THE INFLUENCE OF CLIMATIC CONDITIONS ON THE ADAPTATION OF THE CARDIOVASCULAR SYSTEM OF STUDENTS TO PHYSICAL ACTIVITY: ASPECTS OF SUSTAINABLE DEVELOPMENT IN EDUCATION

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Abstract

This study explores the influence of climatic conditions on the adaptation of the cardiovascular system of students to physical activity, emphasizing the implications for sustainable development in education. As climate change continues to alter environmental conditions, understanding how these factors affect students' physiological responses to physical exercise becomes crucial. The research highlights the importance of incorporating climate-responsive training programs in educational institutions to enhance students' cardiovascular health and overall well-being. By addressing the interconnection between climatic influences and cardiovascular adaptation, the study aims to provide insights into developing sustainable educational practices that promote physical fitness and health resilience among students in varying climatic contexts. The work studied the functional state and assessed the functional reserves of the cardiovascular system in university students at rest and during adaptation to muscle load. Male and female students of the higher educational institution participated in the study of the functional reserves of the cardiovascular system. Blood pressure, heart rate and a number of indices characterizing the functional state of the cardiovascular system were examined. The study of these hemodynamic parameters was carried out at rest and after a functional motor test. It was found that the type of response to dynamic muscle load in male and female students is normotonic. According to the Ruffier index, male and female students have a satisfactory functional state of the cardiovascular system. The values of the adaptation potential indicate the tension of the adaptation mechanisms and some decrease in the physiological reserves of the cardiovascular system. Minor differences were noted between the sexes in adaptation to muscular load (Ruffier test): females had average performance, while males had good performance.

Keywords: cardiovascular system, blood pressure, heart rate, adaptation, muscle load, hypoxia, hypokinesia, student, climatic conditions, cardiovascular adaptation

I. Introduction

In recent years, the impact of climatic conditions on human health has gained increasing attention, particularly in the context of physical activity and exercise. As students represent a vital segment of society engaged in physical education, understanding how environmental factors influence their cardiovascular adaptation to exercise is essential. The cardiovascular system plays a pivotal role in regulating physical performance, and its efficiency is significantly affected by external conditions such as temperature, humidity, and altitude.

Climatic variations can alter how the body responds to physical exertion. For instance, extreme heat can lead to dehydration and heat-related illnesses, while cold conditions may affect circulation and increase the risk of hypothermia. As climate change progresses, educational institutions must consider these factors to foster a safe and effective environment for student athletes and physically active individuals.

This study aims to examine the intricate relationship between climatic conditions and the cardiovascular responses of students during physical activity. By focusing on these dynamics, we can better understand the importance of developing adaptive strategies that align with the principles of sustainable development in education. Incorporating climate-aware practices in physical education can not only enhance students' health outcomes but also promote awareness of environmental issues, ultimately contributing to a more sustainable future for communities.

The findings of this research will serve as a foundation for educators, policymakers, and health professionals to create more effective physical education programs that prioritize cardiovascular health while adapting to changing climatic conditions. By acknowledging the interplay between climate and health, we can work towards fostering resilience among students in the face of environmental challenges, ensuring their well-being and capacity to thrive in diverse settings. Studying at a higher educational institution causes certain functional and structural changes in the body of young people studying. Long-term physical inactivity in higher educational institutions has a significant impact on the functional state of the cardiovascular system in male and female students. The functional state of the cardiovascular system can act as a key factor in assessing the adaptive reactions of the human body [5]. It is believed that its functional indicators are a universal indicator of the adaptive activity of the human body to environmental factors [11, 12].

The functional state of the cardiovascular system is assessed by studying the parameters of hemodynamics at rest [7]. Assessment of the cardiovascular system at rest does not allow for a full characterization of the functional state. Functional tests are used for this purpose . Functional tests with physical activity lead to activation of neurohumoral mechanisms of regulation of the cardiovascular system, increased oxygen transport, increased respiration rate, and the occurrence of tissue hypoxia in the cardiac and skeletal muscles [4]. In poorly adapted and untrained people, adaptation to muscle activity occurs mainly due to an increase in cardiac output. Cardiac output in such people increases due to an increase in heart rate [4].

