ORIGINAL RESEARCH

Submitted: 23.01.2022; Accepted: 9.02.2022; Published online: 23.02.2022

Functional state of the students' cardiovascular system under the conditions of mountain hypoxia

Vakha A. Anzorov*, Svetlana V. Moryakina

Chechen State University named after A.A. Kadyrov, 364024, Russia, Grozny, Sheripova str., 32

*Corresponding author:
vaha-anzorov@mail.ru

Abstract

The article presents the functional state of the cardiovascular system of students under conditions of high-altitude hypoxia. From the analysis of the results of our research, it can be argued that due to the fact that students live under conditions of a reduced oxygen content in the atmospheric air, there is a significant increase in the systolic output of their hearts. Thus, the systolic blood volume of students under the conditions of mountain hypoxia increases, reaching the maximum values of 63.4 ml (P <0.05) in males and 64.4 in females in the middle-level mountains. The range of pulse pressure between the groups of males is 1.5%, and females 1.7. The level of average dynamic blood pressure in males in the middle mountains is 3.5% lower, and in females of the same age is 3.9% lower, respectively, compared to the plains. The drop in the minute blood volume at an altitude of 1600 m among female students was 2.1%, and among peers - 2.2, compared to the 170 m level. The decrease in total peripheral vascular resistance (TPVR) at the maximum altitude was 1.5% in females, and 2.7% in males, compared to the plain-related data. The value of blood circulation efficiency coefficient (CEC) and endurance factor (EF) in the middle-level mountains among female students decreased by 6.2 and 2.7%, among peers - by 4.2 and 5.4%, compared to the plain. Thus, the depth of the changes caused is directly proportional to the level of the acting hypoxia.

Keywords

Student, Hypoxia, Systolic blood volume, Coefficient of blood circulation efficiency, Coefficient of endurance

Imprint

Vakha A. Anzorov, Svetlana V. Moryakina. Functional state of the students' cardiovascular system in the conditions of mountain hypoxia. Cardiometry; Issue 21; February 2022; p. 124-129; DOI: 10.18137/cardiometry.2022.21.124129; Available from: http://www.cardiometry.net/issues/no21-february-2022/functional-state-the-students-cardiovascular

Up to 40% of the Earth's land is formed by mountains, and up to 600 million people live there. Since ancient times, people has been drawn to the mountains and this is due to their attractiveness, recalcitrance, searching for new sources of energy, development of subsoil rich in natural resources, development of mountain sports, erection of sports and recreation facilities.

A distinctive feature of mountain regions is the diversity of their natural and climatic conditions. One of the main factors affecting the systems of the human body in the mountains is the insufficient content of oxygen in the atmospheric air. Human activity under the influence of adverse environmental factors requires increasing stress of the body systems.

Therefore, in physiology, great attention is paid to the problem of adaptation to high-altitude hypoxia. After the organism enters the mountainous area, adaptive changes to the new environmental conditions occur in it.

Under the mountain conditions, a low partial pressure of oxygen can lead to disruption of the functional activity of vital body systems. This, in turn, is due to insufficient energy supply to the cells of the body due to a violation of metabolic processes in them. To overcome the negative effects of the environment, a complex of adaptive reactions is launched by the body, which leads to the normalization of the process of external respiration, improves the diffusion capacity of the lung tissue and reduces the heart rate [17]. An important problem of our time is to increase the efficiency of the functional activity of the body systems, as this determines the state of health and the performance of the body as a whole. The consequence of the adaptive reactions of the body to the effects of hypoxia is the stimulation of the body's systems and its enhanced performance that is widely used in medicine and sports physiology.

Hypoxia therapy improves the general condition of the body, normalizes all types of metabolism, enhances blood circulation, metabolism and increases the body's resistance to adverse factors [5, 8]. Mountain hypoxia was widely used in ancient times to increase the functional reserves of the body [3].

