitive activity of qualified athletes: monograph*. K .: NPF "Slavutich-Dolphin" (in Ukr.)
4. Novikov A. A. (2003). The system of preparation of sportsmen of high qualification. *Theory and Practice nat. Kultury,* 10, 38 (in Ukr.)
5. Platonov V. N. (2004). *System of training athletes in Olympic sports. The general theory and its practical applications.* Kiev, Olympic Literature (in Ukr.)
6. Astrand, P., Rodah, K. (1977). In Astrand P. (Ed). *Text book of work Physiology: Physiologcal bases of exercise.* New York: McGrow Hill Book Co.
7. Bulatova, M. M., Platonov, V. N. (2008). *Medium high mountains and artificial hypoxia in the system of training athletes.* Sports Medicine,1,95-119 (in Ukr.)
8. Suslov, F. P., Gippernreyter, E.B., Kholodov, J. K. (2003). *Sports training in conditions of middle.* M.: Soviet Sport..
9. Filippov, M. M., Davidenko, D. N. (2010). *Physiological mechanisms of hypoxia and compensation in the process of adaptation to muscular activity: Monograph.* SPb.- Kiev: BPA (in Ukr.)
10. Wilmore, J. H., Kostil,l D. L. (2005). *Physiology of Sport.* K.: Olympic Books.
11. Viru A. (1995). *Adaptation in Sport Training.* Times Mirror International Publishers. – London.
12. Costill, D. L., Maglisco, E. W., Richardson, A.B. (1992). *Handbook of sports medicine and science: Swimming.* Blackwell Scientific Publications Oxford.
13. Saltin B. (1996). Exercise and the Environment: Focus on Altitude. *Res. Quarterly Exerc. Sport,(*67):1-10.
14. Dmitruk A. I. (2007). *Hypoxia and port: Educational handbook*. SPb.
15. Boychuk, T. V., Pyatnychuk, D. V., Lapkovsky, E. Y. (2010). Evaluation of the factors affecting the efficiency of the training process with runners on medium a nd long distances and the effect of hypoxia on the functional state of an organism. *Scientific journal Dragomanov National Pedagogical University. Series 15. Theory and methods of teaching, physical culture and sports. Issue 8.. Dragomanov NPU University,*134-138 (in Ukr.)
16. Shpak, T. V., Kiriyenko, N. P. (2008). Training cyclists of high qualification in conditions srednegorja. *Sports medicine,* 1, 137–142 (in Ukr.)
17. Kolchinskaya A. Z. (2008). Interval hypoxic training in the sphere of sports. *Sports Medicine, 1, 9-25 (in Ukr.)*
18. Kravchenko, Yu. V., Ilyin, V. M., Yevtushenko, O. L., Portnychenko, V. I., Yahnytsya, I. O., Cherkes, L. I. (2007). Pulse-periodic hypoxia as a method of accelerating the adaptation to the Highlands. *Bulletin of Cherkassy University,* 105, 43-48 (in Ukr.)
19. Radzievskii P. A. (2005). The mechanisms of adaptation to normobaric hypoxia in the course of interval hypoxic training skilled sportsmen. *Physiol. Ju.,* 2, 90-96 (in Ukr.)
20. Rovna O. A. (2011). *Features of human adaptation to interval normobaric hypoxia in difficult conditions and coordinating motor activity*. Author. di ... kand.nauk. K., (in Ukr.)
21. Tsyganova T. N. (2000). *The effectiveness of the use of adaptation to hypoxia in the course of interval normobaric training in medicine.* M.; Nalchik: IRD KBNTS RAS.
22. Zakusylo, M. P., Radzievssky, P. A. (2002*). The effectiveness of adaptation - to improve the functional status of the respiratory system and increase efficiency in highly skilled athletes.* Scientific Notes, biology and ecology, (20), 47-50 (in Ukr.)
23. Landby, C., Nielsen, T. R., Dela, F., Damsgaard, R. (2005). The influence of intermittent altitule exposure to 4100 m on exercise capacity and blood variables. *Scand. J. Med. Sci. Sport.* 3 (15), 182-187.
24. Dempsey, J. A., Powers, S. K., Gledhill, N. (1988). Cardiovascular and pulmonary adaptation tp physical activity. Exercise, Fitness and Health. *Champaign IL: Human Kinetic Books.*
25. Meyerson F. Z. (1986). *Adaptation to high-altitude hypoxia. Physiology of adaptation processes*. M.: Nauka.
26. Robergs, R. A., Roberts, S. O. (2002). *Fisiologia do Exercicio*. San Paulo: Phorte Editora.
27. Sutton, J. R., Balcomb, A., Killian, K. J., Green, H. J., Young, P. M., Cymerman, A., Reeves, J., Houston, C.S. (1992). In N.L.Jones, K.J.Killian (Ed.). Breathlessness at Altitude. *In Breathlessness, The Cambell Symposium. Toronto:Boehringer Ingelheim. Inc*., 143-148.
28. Malik, A. B., Kidd, R. S. (1973). Independent effects of changes in H+ and CO2 concentrations on hypoxic pulmonary vasoconstriction. *J. Appl. Physiol.*, 3 (26), 318-323.
29. Reeves, I. T., Moore, L. G., Wofei, E. E., Maaeo, R. S., Cymerman, A., Long, A. I. (1992). In Ueda G.,.Reeves I. T, Sekiguchi M. Ed). Activation of Sympathj-Adrenal System at High Altitude. *High-Altitude Medicine. Shinshu University Press,* 10-27.
30. Wolfel, E. E., Groves, B. M., Brooks, G. A. et al. (1991). Oxygen transport during steady state, submaximal exercise in chronic hypoxia. *J. Apll. Physiol*., (70), 1129-1136.
31. Briek, F. J., Gledhill, N., Fmese, A. B, Spnet, L. L., Sutton, J. R., Jones, N. L., Houston, C. S. (1982). Red cell mass and aerobic performance at sea level. Hypoxia: *Man at Altitude. Thieme-Stratton-New York*, 43-50.

