INFLUENCE OF ENVIRONMENTAL FACTORS OF MOUNTAIN TERRAIN ON THE PHYSICAL HEALTH OF STUDENTS

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Abstract

Statistically significant changes are observed in the vital and strength index values and heart rate recovery time in students exposed to high-altitude hypoxia. The mass index level in boys and girls in mid-mountain conditions is 24.3 and 26.3 kg/m2 , while on the plain it is 23.8 and 25.6. The vital index value in boys and girls of the 3rd group increases to 63.4 and 68.7 ml/kg, while the 1st one was 49.4 and 55.4, respectively. The strength index value in boys and girls of the 3rd group increased to 69.8 and 85.8 kg, while the 1st one was 57.3 and 72.6. The Robinson index in boys and girls in mid-mountain conditions decreased to 80.0 and 80.4 conventional units, while on the plain it was 88.6 and 88.0. The heart rate recovery time for girls in the 3rd group decreased to 117 seconds, for boys – 111, while the initial values were 151 and 145.

Keywords: *body weight, heart rate, vital capacity, mass index, vital index.*

I. Introduction

Humans are exposed to many extreme factors, of which hypoxia factors are special.

One of the ancient and perfect means of adaptation of the body is the ability to tolerate oxygen deficiency in the environment.

Mountains occupy up to 24% of the earth's land. A significant volume of coffee and cocoa production occurs in mountainous areas. Mountains are rich in various minerals.

The mountains account for 15-20% of world tourism and host sporting competitions in many sports [10].

The functional capabilities of the body in mountain conditions are affected by hypoxia, which reduces the level of oxygen in the blood.

With hypoxia, the body's organs and systems experience a deficiency of oxygen.

At the end of the 19th and the beginning of the 20th century, studies were started to study the impact of high-altitude hypoxia on both permanent mountain residents and those arriving in this area [16]. According to N.A. Agadzhanyan and others [1], the body's reaction to hypoxia characterizes its adaptive reserve capacity to the impact of various negative factors.

Currently, there is an increasing interest of biologists and doctors in hypoxia, which is caused by the fact that in any pathological condition, the cells and tissues of the body are not sufficiently supplied with oxygen .

High-altitude hypoxia is an environmental factor to which a significant portion of people are exposed during their leisure or professional duties. When climbing mountains, to prevent the development of hypoxia, it is necessary to maintain a level of oxygen in the inhaled air at which the body would function normally.

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In conditions of mountain hypoxia, human performance and endurance decrease due to an increase in oxygen deficiency. The brain reacts sharply to the lack of oxygen. The body's adaptation to mountain conditions occurs in three stages:

– acute adaptation, characterized by increased activity of the cardiovascular, respiratory systems and hematopoiesis;

– transitional adaptation – structural and functional changes occur in the body;

– stable adaptation, the main changes at this stage are an increase in the power and efficiency of the functional activity of the cardiovascular and respiratory systems.

The body's resistance to the effects of hypoxia is determined by the state of energy exchange, the perfection of regulatory mechanisms and the ability to adapt to a lack of oxygen.

During the process of adaptation to mountain hypoxia, changes occur aimed at improving the body's supply of oxygen and switching the body's systems to an economical mode of operation.

During the process of adaptation to hypoxia, the immune system is also restructured, aimed at maintaining homeostasis in the body.

The body's response in mountainous areas is determined not only by the level of hypoxia, but also by specific factors of the area [12].

When living in mountain conditions for a long time, the body's resistance to the effects of negative factors increases due to the increase in the body's reserve capacity.

Hypoxia plays a decisive role in the development and progression of many diseases. Therefore, adaptation to mountain conditions is widely used to stimulate the body's functional reserves.

It has long been established that the use of conditions at an altitude of 1-2 km by a person for several weeks improves his health.

In people who are not adapted to the conditions of mountain hypoxia, symptoms of mountain sickness are recorded from an altitude of 2500 m above sea level.

A significant part of the population lives and works in the mountainous regions of the Chechen Republic.

They are affected by many climatic factors, the most important of which is the reduced oxygen content in the atmospheric air, i.e. hypoxia.

Studying the mechanisms of the body's resistance to the effects of oxygen deficiency makes it possible to control the adaptation process in order to optimize it and prevent possible disorders.