When studying the work of the heart and cardiovascular system, a number of parameters and indices are used [2]. In addition to the common parameters - pulse, heart rate, blood pressure, minute blood volume, cardiac output, various indices are often used - the Ruffier index , the Robinson index, indices characterizing the inotropic and chronotropic reserves of the heart muscle [2].

The study of regional features of adaptation of the circulatory system and heart to dosed functional motor tests in young students is of theoretical and practical interest.

The aim of the work: to assess the functional state of the adaptive mechanisms of the cardiovascular system of students in response to hypoxia caused by dynamic motor load.

II. Methods

Students of the educational institution were involved in the study of the parameters of the cardiovascular system. This work involved male and female students of the Biological and Chemical Faculty and the Agrotechnological Institute of Grozny. The age of the students ranged from 21 to 23 years, which corresponds to mature age, the first period. At the time of the examination, male and female students had no complaints about the state of the cardiovascular system. They gave their verbal consent to participate in the study. Second-year female master's students also took part in the study. Only female master's students were examined, since there were no males among the master's students at the university.

We conducted a functional study of the cardiovascular system in response to physical activity using the Ruffier test, which is often used to assess the functional state of the cardiovascular system. The Ruffier test involves performing 30 squats in one minute.

At rest, blood pressure and heart rate were measured. To measure them, we used an automated device for measuring blood pressure and heart rate – MT-40 (USA). This device automatically measures the pulse and two types of pressure – systolic (BPs , upper) and diastolic (BPd , lower) pressure. Pulse pressure (BPp) was calculated as the difference between the maximum and minimum pressure of the subject. After performing the Ruffier motor test, the subjects ' blood pressure and heart rate were immediately measured.

We studied the following parameters: heart rate, blood pressure (systolic, diastolic, pulse, average), pulse at rest and after a minute of Ruffier's robe . We also determined several different indices - the Kerdo index, the Robinson index, the Ruffier index and the adaptation potential index according to R. M. Baevsky.

Heart rate and blood pressure measurements were taken at rest (15 seconds), after the Ruffier test (15 seconds immediately after the test) and for 15 seconds at the end of the first minute of recovery.

The value of the adaptation potential was calculated at rest, after performing the Ruffier test and after a minute of recovery.

For statistical processing of the results of the study of blood pressure, heart rate and various indices, including the value of the adaptation potential, the Paired Student's criterion was used. The results of the study were processed by the computer program " Biostatistics ".

IV. Discussion

Cardiovascular system parameters at rest and after the Ruffier test . Systolic pressure in male and female students increased significantly after the Ruffier test (Table 1, Fig. 1). According to literature, systolic pressure increases after physical exertion [2, 5].

Table 1: *Systolic pressure (mmHg) in subjects examined after the Ruffier test*

Subjects	State of rest	Ruffier's test	Recovery, 1 min
Girls	118.6±2.32	133.2±2.88**	119.6±2.64
Young men	121.3±2.91	142.4±3.24**	122.3±3.42

*- p< 0.05

Unlike systolic pressure, diastolic pressure does not undergo statistically significant changes in both male and female students after the Ruffier test (Table 2, Fig. 2). According to literature [2], diastolic pressure in response to physical activity either increases slightly or does not change immediately after the load. After a fairly short period of time - less than 3 minutes after the load - this indicator returns to the original value or even decreases. As can be seen from Table 2, we note this pattern in both male and female students.