32. Brooks G. A. (1991). Decreased reliance on lactate during exercise after acclimatization to 4,300 mb *J. Appl. Physiol.*, (71), 43-50.
33. Green H. J. (1992). Altitude acclimatization and energy metabolic adaptations in skeletal muscle during exercise. *J. Apll. Physiol.*, (73), 2701-2708.
34. Wilmore, J. H., Costill, D. L. (2004). *Physiology of sport and exercise*. Champaingn, Illinois: Human Kinetics.
35. Portnichenko, V. I., Ilin, V. N., Podlivaev, B. A.. (2008). Development hypometabolic condition in highly qualified athletes in the conditions of hypoxia. *Sports Medicine*, 1, 74-77 (in Ukr.)
36. Boutellier, U., Derias, O., di Prampero, P., Cerretelli, P. (1990). Aerobic performance at altitude: effects of acclimatization and haematocrit with reference to training. *Int. J. Sports Med.,* 11, 21-26.
37. Ferretti, G., Boutellier, U., Pendergast, D. R. et al. (1990). Oxygen transport system before and after exposure to chronic hypoxia. *Int. J. Sports Med.*, 11, 15-21.
38. Bernstein A. D. (1977). Oxyhemoglobin role in adaptation to hypoxic hypoxia midlands. *Mechanisms of adaptation to sporting activities.* M., 14-15.
39. Cherkes L. I. (2011). Features of the functional state of regulatory systems athletes skilled in the initial phase of adaptation to middle. *Coll. Science. works of Kharkiv National Pedagogical University. Series "Biology and Health Education"*, 13, 113-120 (in Ukr.)
40. Pshennikova M. G. (1986). *Adaptation to physical stress. Physiology of adaptation processes*. – M.: Nauka.
41. Kolb J. (2003). Environmental factors. *Sports Medicine. K.: Olympic Literature,* 265-280 (in Ukr.)
42. Hacker, R., Appelt, D., Buhme, H. (1984). *Energiebereitstestellung und Energieumsatz unter Hypoxiebedingungen.* Leipzig, FKS.
43. Ilyin, V. N., Portnichenko, V. I., Rodriges, A., Cherkes, L. I. (2007). Influence of factors of middle mountains on the functional condition of regulatory systems of an organism in training process of athletes. *Proceedings of the XI International Scientific Congress "Modern Olympic Sport and Sport for All", Minsk, October 10–12, 2007*, 86–88 (in Ukr.)
44. Svedenhag Ya. (1995). Development of endurance runners in training for middle and long distance. *Science in Olympic sports,* 1, 19-27 (in Ukr.)
45. Anholm, J. D., Milne, E. N.,.Stark F. et al. (1999). Radiographic evidence of interstitial pulmonary edema after exercise at altitude. *J. Appl. Physiol.*, (86), 503.509.
46. Montgomery, A. B., Mills, Y., Luse, Y. M. (1989). Incidence of acute mountaine sickness at intermediate altitude. *YAMA.* (261), 732-726.
47. Shephard R. J. (1992). Problems of High Altitude. Endurance in Sport. *Blackwell Sci. Publ.*, 471-478.
48. Platonov V. N. (2002). *Teoria geral del entrenamiento deportivo Olimpico* – Barcelona: Paidotribo.
49. Mirrakhimov, M. M., Yusupova, N. Ya., Raimzhanov, A. R. (1969). The value of red blood cells in the human body to adapt to high altitude. *Mountains and blood system: Proc. rep. Frunze, (*56), 77-78.
50. Wolf, W. V., Schwalm, J., Buschrov, S. (1986). *Untersuchungen fur biologischen Wirkungsrichtung der Kunstichen und naturlichen Hypoxietrainings im DRSV der DDR.* Berlin: SHB.
51. Volkov, N. I., Iordanskaya, F. A., Matveeva, E. A. Changing the performance of athletes in a midlands. *Theory and Practice of Physical Culture*, 7, 26-31.
52. Loffredo, B. M., Glazer, J. L. (2006). The rgogenics of hypoxia training in athletes. *Curr. SportsMed. Rep, 4 (*5), 203-209.
53. Mason, S. D., Rundgvist. H., Papandreou, I. et al. (2007). HIF-1alfa in endurance training: suppression of oxidative mttabolism. *Am. J. Physiol. Regul. Integr. Comp.Physiol.*, 5 (293), 2059-2069.
54. Wilber R. L. (2007). Application of altitude/hypoxic training by elite athletes. *Med. Sci. Sports Exerc,* 9 (39), 1610-1624.
55. Platonov, V. N., Bulatova, M. M. (1995). Hypoxic training in sport. *Hypoxia medical. M.,* 17-23.
56. Palatny I. (2003). Comparative effectiveness of training runners in terms of lowland plains and training. *Young sports science of Ukraine: Coll. works in the field of physical culture and sports. Lviv: NPF "Ukrainian technologies",* 3, 180–183 (in Ukr.)
57. Pyatnychuk, D. V., Boychuk, T. V. (2011). *Construction training runners on medium and long distances in terms of the Carpathian Mountains: method. recom.* Ivano-Frankivsk (in Ukr.)
58. Nummela, A., Rusko, H. (2000). Acclimatization to altitude and normoxic training improve 400-m running performance at sea level. *J. Sports Sci.*, 3, 441-419.
59. Krivoruchenko E. V. (2006). Heart rate variability in the practice of sports medicine and athletic training: a review of the scientific literature. *Sports Medicine. K.: Olympic Books,* 1, 37-46 (in Ukr.)

