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Influence of mountain hypoxia on functional reserves of students

V. A. Anzorov*, and *S. V.* Moryakina

Kadyrov Chechen State University, Grozny, Russia

Abstract. The article provides the level of functional reserves of students living in mountainous areas. The conducted studies indicate that oxygen deficiency in the inhaled air does not lead to a significant change in the indicators of the functional reserves of students. The value of the endurance coefficient and the index of cardiovascular regulation did not change under hypoxia conditions. At an altitude of 1600 m above sea level, the value of the Robinson index decreased in the group of girls to 78.2 arb. units, boys – 76.0 conventional units. units, and on the plain it was 86.2 and 83.2, respectively. The level of adaptation potential, gradually decreasing, reached a minimum value in mid-mountain conditions - 2.01 for both girls and boys, and on the plain it was 2.12 and 2.11, respectively. The Skibinskaya index at an altitude of 1600 m among female students increased to 23.2, and among male students - 39.3, and at an altitude of 170 m it was 18.2 and 30.9, respectively.

1 Introduction

In the process of life, a person sometimes has to overcome conditions on which his health and existence depend.

The main condition for the existence of organisms is their ability to adapt to living conditions. Nature has endowed organisms with this ability.

The body finds itself in a state of hypoxia if it is not sufficiently supplied with oxygen. A person finds himself in this state even in the mountains.

Both domestic and foreign researchers consider hypoxia to be one of the important problems of biology and medicine.

Of all types of adaptation of the body, the most important is its adaptation to hypoxia. Hypoxia or a typical pathological process refers to a deficiency of oxygen caused by a decrease in its supply to the body or a violation of its use.

Human life in modern society is accompanied by constant exposure to unfavorable environmental factors, which in turn leads to increased stress on the body's systems.

Considering that the carrier of health and performance of the body is the achievement of efficiency in the functioning of its organs and systems, one of the important problems of our time is improving their functional activity.

*Corresponding author: vaha-anzorov@mail.ru

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In response to the impact of mountain climate, the creation of optimal conditions for the functional activity of organs and systems of the body and an increase in its performance is carried out through adaptive changes.

Under conditions of hypoxia, the activity of the protective system is strengthened, the metabolic process is normalized, blood circulation is stimulated and the body's condition is improved.

Even in ancient times, our ancestors used hypoxia to stimulate the body's reserves. Adaptation to high mountain conditions, according to N. Agadzhanyan and A. Katkov, is the best means of prolonging life.

For the first time, scientific justification for the use of high-altitude devices to stimulate the body's reserves and treat diseases was given at the end of the twentieth century by N.N. Sirotinin. When preparing athletes to increase the body's resistance and improve the functional activity of the systems supplying it with oxygen, artificial hypoxia is widely used [23].

According to numerous scientists, hypoxia therapy significantly improves the body's condition, eliminates metabolic disorders and stimulates the activity of the cardiovascular and immune systems [7, 12].

This probably explains the high attention of physiologists and doctors to the problem of mountain hypoxia.

The level of reserves of the body's systems determines its functional state. The coordinated activity of organs and systems of the body helps to increase their reserve capabilities.

Determining the functional reserves of the body is the basis for assessing the state of its health. The functional reserves of the body consist of a combination of the following factors: the state of the systems; performance; features of existence. The functional reserves of the body under certain conditions of its existence create the necessary conditions for achieving optimal functioning of its organs and systems. Despite the fact that the study of human adaptation to hypoxia began a long time ago, the changes in the body that occur during this process are still not well understood [16].

2 Research Methodology

Laboratory equipment of the department was used to collect experimental material. The subjects of the research were 60 (30 girls and boys each) students aged 19 to 21 years. Three groups were formed from them: 1st – control (height 170 m, plain); 2nd – experimental I (600 m, low mountains); 3rd – experimental II (1600 m, mid-mountain). The group consisted of 10 girls and 10 boys.