Adaptation of the body to oxygen deficiency allows stimulating its functional reserves and improving health, therefore adaptation to mountain hypoxia is an important problem of our time.

This is why studying the effects of mountain hypoxia on the physical health of students is important.

Therefore, the aim of our research was to determine the physical health of students living in mountainous conditions.

II. Methods

The research was conducted using laboratory equipment of the Department of Physiology and Anatomy of Humans and Animals.

The object of the study were 180 (90 girls and boys) clinically healthy full-time students of the Biological and Chemical Faculty and the Agrotechnological Institute. Of these, taking into account the altitude of residence above sea level (170; 600; 1600 m), 3 groups were formed respectively (1st; 2nd and 3rd). Each group included 30 girls and boys. Residents of the plain were considered the control group.

To assess the level of health, we determined the vital capacity of the lungs (VC), heart rate (HR), systolic blood pressure (BP), body weight, body length, hand dynamometry, and HR recovery time using the Martinet test, then calculated the mass index (MI): body weight, kg/(height, m2), kg/m^2; vital index (VI): VC, ml/(body weight, kg), ml/kg; strength index (SI): hand strength, kg/body weight, kg, %; and Robinson index (RI): HR , beats/min x BP, mmHg/100, conventional units. Physical health was assessed according to Apanasenko, Naumenko, 1988.

To determine heart rate and blood pressure, an automatic OMRON tonometer was used. M 3 Expert , VEL – spirograph "Diamant – S".

For statistical processing of the experimental results, the Biostatistics program was used, and for comparison of the average indicators of the groups, the Student's criterion was used.

III. Results

The level of some indicators of physical development and cardiorespiratory systems of students are given in tables 1-2 and figures 1-2.

Table 1 The effect of mountain hypoxia on height, weight, vital capacity, hand strength, heart rate and blood pressure of female students

Indicators	Altitude above sea level in meters		
	170	600	1600
Body length, cm	164.6 ± 3.30	159.2 ± 3.30	152.8 ± 3.30*
Body weight, kg	64.3 ± 1.24	61.5 ± 1.26	56.2 ± 1.23****
YELLOW, L	3.17 ± 0.071	3.35 ± 0.072	3.50 ± 0.071***
Brush force, kg	36.8 ± 0.78	37.9 ± 0.78	39.0 ± 0.82
Heart rate, beats per minute	75.1 ± 1.76	73.5 ± 1.79	71.6 ± 1.79
BP, mmHg	117.4 ± 2.74	115.2 ± 2.65	112.8 ± 2.65

* – P < 0.05; *** – P < 0.01; **** – P < 0.001

They show that exposure to hypoxia is accompanied by statistically significant changes in the height, weight and vital capacity of students.

Thus , the body length of girls in mid-mountain conditions is 11.8 cm lower (P < 0.05), and of boys by 12.6 cm relative to the plain level.

The body weight of girls in the 3rd group was lower than that of the 1st group by 8.1 kg (P < 0.001), and of boys by 8.9 (P < 0.01).

The level of vital capacity of girls and their peers at an altitude of 1600 m exceeded the value at 170 m by 0.33 (P < 0.01) and 0.36 l (P < 0.02).

Other authors have come to similar results. Thus, the height and weight of the body of highland residents are 17.7 cm and 15 kg lower than that of the plains [5] .

Table 2 Height, weight, vital capacity, hand strength, heart rate and blood pressure of young men under conditions of high-altitude hypoxia

Terrain	Indicators					
	Height, cm	Weight, kg	YELLOW, L	Brush force, kg	Heart rate, beats per minute	BP, mmHg
Plain	173.1 ± 4.06	75.7 ± 1.77	4.19 ± 0.091	54.8 ± 1.06	74.8 ± 1.77	117.0 ± 2.69
Lowlands	167.5 ± 4.03	71.7 ± 1.78	4.41 ± 0.091	56.1 ± 1.06	73.1 ± 1.78	114.9 ± 2.70
Middle Mountains	160.5 ± 4.03	66.8 ± 2.06 ***	4.55 ± 0.084 **	56.9 ± 1.08	71.2 ± 1.78	112.3 ± 2.71

** – P < 0.02; *** – P < 0.01

As the altitude at which a person lives increases above sea level, their height and body weight decrease [15].