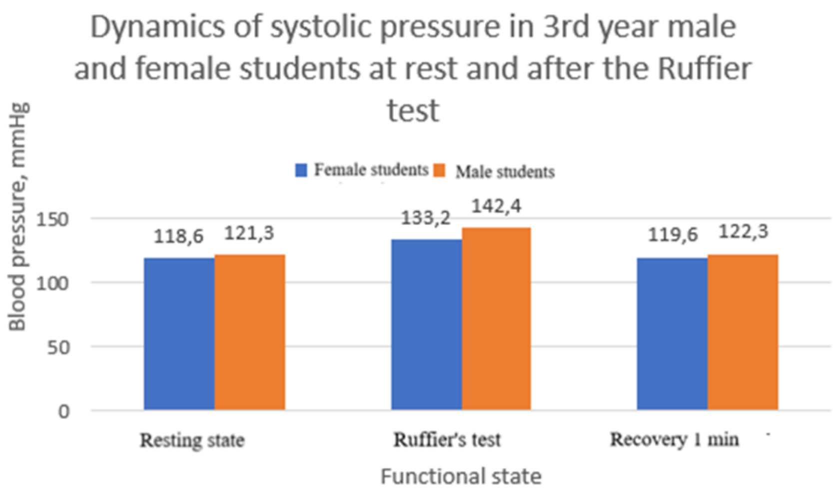

Figure 1: *The nature of changes in systolic blood pressure in 3rd year students after performing a functional motor test*

Table 2: *Diastolic pressure (mmHg) in male and female students after the Ruffier test*

Subject	State of rest	Ruffier's test	Recovery, 1 min
Girls	72.8±2.05	76.4±2.23	68.2±1.72
Young men	74.5±2.11	80.3±2.21	73.7±2.41

p>0.0

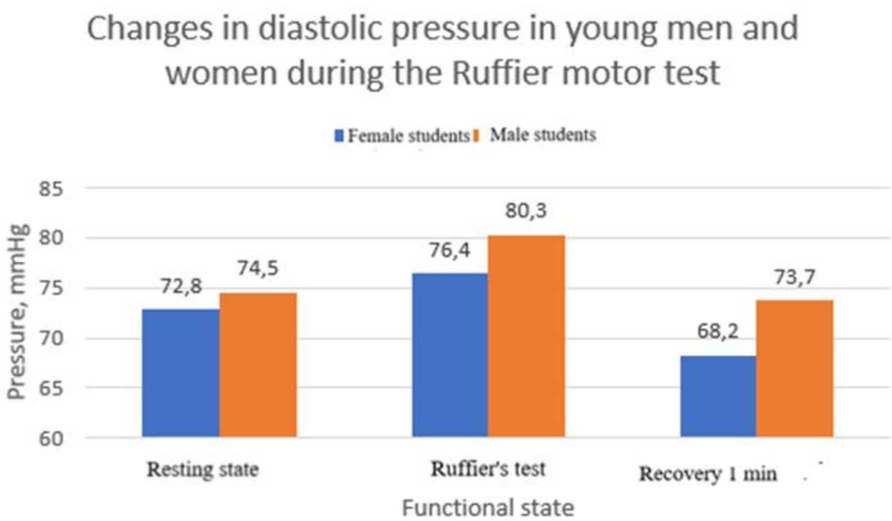

Figure 2: *Lower arterial pressure in 3rd year male and female students after performing the Ruffier test*

It should be noted that the World Health Organization provides the following categories for assessing blood pressure (regardless of gender): systolic pressure of less than 120 mm Hg is considered normal, and less than 130 mm Hg is considered normal systolic pressure. The following categories of assessments are accepted for diastolic pressure: - normal (less than 80) and normal (less than 85). According to these data, the pressure of the surveyed male and female students (general group value) can be considered normal. At the same time, individual fluctuations in blood pressure among male and female students have a wide range.

According to E. A. Ryazanova and L. A. Girenko [9], an increase in heart rate after physical exercise (Martine's test) by more than 31 units indicates an unsatisfactory state of the cardiovascular system. In the present study, the subjects performed physical exercise in the form of the Ruffier test . In those examined by us, the heart rate after the Ruffier test increases quite high, although it does not exceed the limit of 31 units (Table 3, Fig. 3). Moreover, performing the Ruffier test causes a reliable increase in the heart rate (Table 3, Fig. 3).