Резюме. Ільїн В. Н., Філіппов М. М., Пастухова В. А., Сосновський В. В. Підготовка спортсменів з використанням гіпоксичних умов

Актуальність. *Висока ефективність гірської підготовки як засобу підвищення функціональних можливостей спортсменів і спортивних результатів у всіх видах спорту,* *пов'язаних з проявом витривалості спортсменів, доведена багатьма дослідниками, що працюють в галузі спортивної фізіології.*

***Мета статті**. Проаналізувати і узагальнити дані літератури з питань, пов'язаних з підготовкой спортсменів з використанным гіпоксичних умов.*

***Методи.** Аналіз спеціальної науково-методичної літератури, в якій розглядаються фізіологічні механізми з використанням гіпоксичних умов.*

***Результати та обговорення.** Узагальнення результатів численних досліджень, проведених з проблеми адаптації людини до умов висотної гіпоксії, дозволило виділити ряд координованих між собою пристосувальнихмеханізмів: 1) механізми, мобілізація яких може забезпечити достатнє надходження кисню в організм, незважаючи на дефіцит його в середовищі: гіпервентиляція; гіперфункція серця, що забезпечує рух від легенів до тканин збільшеної кількості крові; 2) полицитемия і відповідне збільшення кисневої ємності крові; 3) механізми, які роблять можливим достатнє надходження кисню до мозку, серця та інших життєво важливих органів, незважаючи на гіпоксемію, а саме: розширення артерій і капілярів мозку, серця та ін.; 4) зменшення дифузійного відстані для кисню між капілярної стінкою і мітохондріями клітин за рахунок утворення нових капілярів і зміни властивостей клітинних мембран; 5) збільшення здатності клітин утилізувати кисень внаслідок зростання концентрації міоглобіну; збільшення здатності клітин і тканин утилізувати кисень з крові і утворювати АТФ, незважаючи на брак кисню; 6) збільшення анаеробного ресинтезу АТФ за рахунок активації гліколізу.*

***Висновки.** Показано, що в результаті спортивної підготовки і постійного тренувального дії гіпоксії навантаження в організмі спортсмена відбуваються різноманітні морфологічні та функціональні зміни, які визначають стан тренованості спортсмена. При цьому вельми актуальним є необхідність постійного вдосконалення всіх сторін підготовки спортсмена.*

***Ключові слова:** спортсмени, тренування гипоксичне, працездатність аеробна і анаеробна, зміни морфологічні та функціональні.*

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