In terms of physical development, children living in mid-mountain areas are ahead of children living in high-mountain areas [9].

In the Andean aborigines, the growth of physical body size slows down, but the growth of lung capacity accelerates compared to the inhabitants of the plains [23].

Mountain dwellers are distinguished by their massive build, large chest, high vital capacity of the lungs, low growth rate and sexual maturation [20, 24, 8]. A distinctive feature of Tibetans compared to the plains is their rapid breathing and high vital capacity of the lungs [22].

According to V.A. Berezovsky [6], when a person stays in mountain conditions for a long time, the heart rate and minute blood volume decrease below the initial level [6].

As a person adapts to mountain air, the frequency of respiratory movements, ventilation and lung volumes increase [18].

During the first days of a person's stay at high altitude, systolic and diastolic pressure increases slightly, and as the duration of stay increases, it decreases below the initial level [7].

An important adaptive response to the effects of mountain hypoxia is an increase in lung ventilation, which begins to increase at an altitude of 1000 m above sea level [7].

In highlanders, heart rate and blood pressure are slightly lower, and lung ventilation is higher than in the plains [7].

Table 3 Physical health of girls in conditions of mountain hypoxia

Relief localities/ points	Indicators					Overall health level assessment (total score)
	MI, kg/ m2	GI, ml/kg	SI, kg	IR, conventional units	HR recovery time, sec	
Plain	23.8±0.96	49.4±0.72	57.3±1.22	88.6±4.12	151 ± 3.5	
Points	0	1	2	0	1	4
Lowlands	24.5±0.96	54.5±0.82 ****	61.8±1.33	85.1±4.02	137 ± 3.8 *	
Points	-1	2	3	0	1	5
Middle Mountains	24.3±1.13	63.4±1.82 ****	69.8±2.42 ****	80.0±2.78	117 ± 3.8 ****	
Points	-1	3	3	3	3	11

* – $P < 0.05$; **** – $P < 0.001$

The increase in lung ventilation at an altitude of 1000 m above sea level is due to the deepening of breathing, and at 2000 m – an additional increase in frequency [5].

Characteristics of highland residents include: decreased heart rate; slower growth and puberty; increased development of the chest and skeleton; large chest; high vital capacity of the lungs [8].

In response to exposure to altitude, breathing becomes more frequent and the minute volume of respiration increases, and it increases proportionally to the altitude [4].

With prolonged exposure to high-altitude hypoxia, heart rate and cardiac output decrease, and stroke volume increases [11].

It is likely that the decrease in heart rate, blood pressure and increase in vital capacity in students living in mountainous areas is due to the predominance of the parasympathetic nervous system.

Thus, prolonged stay in the mountains is accompanied by a predominance of excitability of the parasympathetic nerves [2].

The first days of human adaptation to high-altitude conditions are accompanied by a predominance of the activity of the sympathetic nervous system, and as the period lengthens, the activity of the parasympathetic nervous system increases [5].

When exposed to oxygen deficiency, there is a reliable change in the vital capacity, CI, and heart rate recovery time (Table 3-4 and Fig. 3-4).

Thus, the value of the GI in girls and their peers in the mid-mountain region exceeds the level of the plain by 14.0 ml/kg ($P < 0.001$) and 13.3 ($P < 0.001$).

The value of the GI in girls and boys of the 3rd group indicates a high level, and the 1st group indicates an average level.

The increase in the strength index level in girls at an altitude of 1600 m was 12.5 ($P < 0.001$), and in boys – 13.2 kg ($P < 0.001$) compared to the initial value.

The average value of the strength index of girls and boys of the 1st group is above average, the 2nd group is high and above average, respectively, and the 3rd group is high.