Table 3: *Heart rate (bpm) in male and female students after the Ruffier test*

Subjects	State of rest	Ruffier's test	Recovery, 1 min
Girls	80.1±2.44	107.5±3.22**	88.7±3.55
Young men	73.4±2.32	98.6±3.65**	79.9±3.67

** p< 0.02

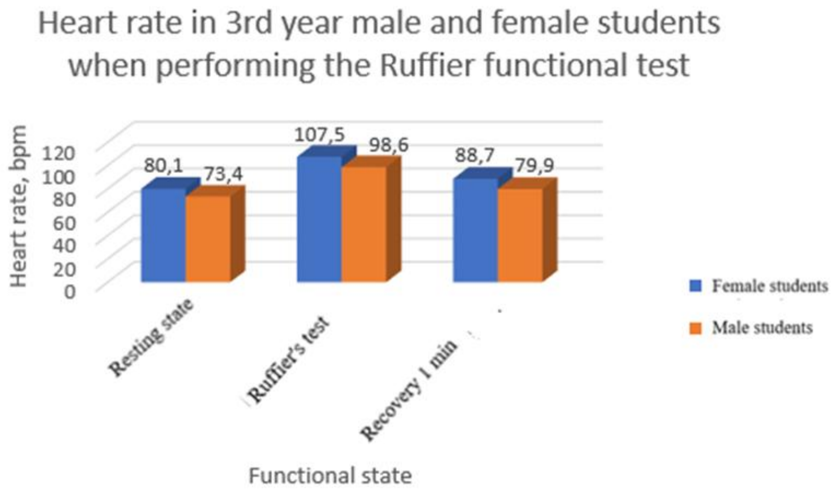

Figure 3: *Heart rate dynamics in 3rd year students after short-term physical activity*

An increase in pulse rate by 27.4 units was noted in girls and by 25.2 units in boys. Consequently, it can be concluded that the organism and cardiovascular system of the students we examined are satisfactorily adapted to physical activity.

Evaluation of the functional state of the cardiovascular system by indices at rest and after performing the Ruffier test . At rest, the Kerdo index in female students indicates the prevalence of sympathetic influences on the work of the heart. As can be seen from Table 4 and Figure 4, girls have a more pronounced sympathetic effect on the activity of the heart and blood circulation: their CI is +9 at rest. Kerdo index values from -10 to +10 are considered normative. Positive CI values indicate the prevalence of sympathetic influences on the work of the heart. In young men, the CI value is negative (-1.5) (Table 4), which indicates a parasympathetic effect on the work of the heart at rest.

After performing the test In Ruffier , both in girls (+29 c.u.) and in boys (+18.5 c.u.), the influence of the sympathetic branch of the autonomic nervous system increases. The values of the Kerdo index after the load and a decrease in its value after 1 minute indicate a satisfactory state of the cardiovascular system of male and female students. At the same time, sympathicotonia is more pronounced in female students and it persists after 1 minute of recovery. In young men, sympathicotonia is noted after the load, and normotonia after a minute of recovery . Female and male individuals responded differently to physical activity.

Table 4: *Kerdo index (cu) in male and female students after the Ruffier test*

Subjects	Peace	Ruffier's test	Recovery, 1 min
Girls	0.091 (+9 USD)	0.29 (+29 USD)	0.231 (+23.1 USD)
Young men	-0.015 (-1.5 USD)	0.185 (+18.5 USD)	0.077 (+7.7 USD)