The higher is the level of the body's performance, the better are the functional abilities of the body's systems that provide it with oxygen, which include the systems of respiration and blood circulation [6]. According to many researchers, the most effective method of exposure to hypoxia is to stay in the mountains [7, 11, 13, 14]. Moreover, at the initial stage of the influence of the mountain climate, the body's working capacity decreases [9]. This is accompanied by an unusual increase in the function of the respiratory and circulatory systems.

According to some authors, the effect of intermittent hypoxia is highly effective for improving the performance [1, 2, 4. 12].

A feature of the population living in mountainous areas is the presence of good health and high efficiency in their activities, which persist until their old age [16]. Despite the numerous studies conducted to study the effect of hypoxia made on the body, they are mainly devoted to the level of the human performance, but not the state of functional systems.

Due to the fact that a significant part of the population lives in the mountainous regions of the Chechen Republic, it is important to study the effect of high-altitude hypoxia on the functional state of the cardiovascular system.

Materials and methods

The experimental material was collected in the laboratories of the Department of Physiology and Anatomy of Humans and Animals. 150 (75 females and males) students were involved into our research.

The age of the test subjects ranged from 19 to 21 years. According to the principle of analogues (by age, weight and gender), depending on the height of their residence above sea level (170 m - Grozny, 600 m - Shatoysky district and 1600 m - Sharoysky district) were divided into three groups. Each group consisted of 25 students.

To analyze the functional state of the cardiovascular system, we used the rhythm of heart contraction, blood pressure and some calculated indicators. Biometric checking of the results of the experiment was carried out using the program "Biostatistics".

Results and Discussion

The state of the cardiovascular system of students under hypoxia conditions is shown in Tables 1, 2 and in Figure 1 herein.

Table 1

Cardiovascular system of young males

Altitude above sea level, meters	Systolic blood pressure, mm Hg	Diastolic blood pressure, mm Hg	Heart rate, beats per minute
170	120.4±3.50	80.6±2.03	73.2±2.29
600	119.6 ±3.38	79.6±2.06	71.8±2.08
1600	117.2±3.29	77.1±2.18	69.6±2.50

Table 2

Indicators of the cardiovascular system of female students

Altitude above sea level, meters	Systolic blood pressure, mm Hg	Diastolic blood pressure, mm Hg	Heart rate, beats per minute
170	119.7±3.32	78.6±2.32	75.8±3.15
600	117.9±3.29	77.0±2.77	74.4±2.94
1600	115.5±3.14	75.1±2.85	72.2±3.07

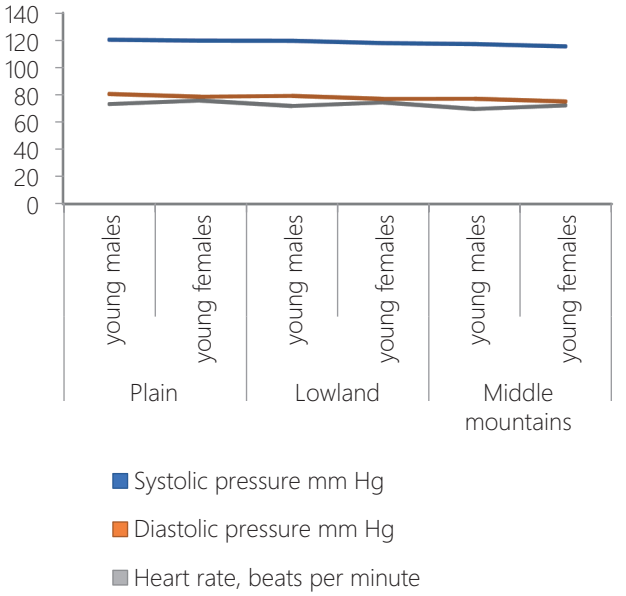

Figure 1. The effect of hypoxia on the parameters of the cardiovascular system

The level of the studied indicators under conditions of insufficient oxygen content in the inhaled air shows a gradual slight decrease.

