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УДК 371.71 + 612.176
МРНТИ 34.39.51 *https://doi.org/10.51889/1728-8975.2022.74.4.015*

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FUNCTIONAL STATE OF THE CARDIOVASCULAR SYSTEM OF STUDENTS IN A MODERN SCHOOL

Abstract

Our research was aimed at studying and identifying the features of changes in the health status of senior students in the transition to the updated content of education. The peculiarities of changes in the functional state of the cardiovascular system, adaptive capabilities of the body are revealed.

The state of hemodynamics of 10th grade students during the period of adaptation to the updated training format revealed signs of tension in the work of the cardiovascular system of adolescents. During the academic year, the detrained cardiovascular system of adolescents was revealed due to the tension of hypodynamic processes, fatigue of the central nervous system, violations of the regulatory mechanisms of the circulatory system.

Keywords: adolescents, hemodynamics, cardiovascular system, updated content of education

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ҚАЗІРГІ МЕКТЕП ЖАҒДАЙЫНДАҒЫ ОҚУШЫЛАРДЫҢ ЖҮРЕК-ҚАНТАМЫР ЖҮЙЕСІНІҢ ФУНКЦИОНАЛДЫҚ ЖАҒДАЙЫ

Аңдатпа

Біз жүргізген зерттеу, жаңартылған білім беру мазмұнына көшу барысында, жоғары сынып оқушыларының денсаулық жағдайындағы өзгерістердің ерекшеліктерін зерттеуге

және анықтауға бағытталған. Жүрек-қантамыр жүйесінің функционалдық күйінің өзгеру ерекшеліктері, ағзаның бейімделу мүмкіндіктері анықталды.

Жаңартылған оқыту форматына бейімделу кезеңіндегі 10-сынып оқушыларының гемодинамикасының жағдайы, жасөспірімдердің жүрек-қантамыр жүйесінің жұмысындағы шиеленіс белгілерін анықтады. Оқу жылы барысында жасөспірімдерде гиподинамикалық процестердің шиеленісуіне, орталық жүйке жүйесінің шаршауына, қан айналымы жүйесінің реттеу механизмдерінің бұзылуына байланысты жүрек-тамыр жүйесінің физиологиялық өзгерістері анықталды.

Түйін сөздер: жасөспірімдер, гемодинамика, жүрек-қан тамырлар жүйесі, жаңартылған білім беру мазмұны

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ФУНКЦИОНАЛЬНОЕ СОСТОЯНИЕ СЕРДЕЧНО-СОСУДИСТОЙ СИСТЕМЫ УЧАЩИХСЯ В УСЛОВИЯХ СОВРЕМЕННОЙ ШКОЛЫ

Аннотация

Проведенное нами исследование было направлено на изучение и выявление особенности изменений в статусе здоровья учеников старшего класса в переходе на обновленное содержание образования. Выявлены особенности изменений функционального состояния сердечно-сосудистой системы, адаптационных возможностей организма.

Состояние гемодинамики учеников 10-го класса в период адаптации к обновленному формату обучения выявило признаки напряжения в работе сердечно-сосудистой системы подростков. На протяжении учебного года выявлены детренированность ССС подростков вследствие напряжения гиподинамических процессов, утомления ЦНС, нарушения регуляторных механизмов системы кровообращения.

Ключевые слова: подростки, гемодинамика, сердечно-сосудистая система, обновленное содержание образования

Introduction. School education in Kazakhstan is undergoing significant transformations due to the intensive growth of digitalization, the information space that invades the daily lives of children. Against this background, we see a serious reduced general condition in the health of schoolchildren, which requires special attention to this problem. The negative dynamics in the state of health of students, especially of high school age, causes serious concern. The impact of innovative educational loads with a high level of psycho-emotional and intellectual stress in the conditions of the updated content of education negatively affects the functional capabilities of the body of schoolchildren, causing a decrease in adaptive reserves, the emergence of a situation of misalignment of the mechanisms of regulation of autonomic functions, which declare itself in the form of deterioration of working capacity, increased fatigue and, as a consequence, to a sharp deterioration in well-being. In addition, during puberty, problems appear in the work of the heart, lungs, and circulatory system, leading to a decrease or increase in vascular tone.