p>0.05

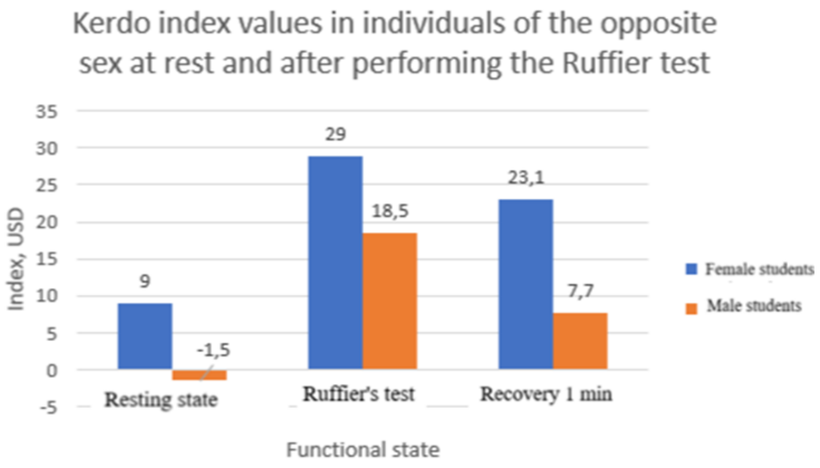

Figure 4: *Changes in the Kerdo vegetative index in students and third-year students*

Analysis of the functional state of the cardiovascular system using the Robinson index revealed the following features (Table 5, Fig. 5). The Robinson index values for girls were - 94.9 c.u., and for boys - 89.0 c.u. For girls, this indicator exceeded the standard limits of the index in a state of rest (85-94 c.u.), corresponding to the average functional state of the cardiovascular system [10].

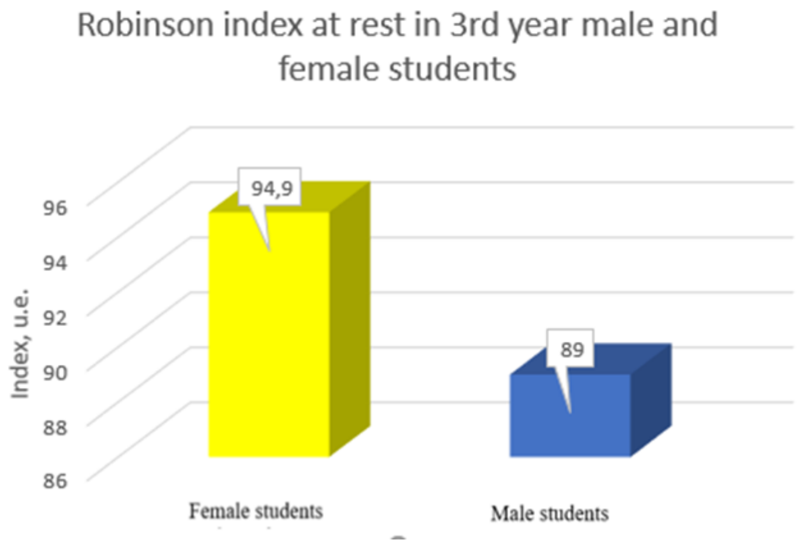

Figure 5: *Comparison of Robinson indices in individuals of the opposite sex. The Robinson index evaluates the functional state of the cardiovascular system at rest.*

As can be seen from Table 5, the IR indicators of female students were at the upper limit of the average functional state. The girls showed a slight decrease in the functional capabilities of the circulatory system.

Table 5: *Robinson index at rest in male and female students*

Floor	IR	Meaning
Girls	94.9 (cu); The upper literary limit of the average functional state of the cardiovascular system is 94 (cu).	Upper limit of the average functional state of the cardiovascular system. Some decrease in the functional capabilities of the cardiovascular system
Young men	89.0 (cu); The upper limit of the average functional state is equal to 94 (cu).	The value falls within the limits of the average functional state of the cardiovascular system. Average functional capabilities of the cardiovascular system

Ruffier index allows us to draw a conclusion about the state of the functional reserves of the cardiovascular system after performing a physical load. According to our data, the students we examined had average Ruffier index values . Thus, for girls its value was 7.63 c.u. , and for boys 5.19 c.u. (Table 6, Fig. 6). The literary norm of more than 15 c.u. indicates low reserves of the cardiovascular system.

Physical activity allows us to identify the features of the functioning of the circulatory system, hemodynamic parameters that are hidden when examining a person at rest. Physical activity is considered a stress factor for the body. It causes hypoxia in the cardiac and skeletal muscles [4]. The Ruffier index allows us to adequately assess the adaptive capabilities of the body, the circulatory system in response to muscle activity.