The physiological reserves of students were determined using regulatory indicators of the body: endurance coefficient (EF); index of cardiovascular regulation (CVRI); Robinson index (RI). The adaptive capabilities of the cardiovascular and respiratory systems were assessed using the adaptive potential (AP) and the Skibinsky index (IS). Biometric control of research results was carried out using the Biostatistics program.

3 Results and Discussions

The effect of mountain hypoxia on the heart rate (HR) and blood pressure of students is shown in Tables 1-2. From the presented data we can conclude that exposure to mountain hypoxia leads to a slight decrease in the indicators of the cardiovascular system of students. Thus, the drop in heart rate at an altitude of 600 m in girls and their peers was 1.6 mm Hg each. Art., and 1600 m – 4.0 and 3.4 mm Hg. Art., relative to the original values.

Table 1. State of the cardiovascular system of girls.

Groups Control	Indicators		
	Blood pressure, mmHg Art..	ADD, mm Hg. Art.	Heart rate, beats per minute
Experience I	115,2±4,53	75,0±3,16	74,4±2,94
Experience II	112,8±4,94	73,4±3,20	72,8±2,99
Groups	109,6±4,62	71,2±3,44	70,8±3,26

The level of systolic blood pressure (SBP) in female students and their peers in low-altitude conditions is lower by 2.4 and 2.2 mmHg. Art., and middle mountains – 5.6 and 5.0 mm Hg. Art., compared with the level of control students.

Table 2. Cardiovascular system of young men.

Indicators	Groups		
	Control	Experience I	Experience II
Blood pressure, mmHg Art..	113,4±4,39	111,2±4.52	108,4±4,57
ADD, mm Hg. Art.	73,2±2,75	71,6±2,98	69,8±3,12
Heart rate, beats per minute	73,0±2,65	71,4±2,87	69,6±2,86

Diastolic pressure (DBP) in female students and their peers at an altitude of 600 m is lower by 1.6 and 1.6 mmHg. Art., and 1600 m – 3.8 and 3.4 mm Hg. Art., compared with the values of the plain indicators.

Adaptation to reduced oxygen levels in the environment begins with an increase in heart rate and minute blood volume [24].

Long-term exposure to oxygen deficiency in the inhaled air leads to a decrease in these indicators below the initial values [11]. The reasons for the increase in minute blood volume are an increase in heart rate and the amount of blood ejected by the heart in one contraction.

Obviously, the decrease in heart rate and blood pressure is caused by increased excitability of the parasympathetic branch of the autonomic nervous system.

Other scientists came to similar statements in their studies [2, 22].

The onset of exposure to a mountain climate is accompanied by an increase in the weight and size of the adrenal glands, but prolonged exposure reduces their function, according to [21].

Anthropometric indicators of students exposed to high-altitude hypoxia are given in Tables 3-4.

Table 3. State of indicators of physical development of female students in conditions of mountain hypoxia.

Terrain	Height in cm	Age in years	Body weight in kg
Plain	163±5,19	18,9±0,40	62±2,0
Lowlands	157±4,88	19,3±0,41	59±2,3
Srednegorye	151±4,63	19,2±0,46	54±2,3*

* – $P < 0,05$

Analysis of the presented data shows that under conditions of hypoxia there is a decrease in the length and body weight of students, and the drop in body weight in girls is significant.

Table 4. Height, weight and age of young men under conditions of oxygen deficiency in atmospheric air.

Terrain	Height in cm	Age in years	Body weight in kg
Plain	172±7,1	20, 4±0,50	74±4,8
Lowlands	166±7,3	19,6±0,46	70±4,6
Srednegorye	159±7,1	20,0±0,51	65±4,8

The body weight of female students and their peers at an altitude of 600 meters above sea level is lower by 3 and 4 kg, and at 1600 – 8 (P < 0.05) and 9, relative to the initial level.

The body length of girls living in low and mid-mountain conditions decreased by 7 and 12 cm, for boys - 6 and 13, compared to the values of the plain.

The age difference between the average values of the groups of female students was 0.4 years, for males – 0.8.

Our data was confirmed by other researchers. Thus, among the population living in mountainous areas, height is 10-17 cm lower, and body weight is 8-10 kg less [17]. The respiratory system of students is shown in Tables 5-6.