In adolescence, there is a forced growth of the heart, its mass, the heart rate (HR) decreases, and systolic blood pressure (SAD) increases. From the age of fourteen, a gender difference in the work of the cardiovascular system is revealed [1].

Materials and methods. The work was performed at the Department of Biology of the Institute of Natural Sciences and Geography on the basis of SMI "Gymnasium 35" Medeu district of Almaty.

As the object of this study, volunteers were involved on a voluntary basis – students of the 10th "B"

class of both sexes. A total of 22 people took part (girls – 14, boys – 8). The work was carried out on the basis of ethical principles of conducting research on humans, as well as taking into account the age of students (16-17 years). The volunteers and their parents were provided with full information about the planned studies and requested written permission from parents to participate in the experiment, as well as the consent of the participants themselves.

Simple, accessible, valid methods of studying the functional state of the cardiovascular system (hereinafter referred to as CVS) of schoolchildren were used, which do not require special stationary equipment.

To assess the functional state of the CVS, measurements of primary indicators were carried out – height, weight, heart rate (HR), blood pressure (BP), allowing further calculation of system characteristics-pulse (PD) and average dynamic pressure (ADP), minute blood volume (MBV) and peripheral resistance (PR).

The measurement of the parameters of the physical development of students was carried out in the medical office of the school using a standard height meter and electronic scales on an empty stomach, without shoes, in light clothes, in the presence of a school medical staff.

The pulse was calculated by counting the heart rate on the wrist joint on the radial artery in a sitting position for 10 seconds.

Arterial pressure (BP) was measured by Korotkov's auscultative method [2], using a manual tonometer AND (manufactured by A&D Company, Limited (Tokyo, Japan)).

The functional state of the subjects was assessed according to several system characteristics as a result of the following tests. The minute volume of blood circulation (MVC) was determined [3], which allows us to judge the mechanical activity of the heart muscle. The consistency of regulation of cardiac output and peripheral resistance was judged by the data of average dynamic pressure (ADP) [3]. The coefficient of efficiency of blood circulation, CEC, was also determined [3]. This coefficient helps to evaluate one of the main functional characteristics-physical performance, which directly depends on the state of the CVS. The Martinet test was carried out according to the standard scheme [3]. The study of the tolerance of dynamic strain, which makes it possible to assess the optimality of vegetative maintenance of the CVS, was carried out using the Rufier test [3].

Results and their discussion. The study of the indicators of the state of the CVS of adolescents studying in the 10th grade was carried out throughout almost the entire school year, starting from the second quarter (period 1), then at the end of the second quarter immediately after the week of summative assessment for the section (SASs) and summative assessment for the quarter (SAQs) (period 2), then during the vacation period (period 3) and at the end of the third quarter (period 4).

Prior to the functional tests, anthropometric measurements of the height and weight data necessary for further calculations according to the methods described above were made. The study of the dynamics of the cardiac system by indicators such as blood pressure, heart rate and average dynamic blood pressure was carried out during the above periods.

As can be seen from Figure 1, the level of SAP (systolic blood pressure) by the time of the end of the second quarter during the period of intense load in the form of SASs in all disciplines and the final week of the SAQ, revealed a slight increase in SAP compared to the level of the beginning of the quarter.

So, in the group of girls, this indicator increased by 3.03 mmHg, in the group of boys – by 4 mmHg. The indicators of diastolic blood pressure (DAP) revealed a slight decrease in the level of DAP in girls by 2.65 mmHg, while in boys an increase of 5 mmHg was recorded. Dynamics average dynamic pressure (ADP), which can be used to judge the consistency of regulation of cardiac output and peripheral resistance, practically did not change in the group of girls, whereas in the group of boys its increase by 4.6 mmHg was observed.