Table 6: *Ruffier index in male and female students*

Floor	IR values, c.u.
Girls	7.63 (from 7 to 9 – average heart performance [8]
Young men	5.19 (4 to 6 – good cardiac performance in response to physical activity [8]

Ruffier index in persons of the opposite sex, calculated based on changes in the parameters of the cardiovascular system after physical exercise

The magnitude of the adaptation potential at rest and after the Ruffier test .

AP is an integral indicator that takes into account the parameters of physical development and indicators of the cardiovascular system [3].

7 and Figure 7 below show the values of the adaptation potential of male and female students. For female students, the AP was 2.24 c.u., and for male students, it was 2.21 c.u. These values were determined in a state of rest.

According to some authors [1, 3], AP values below 2.6 c.u. are considered satisfactory adaptation of the circulatory system. In the male and female students we examined, AP at rest did not exceed this value. However, after performing the Ruffier test, the AP value rose above 2.6 c.u. (Table 7, Fig. 7). This AP value corresponds to the tension of the adaptation mechanisms. The reason for this is clear: physical activity causes an increase in blood pressure and heart rate. And AP is closely related to the parameters of the cardiovascular system and is calculated based on three of its parameters - systolic and diastolic pressure and pulse. At the same time, the AP values were higher in absolute value in female students, which may indicate a less pronounced adaptation to muscle loads in them compared to male students.

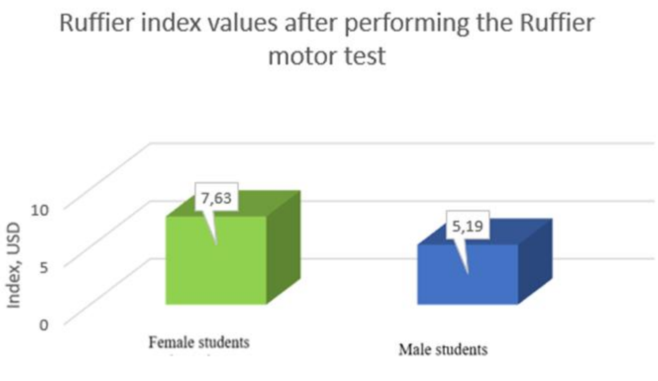

Figure 6: Ruffier index in male and female students

However, according to other authors, there are other limits for the AP values and their interpretation. They are most often found in the literature. In particular, the AP value of up to 2.10 c.u. is accepted as satisfactory adaptation and indicates sufficient functional reserves of the circulatory system. The functional stress of the adaptation mechanisms corresponds to AP values from 2.11 to 3.20 c.u. AP values from 3.21 to 4.30 c.u. are unsatisfactory adaptation, expressed in insufficient adaptability to physical activity, and finally, a breakdown of adaptation, corresponding to AP values of more than 4.30 c.u., a sharp decrease in the functional capabilities of the cardiovascular system [6]. According to this author, the AP values of our male and female students correspond to the stress of the adaptation mechanisms even at rest. After loading, the AP values increase even more, although they correspond to the state of tension of the adaptation mechanisms, that is, they are in the range from 2.11 to 3.20 conventional units.

Table 7: *The magnitude of the adaptive potential of male and female students studying in senior years*

Floor	AP at rest, c.u.	AP after Ruffier's test , c.u.	AP after 1 min recovery, c.u.
Students	2.21±0.176	2.82±0.210	2.34±0.176
Female students	2.24±0.195	2.86±0.193	2.38±0.182
r	>0.05	>0.05	>0.05