Thus, the drop in the maximum blood pressure in young males at an altitude of 600 meters above sea level is 0.8 mm Hg, 1600 - 3.2 mm Hg, and for females 1.8 and 4.2, respectively, compared to the plain-related data - 120.4 and 119.7.

Under conditions of lowlands and middle mountains, diastolic blood pressure in females is lower by 1.6 and 3.5 mm Hg, in peers - 1.4 and 3.5 mm Hg, than on the plains.

At an altitude of 600 and 1600 meters, the heart rate in young males is less than 1.4 and 3.6 beats per minute, and in peers - 1.4 and 3.6, respectively, than at the level of 170 meters.

Apparently, the drop in heart rate is due to an increase in the excitability of the vagus nerve.

Our colleagues came to similar conclusions [6, 19]. The lack of oxygen in the inhaled air contributes to an increase in the weight and size of the adrenal glands, although deepening of hypoxia leads to the suppression of their functional activity, according to [18].

The results of the conducted studies are shown in Tables 3-5 and in Figures 2-3 herein. They show that the only of the studied indicators, which undergoes a significant change when exposed to high-altitude hypoxia in students, is the systolic blood volume.

Table 3

The functional state of the cardiovascular system of young males

Altitude above sea level, meters	Indicators		
	Pulse pressure (PP), mm Hg	Average dynamic blood pressure (BP av.dyn.), mm Hg	Systolic blood volume (SBV), ml
170	39.8±1.47	97.3±2.65	60.9±0.43
600	40.4±1.41	96.2±2.60	61.8±0.43
1600	40.1±1.15	93.9±2.65	63.4±0.55*

* - P < 0,05

Table 4

The level of indicators in young males

Terrain	Indicators			
	Minute blood volume (MBV), l/min	Total peripheral vascular resistance (TPVR), dyn·s·cm-5	Circulation Efficiency Coefficient (CEC)	Endurance Factor (EF)
Plain	4.5±0.11	1678±34.7	2925±189.6	18.4±0.30
Lowlands	4.4±0.10	1626±62.2	2912±176.8	17.8±0.27
Middle mountains	4.4±0.12	1632±23.9	2801±170.1	17.4±0.37

The level of pulse pressure in young males of different groups ranged from 39.8 mm Hg on the plain up to 40.4 in the lowlands, and in females from 40.4 mm Hg at an altitude of 1600 meters to 41.1 on the plain. The given values of PP correspond to the norm. The value of the average dynamic pressure of students with increasing altitude demonstrated a gradual decrease.

So, in the middle mountains, its level is lower by 3.4 mm Hg in males and 3.7 in females compared to the plain-related data.

The average level of blood pressure in students in the plains and in young males in the middle mountains is above the upper limit of the norm.

The amount of blood ejected into the arterial system by the ventricles of the heart per contraction in

Table 5

The effect of hypoxia on the function of the cardiovascular system in young females

Terrain	Indicators						
	PP, mm Hg	BP av.dyn, mm Hg	SBV, ml	MBV, l/min	TPVR, dy-n·s·cm-5	CEC	EF
Plain	41,1±2,69	95,8±2,70	62,8±2,27	4,8±0,35	1577±160,0	3130±284,1	18,7±1,36
Lowlands	40,9±2,48	93,9±2,88	63,4±2,12	4,8±0,34	1562±164,5	3054±257,4	18,4±1,26
Middle mountains	40,4±2,95	92,1±2,60	64,4±2,57	4,7±0,35	1553±159,5	2936±305,3	18,2±1,26