Table 5. The influence of mountain hypoxia on the state of the respiratory system of female students.

Indicators	Altitude above sea level in meters		
	170	600	1600
Stange test	43±1,3	45±1,7	47±1,9
Genchi sample	30±1,0	31±1,4	33±1,6
VC	3,10±0,104	3,22±0,114	3,41±0,112

Analysis of the presented results shows that when breathing air with a reduced oxygen content, there is a slight increase in the studied indicators in students.

Thus, the increase in vital capacity, Stange and Genchi tests in girls in low-mountain conditions was 0.12 l, 2 and 1 s, and in boys – 0.31 l, 2 and 2 s, compared with the values of the plain.

The value of vital vital capacity, Stange and Genchi tests in female students at an altitude of 1600 m is higher by 0.31 l, 4 and 3 s, in peers - 0.44 l, 5 and 4 s, relative to the initial values.

The results of our research are confirmed by other authors. Thus, people living in mountainous conditions have a frequent rhythm of respiratory movements, have increased ventilation of the lungs, high tidal volume and greater lung capacity [19].

Barbashova Z.I. [5] believes that when exposed to high-altitude hypoxia, an increase in lung ventilation in humans occurs.

Aidaralieva A.A. [3], based on the results of her studies, came to the conclusion that the reason for the increase in ventilation of the lungs in conditions of oxygen deficiency is an increase in tidal volume.

Table 6. Indicators of the respiratory system of young men.

Indicators	Topography		
	Plain Low	Mountains	Middle Mountains
Stange test	54±1,8	56±1,7	59±2,0
Genchi sample	38±1,4	40±1,5	42±1,4
VC	4,15±0,154	4,46±0,161	4,59±0,163

She also claims that hypoxia does not lead to a significant change in the frequency of respiratory movements.

Mountain dwellers are characterized by the following features: large chest; high vital capacity; high level of oxygen in the blood; high affinity of hemoglobin for oxygen [12, 20].

The body's initial response to oxygen deficiency in the environment is an increase in the volume of ventilation of the alveoli, which is caused by faster and deeper breathing, as well as an increase in the number of alveoli supplying blood; with continued exposure, a drop in volume occurs [10]. Under conditions of hypoxia, the excitability of the autonomic nervous system undergoes changes.

Thus, the excitability of the sympathetic branch predominates in the initial period of exposure to hypoxia, and the parasympathetic branch predominates during prolonged exposure [1, 22].

Insufficient oxygen levels in the inhaled air lead to a decrease in the production of hormones by the adrenal glands [25].

Exposure to both acute and chronic hypoxia leads to an increase in pulmonary ventilation [18].

Probably, due to an increase in the tone of the inspiratory muscles due to a lack of oxygen, the value of vital capacity in students increases.

Residents of mountainous areas have a 10% higher vital capacity due to increased tone of the inspiratory muscles [1].

Apparently, increased activity of the respiratory system caused by oxygen deficiency is the reason for the increased activity of this system under hypoxic conditions.

According to E.V. Mateeva and N.I. Panteleeva [14], adaptation to low oxygen content in the atmosphere stimulates the function of the respiratory system, since it supplies oxygen.

Also M.O. Berova [6] reports that under hypoxic conditions the function of the respiratory and immune systems is stimulated. Exposure to mountain hypoxia increases the excitability of chemoreceptors, which leads to a deepening and acceleration of the breathing process [8].

The dynamics of indicators of functional reserves of students under hypoxia conditions are shown in tables 7-8 and figures 1-2.

Table 7. Indicators of the respiratory system of young men.

Indicators	Altitude above sea level in meters		
	170	600	1600
endurance coefficient (EF), conventional units	18,5±0,16	18,5±0,29	18,4±0,40
index of cardiovascular regulation (CVRI), %	100,8±0,32	100,8±0,32	100,5±0,52
Robinson index IR, conventional units	86,2±6,78	82,7±6,98	78,2±6,83
adaptation potential (AP)	2,12±0,123	2,10±0,135	2,01±0,135
Skibinsky index (IS)	18,2±1,82	20,4±2,26	23,2±2,65

The difference between the average indicators of different groups of the level of endurance coefficient among female students and their peers was 0.1 and 0.2 conventional units.