As for changes in heart rate readings, its increase was 2.74 and 6.08 beats/min in girls and boys, respectively.

During the winter holidays, the performance indicators of the CVS were reduced: SAP – by 8.3

mmHg and 7.04 mmHg, DAP – by 2.2 mmHg and 3.8 mmHg, respectively, in the groups of girls and boys, and the heart rate decreased by 8 beats/min in girls and 4 beats/min for young men. The results of the ADP changes were also reduced by 4.2 mmHg and 4.9 mmHg in the respective groups. Thus, we can talk about a decrease in all indicators of the functional state of the CVS almost to the control values identified at the beginning of the study.

The next period of research was conducted closer to the end of the third quarter, in March. SAP in girls increased by 8.06 mmHg and in boys by 5.11 mmHg, DAP – respectively by 5.3 mmHg and 7 mmHg, heart rate – by 6.6 beats/min and 9.07 beats/min, and ADP indicators – by 6.2 mmHg and 7.01 mmHg.

During the educational year, there is a slight increase in tension from the CVS indicators, namely the level of blood pressure, heart rate and ADP. It is quite logical to assume that this condition is caused by a significant mental load associated with a reduced degree of motor activity, as well as an increased level of emotional component accompanying the adaptation period to the new learning system. In addition, the transition to an updated teaching system with its specific structure, involving SASs and SAQ, occurred at the end of puberty.

In order to better understand the changes in the functional state of the CVS in dynamics, the following indicators were calculated: systolic volume (SV), minute circulation volume (MCV), circulatory efficiency coefficient (CEC).

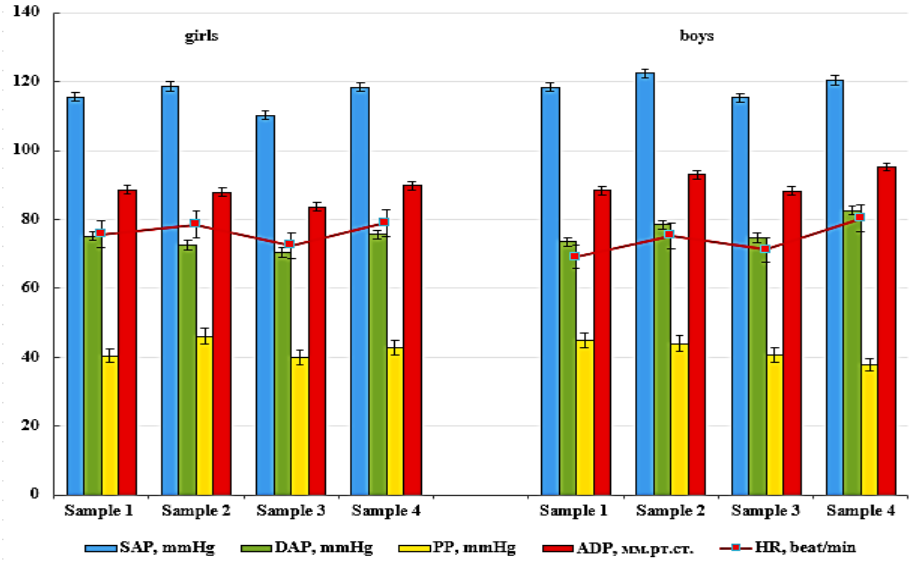

Figure 1. Dynamics of indicators of blood pressure,
heart rate and average dynamic pressure during the 2019–2020 academic year

On the abscissa axis – the value of blood pressure, in mmHg (SAP – systolic blood pressure, DAP – diastolic blood pressure, ADP – average dynamic pressure), heart rate, in beats /min (HR); on the ordinate axis – study periods: sample 1 – the beginning of the 2nd quarter, sample 2 – the end of the second quarter, sample 3 – holidays, sample 4 – the end of the 3rd quarter. *– $p \geqslant 0{,}05$

Systolic volume (Figure 2), as it turned out during the experiment, undergoes the following fluctuations in the volume of circulation. So, by the end of the second quarter, girls had an increase in SV by 7.6% relative to the control values (at the beginning of the quarter), while boys showed a decrease in this indicator by 5.2%.