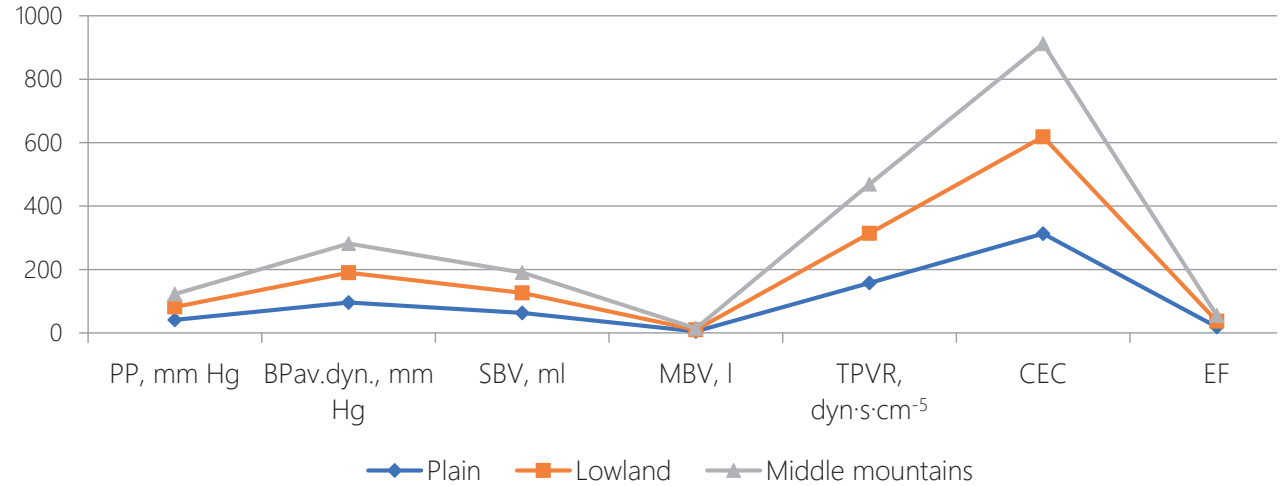

Figure 2. Dynamics of indicators of the cardiovascular system functional state in young males