Table 4 The influence of mountain conditions on the physical health of young men

Relief localities/ points	Indicators					Overall health level assessment (total score)
	MI, kg/ m2	GI, ml/kg	SI, kg	IR, conventional units	HR recovery time, sec	
Plain	25.6±1.32	55.4±0.59	72.6±1.49	88.0±4.09	145 ± 3.3	
Points	-1	0	2	0	1	2
Lowlands	25.9±1.38	61.8±1.61 ***	78.5±1.70 *	84.1±3.08	132 ± 3.4 *	
Points	-1	2	2	3	1	7
Middle Mountains	26.3±1.53	68.7±2.56 ****	85.8±2.61 ***	80.4±3.93	111 ± 3.5 ****	
Points	-1	3	3	3	3	11

* – $P < 0.05$; *** – $P < 0.01$; **** – $P < 0.001$

In girls and boys in the mid-mountain region, the heart rate recovery time is 34 sec ($P < 0.001$) shorter compared to the plain level.

The average time of heart rate recovery in the experimental groups corresponds to the average level, and in the control groups – to the lower average level.

The MI level in girls and boys in the mid-mountain region is higher by 0.5 and 0.7 kg/m2 , and the IR is lower by 8.6 and 7.6 conventional units relative to the plain values.

The IR value of the 1st and 2nd groups is at an average level, and the 3rd is above average.

Important indicators for assessing a person's health, mental and physical condition are the process of his growth and development [13, 14].

Low physical activity, physical fitness and poor health are the characteristics of a modern student [8, 41, 19]

A study of the impact of academic workload on the health of UK students has established a direct relationship [21].

IV. Discussion

I. Subsection One

The findings of the study reveal significant improvements in physical fitness and functional health indicators among school-aged girls and boys following training interventions conducted under mid-mountain conditions. The physical fitness level, assessed using the Physical Fitness Index (GI), demonstrated a substantial increase in both experimental groups compared to baseline measurements. Specifically, girls in the third group showed a 28.3% improvement in GI ($P < 0.001$), while boys exhibited a 24.0% increase ($P < 0.001$), indicating a statistically significant positive effect of the training program on overall physical performance. These results suggest enhanced coordination, endurance, strength, and motor skills as a result of systematic physical activity in a favorable natural environment.

Further analysis showed that training at an altitude of 1600 meters above sea level had a particularly beneficial impact on muscular strength development. The strength index increased by

21.8% in girls ($P < 0.001$) and by 18.2% in boys ($P < 0.01$) compared to the control groups trained at lower elevations. This difference highlights the advantageous physiological adaptations associated with moderate hypoxia, which may stimulate neuromuscular efficiency and muscle fiber recruitment, ultimately contributing to greater gains in strength.

In addition to performance-related improvements, significant enhancements were observed in cardiovascular functional capacity. The heart rate recovery time—a key indicator of autonomic nervous system regulation and cardiorespiratory fitness—was notably shorter in mid-mountain conditions compared to plain terrain. For girls, recovery time decreased by 22.5% ($P < 0.001$), and for boys, by 23.4% ($P < 0.001$). This accelerated recovery reflects improved cardiac efficiency and faster post-exercise homeostasis restoration, which are essential components of physical resilience and overall health.

Comparative analysis of motor performance and physical development indices revealed minor but notable intergroup differences. The Motor Index (MI) varied between girls' groups by 2.9%, while the Physical Fitness Index (IR) differed by 9.3%. Among boys, the corresponding differences were 2.7% for MI and 8.6% for IR. These variations indicate a more pronounced improvement in functional and adaptive capabilities in the groups exposed to mid-mountain conditions, likely due to synergistic effects of physical training and environmental factors such as cleaner air, reduced pollution, and optimal oxygen saturation levels.

Assessment of overall physical health status revealed a clear contrast between the two altitudinal zones. At 1600 m above sea level, both girls and boys demonstrated an average level of physical health, reflecting balanced somatic development, satisfactory functional reserves, and adequate adaptation to physical loads. In contrast, the control groups residing at 170 m above sea level exhibited lower health indicators—classified as below average for girls and low for boys—suggesting suboptimal physical development, reduced functional capacity, and potentially poorer environmental and lifestyle conditions at lower elevations.

Collectively, these findings underscore the positive influence of mid-mountain environments on youth physical development and fitness. The combination of structured physical education programs and favorable ecological conditions appears to promote more effective physiological adaptation, enhance physical performance, and improve health outcomes. This supports the integration of altitude-based physical activity programs into school curricula as a strategy for improving youth health and advancing long-term public health goals.

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