p>0.05

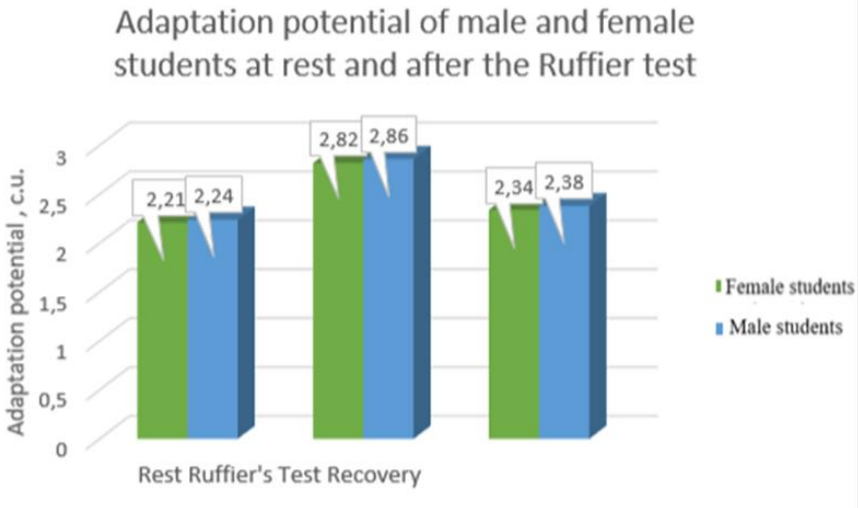

Figure 7: *The magnitude of the adaptation potential in individuals of the opposite sex at rest, after performing the Ruffier test and one minute of recovery*

No statistically significant differences in the magnitude of AP between male and female students were found at rest and after exercise.

Thus, the functional state of the cardiovascular system in 3rd year male and female students can be characterized as satisfactory. Physiological reserves of the body and cardiovascular system in male and female students are characterized by average functional capabilities. At the same time, students demonstrated higher physiological reserves of the cardiovascular system. In general, males are more adapted to muscle loads and to hypoxic conditions that occur in the cardiac and skeletal muscles during dynamic muscle loads.

Assessment of the functional state of the cardiovascular system of graduate students based on the results of the Ruffier test . After performing the Ruffier test, the HR of graduate students increased by 29% compared to rest, and after 1 minute of recovery, the increase in HR was 7%.

The dynamics of changes in heart rate in second-year full-time female master's students is presented in Table 8. As can be seen from the table below, after the functional test, the increase in heart rate is statistically significant (Table 8, Fig. 8). After one minute of recovery, the increase in heart rate was still significantly higher than at rest. Compared with third-year students, the recovery of female master's students after the Ruffier test is delayed, since even after one minute the heart rate does not reach the resting value . Such results can possibly be explained by a longer period of physical inactivity in female master's students, since the duration of their studies at the university is more than five years.

Table 8: *Heart rate indicators at rest and after performing the Ruffier test in 2nd year female master's students*

Functional state	Peace	Ruffier's test	Recovery, 1 minute
Heart rate, bpm	78.8±3.75	101.5±3.81***	83.9±0.40***

Ruffier index obtained by us when performing the Ruffier test on graduate students was 6.42 U (Table 9). Values above 6 to 10 indicate average performance of the cardiovascular system [8]. According to this source, the Ruffier index value from 6 to 7 occupies an intermediate position between good and average performance.

Thus , it can be concluded that the functional state of the cardiovascular system of second-year master's students is satisfactory.

Table 9: *Ruffier index after performing the Ruffier test*

Functional state	Ruffier's test
Index Ruthie	6.42±1.111

Evaluation of functional reserves of the cardiovascular system , health of young people studying is an urgent task. Most methods of evaluating functional reserves calculate some integral indices that are based on measurements of hemodynamic parameters at rest. At the same time, measurements at rest cannot fully reflect the state of human functional reserves and adaptive capabilities. To study the reserves of the cardiovascular system, motor tests are used. Motor muscle load causes hypoxia in the human body. Physical activity acts as a stress factor. In response to such an impact, human functional reserves are mobilized. As a rule, those well adapted to motor activity have good functional reserves of the body. Young people studying, due to the specifics of the educational process, are at risk, so assessing their health and functional reserves using functional motor tests is of practical importance.