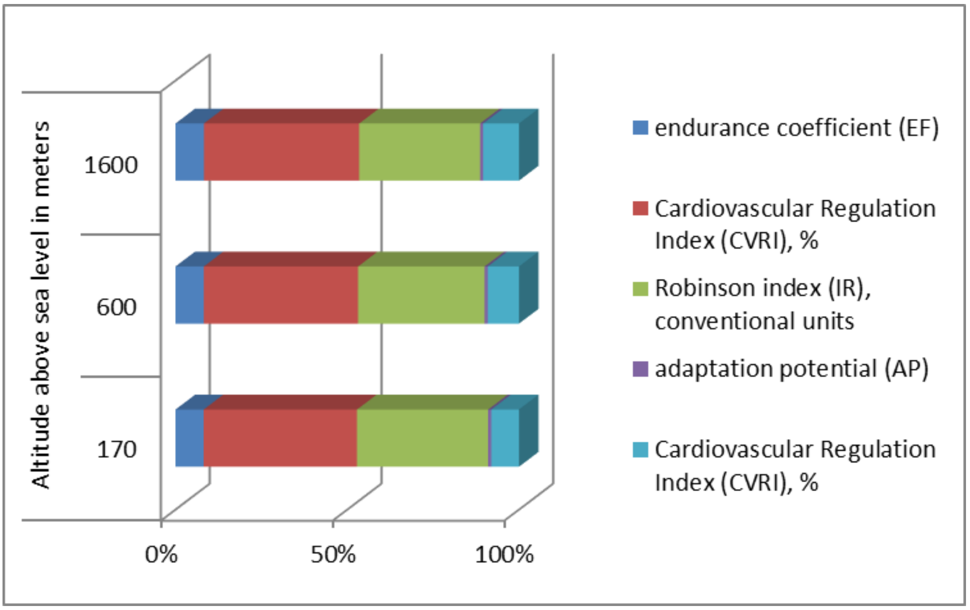

Fig.1. Functional reserves of girls under conditions of hypoxia.

The level of the endurance coefficient for all experimental groups of students goes beyond the upper limit of the norm, which indicates insufficient functional activity of the cardiovascular system.

Table 8. The influence of hypoxia on the indicators of functional reserves of young men.

Indicators	Topography		
	Plain Low	Mountains Middle	Mountains
endurance coefficient (EF), conventional units	18,2±0,15	18,0±0,21	18,0±0,28
index of cardiovascular regulation (CVRI), %	100,3±0,51	100,3±0,52	100,2±0,93
Robinson index IR, conventional units	83,2±6,24	79,9±6,45	76,0±6,30
adaptation potential (AP)	2,11±0,128	2,05±0,130	2,01±0,134
Skibinsky index (IS)	30,9±2,27	35,3±2,60	39,3±3,00

Apparently, this is a consequence of insufficient training of the body. A small number of students perform physical activity, and even fewer participate in sports sections [4]. When exposed to mountain hypoxia, the index of cardiovascular regulation did not change.

The average value of the cardiovascular regulation index for the groups of examined students is above 90%, but below 110%, which is an indicator of the cardiovascular type of regulation.

Under conditions of hypoxia, the level of the Robinson index and adaptive potential in students decreases slightly, and the Skibinskaya index increases insignificantly.

Thus, the drop in the Robinson index in low-altitude conditions among female students and their peers was 3.5 and 3.3 conventional units. units, and in the middle mountains - 8.0 and 7.2 arb. units, relative to the initial level.

The average level of the Robinson index of students indicates an above-average state of regulation of the cardiovascular system.

The value of adaptation potential at an altitude of 600 m above sea level is lower for girls by 0.02, for boys - 0.06, and 1600 - 0.11 and 0.10, respectively, compared to the level of 170 m. Our data is confirmed by other authors .