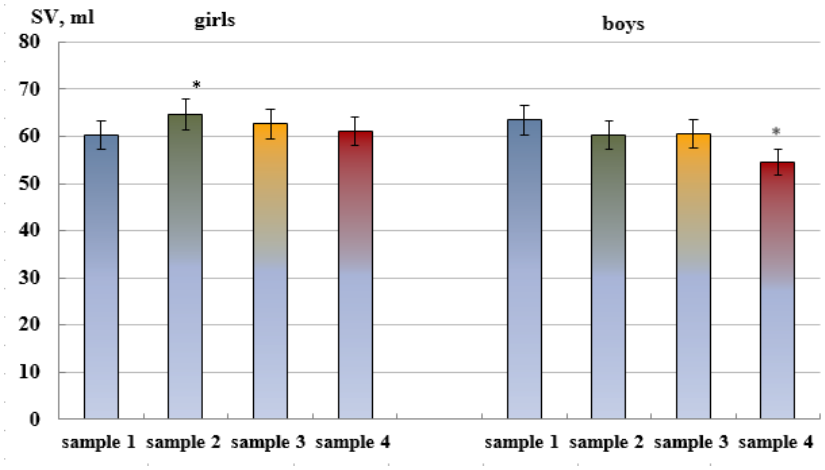

Figure 2. Dynamics of systolic volume (SV) indicators during the educational year

On the abscissa axis – the value of systolic volume (SV), in ml.; on the ordinate axis – study periods: sample 1 – the beginning of the 2nd quarter, sample 2 – the end of the second quarter, sample 3 – holidays, sample 4 – the end of the 3rd quarter. *– p⩾ 0,05

Further dynamics of SV in the group of girls during the holidays did not show significant shifts in the number, remaining slightly higher than the primary indicators, then decreased up to control values by the end of the study period (end of the third quarter).

In youth, the picture of the dynamics of SV is somewhat different: during the holidays, the changes in the indicator did not change relative to the level recorded at the end of the second quarter, but by the end of the third quarter, SV decreased by 10.03% relative to the vacation period and by 14% relative to the level of SV at the beginning of the second quarter, which is slightly lower than the standard values of SV in adolescents aged 16-17 years (the norm is 60-65 ml).

Figure 3 shows what changes the minute volume of blood circulation (MVC) underwent during the study period. In the group of girls, the value of the MVC during the end of the second quarter increased by 12% relative to the initial indicators, then during the holidays it returned almost to the background values. And then by the time of the end of the third quarter, it again increased by 6% relative to the data from the beginning of the research. If we compare the indicators of the MVC of girls with the data of similar studies, the trend of lower MVC indicators in Almaty schoolgirls compared to their peers living in flat areas is revealed [4].

Whereas in the group of youth, the indicators of the dynamics of the MVC were stable throughout the entire period of the experiment, only by the end of the second quarter exceeding the background indicators by only 3%, which is a slight increase.

It should be noted that the average background indicators of the MVC in both boys and girls in this age group are almost identical, which does not contradict the literature data [5]. The rise in the level of MVC registered in our results in girls can be explained by a more labile psych emotional component than in boys. Although there are several contradictions with the literature data [5], which show a more stable state of the cardiovascular system in girls by the age of 17.

It is likely that in our research we touched upon the moment of the final completion of the functional development of the CVS, which could affect the results.

The circulatory efficiency coefficient (CEC), as an indicator of the cost of CVS for the movement of blood through the bloodstream, is also effective for assessing the adaptive capabilities of the adolescent body in the presented study.