1. Based on the nature of the change in blood pressure and heart rate in response to a motor test (Ruffier test), male and female students exhibit a normotonic type of response from the cardiovascular system;
2. The value of the Ruffier index indicates a satisfactory functional state of the cardiovascular system in male and female students;
3. According to the Robinson index, average (in girls) and good (in boys) functional capabilities of the cardiovascular system are noted;

According to the Kerdo index, sympathetic influences on the work of the heart at rest slightly prevailed in third-year female students ; parasympathetic influences prevailed in young men; an increase in the index was noted in both male and female students after the Ruffier test and an increase in the influence of the sympathetic link on the work of the heart;

5. The value of the adaptive potential of male and female students corresponds to the tension of the adaptation mechanisms, while the functional reserves are still preserved, although reduced;
6. The Ruffier index is an important indicator for assessing the physiological reserves of the cardiovascular system, as it characterizes its response to a motor test and adaptation to muscle work;
7. The cardiovascular system of the examined male and female students demonstrates satisfactory adaptation to short-term physical activity.

The interplay between climatic conditions and the adaptation of the cardiovascular system in students to physical activity is a critical area of study, especially in the context of sustainable development in education. Understanding how different climatic factors influence cardiovascular responses can lead to more effective training regimens, promote healthier lifestyles, and ensure the safety and well-being of students during physical activity.

1. Impact of Climate on Cardiovascular Responses: The body's cardiovascular system is designed to respond to the demands placed upon it during physical activity. However, external climatic conditions can significantly alter this response. For example, in hot and humid environments, the body may struggle to regulate its core temperature, leading to increased heart rates and potential heat-related illnesses. Conversely, in cold climates, blood vessels constrict to conserve heat, which may impair circulation and overall cardiovascular efficiency. Understanding these responses allows educators to tailor physical activities and training programs that account for local climate variations, ensuring that students can perform safely and effectively.

2. Adapting Training Regimens: Educators and coaches must adapt training regimens to the specific climatic conditions that students face. This includes modifying the timing of physical activities, choosing appropriate types of exercise, and ensuring adequate hydration and nutrition. For example, conducting outdoor training sessions during cooler parts of the day can mitigate heat stress, while incorporating warm-up routines that prepare the cardiovascular system for exertion in colder climates can enhance performance and reduce injury risks. By developing adaptive training strategies, educational institutions can improve cardiovascular health and performance among students while also instilling lifelong habits of safety and awareness regarding environmental conditions.

3. Importance of Education and Awareness: Promoting awareness of the effects of climate on health is essential for fostering resilience among students. Educational programs should emphasize not only the physical aspects of fitness but also the environmental context in which students operate. This can be achieved through integrated curricula that connect physical education with environmental science, encouraging students to understand how their surroundings impact their health. By educating students about the importance of adapting to climate conditions, we empower them to make informed decisions about their health and well-being.

4. Sustainable Development Goals: This discussion aligns with several Sustainable Development Goals (SDGs), particularly Goal 3 (Good Health and Well-Being) and Goal 4 (Quality Education). By focusing on the intersection of climate, health, and education, we can develop holistic approaches that promote student well-being while addressing environmental challenges. Schools can act as models for sustainable practices, promoting outdoor activities that are climate-sensitive and fostering a culture of health and fitness. Furthermore, students equipped with knowledge about the relationship between climate and health are more likely to engage in sustainable behaviors, contributing to community resilience and environmental stewardship.

5. Future Research Directions: Further research is needed to explore the long-term effects of climatic conditions on cardiovascular health in various populations. Longitudinal studies can provide valuable insights into how consistent exposure to specific climatic factors influences cardiovascular adaptation over time. Additionally, investigating the role of technology, such as wearable fitness trackers, in monitoring cardiovascular responses under varying climatic conditions can offer practical solutions for enhancing student health and performance.

In conclusion, the influence of climatic conditions on the adaptation of the cardiovascular system in students is a multifaceted issue that requires careful consideration in educational settings. By understanding these dynamics and implementing adaptive strategies, we can promote not only the physical health of students but also a broader commitment to sustainable development and environmental awareness.

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