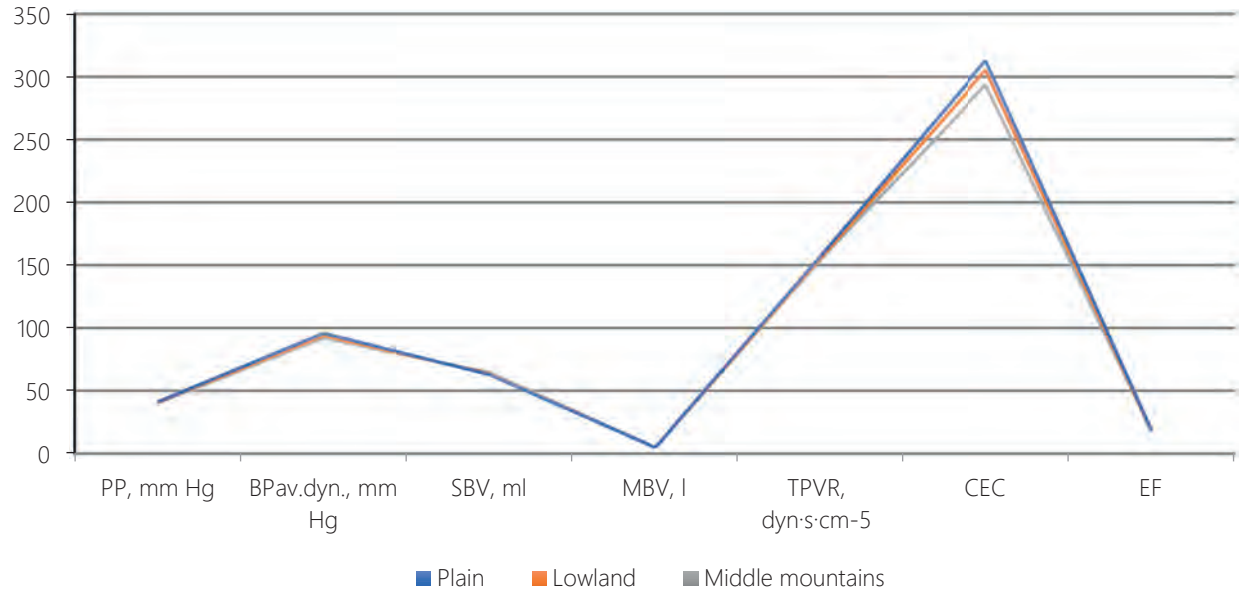

Figure 3. Cardiovascular system of female students in conditions of hypoxia

young males living at an altitude of 1600 meters is 2.5 ml higher (P <0.05), and in female students 1.6 ml higher than those recorded on the plain. The SBV value is within the normal range. The minute blood volume in students under the influence of hypoxia slightly decreases. Thus, the decrease in the level of MBV in young men and their peers in the middle mountains is 0.1 l/min, compared to the plain. For all groups of students, the value of the TPVR is below the norm.

The value of the total peripheral vascular resistance decreases with the deepening of hypoxia. Its level at a height of 600 meters is higher for female students and their peers by 15 and 52 dyn·s·cm^{-5}, and 1600 - 24 and 46, respectively, than it is the case with the level of 170 meters. The average values of TPVR by groups remain within the norm.

The decrease in CEC in males and females in the lowlands is 13 and 76, in the middle mountains 124 and 194, respectively, as compared to the plains. The impact of mountain hypoxia leads to a slight decrease in the endurance factor of students. Its fall at an altitude of 1600 meters is 0.5 for female students and 0.2 for their peers versus the data recorded on the plain.

The average levels of CEC and EF are above the upper limit of the norm, which indicates the presence of fatigue and insufficient fitness of the cardiovascular system. The beginning of adaptation to the lack of oxygen in the inhaled air is accompanied by an increase in the heart rate and minute volume of blood [20].

The minute volume of blood increases due to a rise in the heart rate and systolic blood ejection. With prolonged exposure to a reduced oxygen content in the atmospheric air, their level decreases, even below the initial values [10]. Moreover, the constant increase in the study load increases the mental load of students, which reduces their physical activity. This, in turn, inhibits the functional activity of body systems, including the cardiovascular system.

The low level of physical fitness and poor health of students are reported [15]. In this connection, in order to improve their health, it is necessary to increase the role of physical exercises.

Under the influence of oxygen deficiency in the atmospheric air, only the systolic blood volume shows significant changes among the indicators of the functional state of the cardiovascular system.

Conclusions

1. The systolic blood volume is the only indicator of the students' cardiovascular system functional state that demonstrates significant changes under the influence of high-altitude hypoxia.

2. The difference between the maximum and minimum values of pulse pressure between the groups of males and females has been reported to be 0.6 and 0.7 mm Hg, respectively.

3. The value of the average dynamic pressure in young males at an altitude of 1600 meters is lower by 3.4 mm Hg, and in female students 3.7, as compared to the data recorded at the level of 170 meters.

4. The average level of systolic blood volume of females under the conditions of middle mountains

has increased by 1.6 ml, and peers by 2.5 (P <0.05), as compared to the data reported for the plain.

5. The range of the MBV and EF indicators between groups of young males has demonstrated changes from 4.4 and 17.4 liters to 4.5 and 18.4, and peers from 4.7 and 18.2 to 4.8 and 18.7, respectively.

6. The value of TPVR at an altitude of 600 meters is lower by 52 dyn·s·cm^{-5} for males, and in the middle mountains by 24 for females.

7. The drop in CEC for the group of female students living in the middle mountains has been recorded to be 194 and 124 for peers, respectively, as compared to the data obtained under the plain conditions

Statement on ethical issues

Research involving people and/or animals is in full compliance with current national and international ethical standards.

Conflict of interest

None declared.

Author contributions

The authors read the ICMJE criteria for authorship and approved the final manuscript.