An increased value of CEC was revealed in both girls and boys, and throughout the school year. So, by the end of the second quarter, when students were in the mode of intellectual and emotional loads associated

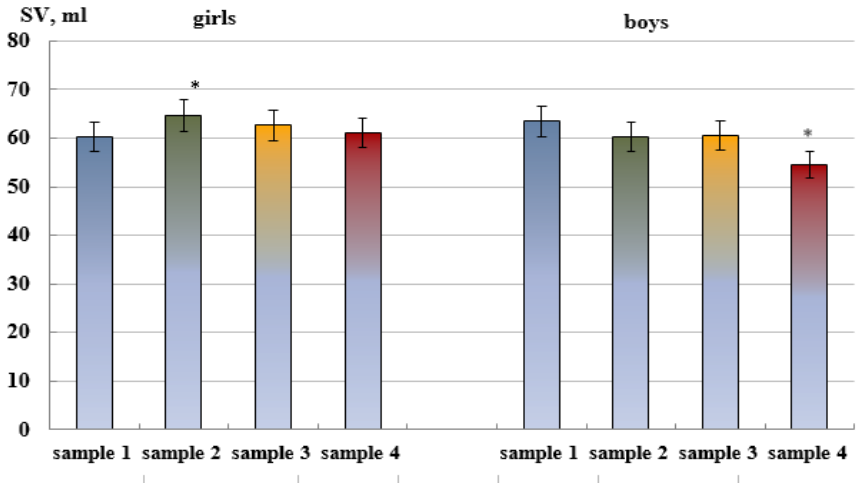

Figure 3. Dynamics of indicators of minute volume of blood circulation (MVC) during the educational year

On the abscissa axis – the value of the minute volume of blood circulation (MVC), in ml.; on the ordinate axis – study periods: sample 1 – the beginning of the 2nd quarter, sample 2 – the end of the second quarter, sample 3 – holidays, sample 4 – the end of the 3rd quarter. *– p⩾ 0,05

with passing in all subjects of the SAS and then the SAQ, the value of the CEC increased relative to background values by 18.23% in the group of girls, but at the same time there was some slight decrease in the CEC in boys.

During the winter holidays, the CEC indicators decreased in both groups – by 20% and 6.6%, respectively, in girls and boys, but at the same time they did not reach the indicators of the accepted norm (2600 standard unit) (Figure 4).

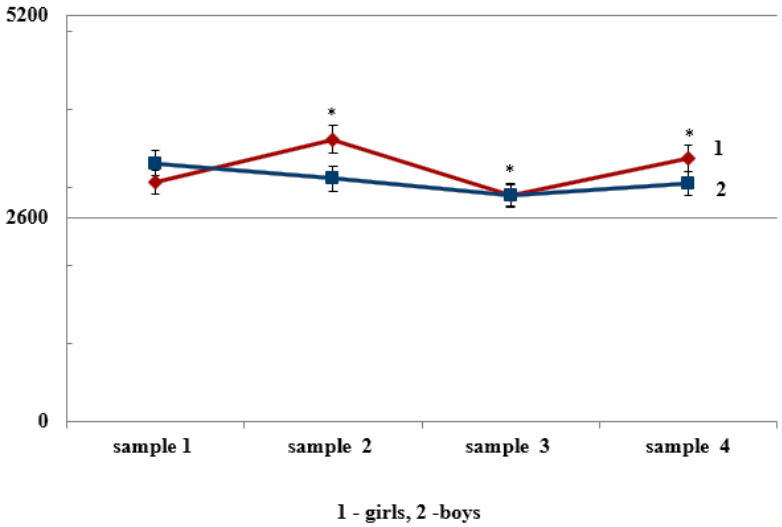

Figure 4. Dynamics of indicators of the circulatory efficiency coefficient (CEC) during the educational year

On the abscissa axis – the value of the circulatory efficiency coefficient (CEC), in units; on the ordinate axis – study periods: sample 1 – the beginning of the 2nd quarter, sample 2 – the end of the second quarter, sample 3 – holidays, sample 4 – the end of the 3rd quarter. 1 – a group of girls, 2 – a group of boys. *– p⩾ 0,05

Then, with further tracking of the dynamics of CEC, at the end of the third quarter, the

indicators again increased by 16.7% and 4.8% in the groups of girls and boys compared with the data observed during the vacation.