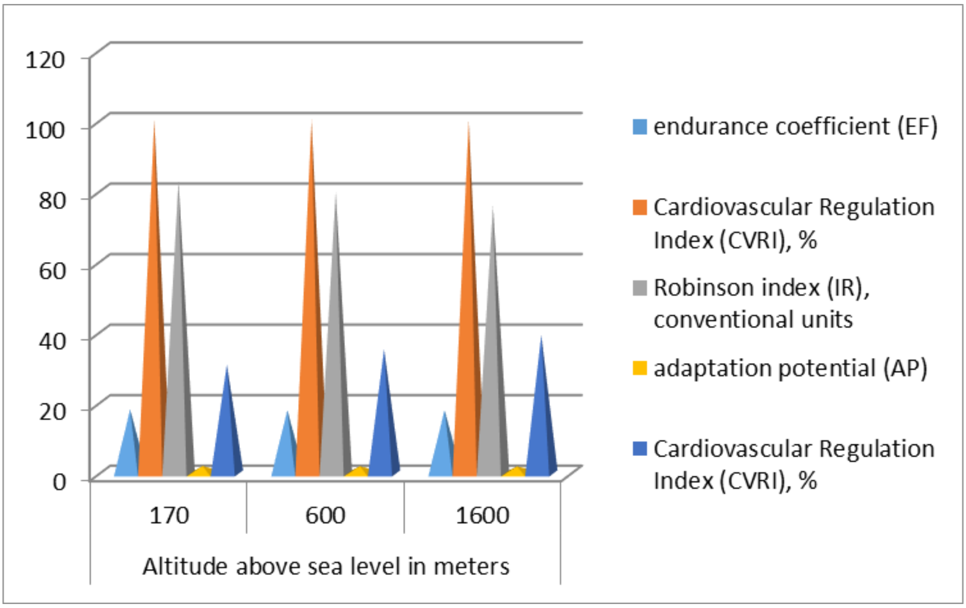

Fig.2. Level of functional reserves of young men with reduced oxygen content in the atmospheric air.

So, according to N.A. Meshkov [15], the body's response to the influence of unfavorable environmental factors is a decrease in reserve capabilities and adaptive potential.

The average value of adaptation potential ranges from 2.01 to 2.12, which indicates satisfactory adaptation.

The increase in the level of the Skibinskaya index among female students in low-mountain conditions was 2.2; for male students – 4.4, and in mid-mountain conditions – 5.0 and 8.4, respectively, relative to the values of those living on the plain. The Skibinskaya index level for female students ranges from 10 to 29, and for male students from 30 to 60, which indicates satisfactory functional capabilities of the respiratory and circulatory organs in girls and good in males.

Thus, according to scientists, the widespread use of hypoxia therapy is aimed at enhancing the functional activity of the cardiovascular, respiratory and immune systems of the body [9, 13].

From the results of the studies, it can be stated that when exposed to mountain hypoxia, there is a slight decrease in the value of the Robinson index and adaptive potential, an insignificant increase in the Skibinskaya index, and the level of the endurance coefficient and the cardiovascular regulation index does not change.

4 Conclusions

1. The level of endurance coefficient at an altitude of 1600 m above sea level among female students and their peers is lower by 0.5 and 1.1%, relative to the initial value.

2. The decrease in the value of the cardiovascular regulation index in mid-mountain conditions was 0.3 for girls and 0.1% for boys, compared with the value in the control group.

3. The value of the Robinson index at an altitude of 600 m among female students and their peers decreased by 4.1 and 4.0%, and at 1600 - 9.3 and 8.7, respectively, relative to the level of the control group.

4. The value of adaptation potential in low and middle mountain conditions is lower for girls by 0.9 and 5.2%, for boys – 2.8 and 4.7, compared to the value of those living on the plain.

5. The increase in the level of the Skibinskaya index at an altitude of 600 m above sea level among female students and their peers was 12.1 and 14.2%, and 1600 - 27.5 and 27.2, respectively, relative to the value of the inhabitants of the plain.

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