References

1. Anzorov VA, Moryakina SV. The state of the cardiovascular system of students under the influence of mountain hypoxia. Modern Science: Actual Problems of Theory and Practice. Series: Natural and technical sciences. Publisher: Scientific Technologies LLC. Moscow, 2020; 10:140-143. [in Russian]
2. Arbuzova OV. Age-related changes in the cardiorespiratory system and physical performance of swimmers during normobaric hypoxic training: Dissertation. Ulyanovsk, 2009. 156 p. [in Russian]
3. Baev OA. Adaptive potential of the cardiovascular system of students. Scientific Bulletin of the State Educational Institution of the LPR "Lugansk National Agrarian University". 2018; 3: 108-116. [in Russian]
4. Boyarkina AA, Kuvshinov IV. Evaluation of the functional state of the cardiovascular system of students. V International Baltic Forum: proceedings. Kaliningrad, 2017. 865-869. [in Russian]
5. Buykova OM, Bulnaeva GI. Functional tests in medical and mass physical culture: textbook. FGBOU VO IGMU of the Ministry of Health of Russia. Course of physical therapy and sports medicine. Department of Physical Education. Irkutsk: IGMU, 2017. 24 p. [in Russian]
6. Graevskaya ND, Dolmatova TI. Sports medicine: a course of lectures and practical exercises. M.: Soviet sport, 2004. 304 p. [in Russian]
7. Irgebaev MI. Influence of altitude on adaptation to mountain conditions during sports trips. Theory and methodology of physical culture. Almaty: Kazakh Academy of Sports and Tourism, 2017; 2(48): 17-22. [in Russian]
8. Kolchinskaya AZ. Oxygen. The physical state. Working capacity. Kiev: Naukova Dumka, 1991. 206 p. [in Russian]
9. Kolchinskaya AZ. Hypoxic load hypoxia: damaging and constructive effects. Hypoxia medical. 1993; 3: 8-13. [in Russian]
10. Latyshev VS. Comparative characteristics of the parameters of resistance to hypoxia in boys and girls from different regions. XXII All-Russian Scientific and Practical Conference of Nizhnevartovsk State University. April 06–07, 2020 Publisher: Nizhnevartovsk State University, 2020. 90-93. [in Russian]
11. Naumenko SE. Mountain sickness: a textbook. Novosibirsk State University. Novosibirsk: CPI NSU, 2018. p.18-19. [in Russian]
12. Nudelman LM. Theory and practice of physical culture. 2005; 12: 34-36. [in Russian]
13. Radchenko AS, Borisenko NS, Kalinichenko AN. Changes in the activity of the right heart as a result of normobaric hypoxic preconditioning. Proceedings of the XXIII Congress of the Physiological Society named after I.P. Pavlov. Voronezh: ISTOKI, 2017. 1508-1510. [in Russian]
14. Radchenko AS, Shabanov PD. Influence of hyperoxia and hypoxia on adaptation during muscular work. Reviews of Clinical Pharmacology and Drug Therapy. 2018; 16(3): 68-77. [in Russian]
15. Smirnova AV, Koryagina OA. Adaptive reactions of the cardiovascular system to the training load in students with different types of constitution. International Student Scientific Bulletin. 2020; 1. URL: https://eduherald.ru/ru/article/view?id=19891 . [in Russian]
16. Chesnokova NP, Brill GE, Polutova NV, Bizenkova MN. Lecture 10. Hypoxia: types, etiology, pathogenesis. Scientific Review. Medical Sciences. 2017; 2: 53-55. [in Russian]
17. Shaov MT, Pshikova OV, Kurdanov KhA. Neuroimprinting – technologies for controlling the physiological functions of the body and human health

during hypoxia. Voronezh: Scientific book, 2013. 134 p. [in Russian]
18. Effects of hypoxia and atrial natriuretic peptide on aldosterone secretion in healthy subjects / RGJ Westendorp [et al.]. Journal of Applied Physiology. 1993; 75: 534-539.
19. Hypoxic ventilatory drive in normal man. Journal of Clinical Investigation / JV Weil [et al.]. 1970; 49: 1061-1072.
20. Operation Everest III: Modifications of cardiac function secondary to altitude-induced hypoxia. An echocardiographic and doppler study. American Journal of Respiratory and Critical Care Medicine. 2000; 161: 264-270.