As can be seen, the indicators of the dynamics of the CEC during the school year revealed clear signs of tension in the work of the cardiovascular system of adolescents and ambiguous with respect to gender. The girls had more pronounced differences in the CEC curve, which is especially evident in the decrease in indicators during the vacation and sharp rises during periods of intensive educational activity. In youth, the maximum value of the CEC is shown at the beginning of the study with further smoother changes in the curve.

A more complete picture of the state of hemodynamic parameters was studied using such a widely used method for mass screening as the Martinet test. In Figure 5 the results of these studies are presented.

The changes were judged by the difference in hemodynamic parameters at rest and after physical exertion in the form of squats. Martinet's test revealed significant changes in hemodynamics during the educational year. So, in girls, compared with the beginning of the second quarter, when the result on the difference between the indicators (heart rate, SAP and DAP) at rest and after exercise was good (less than 5), then at the end of the quarter this difference showed a spread from 6.04 to 9.02, which indicates a satisfactory state of the circulatory system, although the data on SAP was approaching a critical level. During the vacation, the difference between the indicators decreased, but not to optimal values (from 5.07 to 5.53). And by the end of the third quarter, in March, an increase in the difference was recorded, especially in terms of heart rate – the state of the system almost approached an unsatisfactory level – 9.6.

In the group of boys, the dynamics of heart rate, SAP and DAP indicators before and after exercise at the beginning of the second quarter was also good, but slightly higher than in girls. By the end of the quarter, these indicators had almost doubled, except for DAP, which even slightly decreased.

In general, the state of hemodynamics can be described as satisfactory. The test results at the time of the holidays showed the same trends towards a decrease in the difference in indicators at rest and after dynamic loading towards a state that is good. But at the end of the third quarter, an unfavorable picture was revealed in the boys, namely, the level of difference in heart rate and SAP reached critical values – more than 10, which indicates an unsatisfactory degree of the state of the CVS.

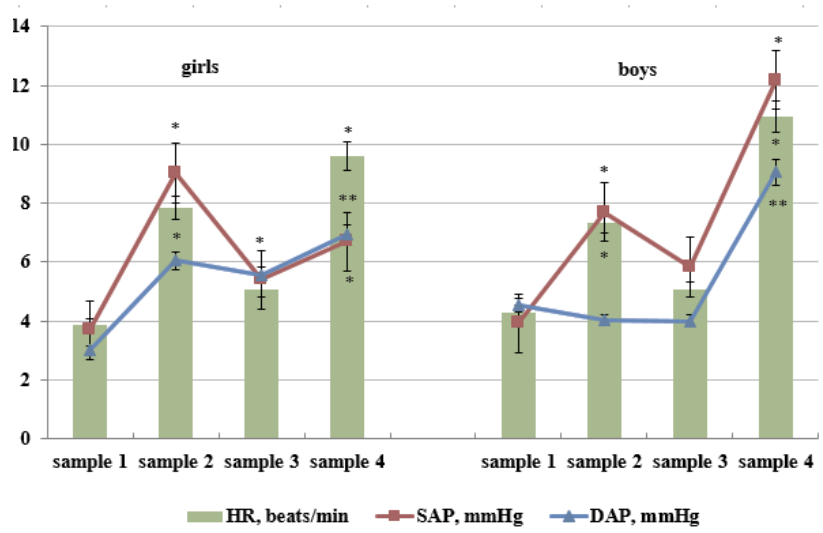

Figure 5. Dynamics of the Martinet sample indicators during the educational year

On the abscissa axis – the value of blood pressure, in mmHg (SAP – systolic blood pressure, DAP – diastolic blood pressure, heart rate, in beats /min (HR); on the ordinate axis – study periods:

sample 1 – the beginning of the 2nd quarter, sample 2 – the end of the second quarter, sample 3 – holidays, sample 4 – the end of the 3rd quarter. *– p⩾ 0,05

This gives grounds to assert that adaptation to the new format of training takes place with tension from the circulatory system, negatively affecting the overall functional state of young people, especially teenage boys.

Another, no less interesting method of assessing the vegetative state of the body is the determination of the Roufier index (Figure 6).

The tolerance of dynamic load, which made it possible to assess how optimally vegetative maintenance of the functions of the cardiovascular system occurs, underwent significant fluctuations during the experiment.

In the group of girls at the end of the second quarter, the Rufier index (IR) increased by 70.6% compared to the initial level, which indicates that the test was performed on the Rufier scale at "weak". During the holidays, the IR returned to the indicator "good", even slightly less than the first sample. And at the end of the third quarter, the test also showed a "weak" level, an increase of which amounted to 144.4% relative to the vacation level.

The changes in the parameters of the Rufier test in the teenage boys were even more serious. Thus, the second sample revealed an increase in the index by 86.2% compared to the first sample at the beginning of the second quarter, which characterizes the state of the CVS as close to unsatisfactory. During the vocation period, the vegetative status of the teenagers returned to a satisfactory level, without reaching the primary indicators. The Rufier test at the end of the third quarter showed an increase in IR by 114.8%, thereby revealing a rather serious unsatisfactory vegetative support of the circulatory system.

Both girls and boys during the entire study period were not shown to perform the Rufier test "perfectly", which indicates a fairly low level of physical fitness of adolescents, detrained CVS, whose condition worsened during the educational year, revealing as possible causes increased hypodynamic processes, tension and fatigue of the central nervous system, violation of regulatory mechanisms of circulation.

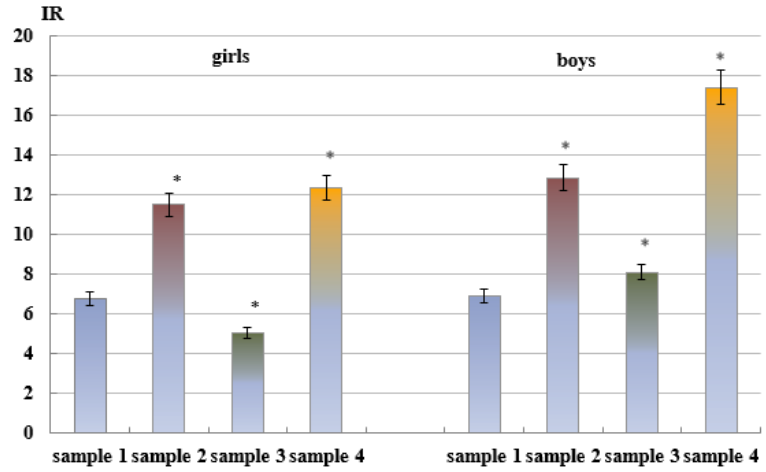

Figure 6. Dynamics of the Rufier Index (IR) during the educational year

On the abscissa – IR axis, standard units; on the ordinate axis – study periods: sample 1 – the beginning of the 2nd quarter, sample 2 – the end of the second quarter, sample 3 – holidays, sample 4 – the end of the 3rd quarter. *– p⩾ 0,05

Thus, it can be stated that the state of hemodynamics of 10th grade students during the period of adaptation to the updated training format revealed clear signs of tension in the work of the cardiovascular system of adolescents. There were some differences in the reactions of the CVS of a

gender nature, which is probably due to the age-related features of the formation of the cardiac system in girls and boys, as well as the psycho-emotional component. In general, the experiment revealed a fairly low level of physical fitness of adolescents, deconditioning CVS, whose condition worsened during the school year. Possible causes were stress of hypodynamic processes, fatigue of the central nervous system, violation of the regulatory mechanisms of the circulatory system.

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