MONITORING THE CARDIORESPIRATORY SYSTEM INDICES IN STUDENTS UNDER ADAPTATION TO VARIOUS PHYSICAL ACTIVITIES

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Abstract: One of the major issues of adolescent sports physiology and medicine is prevention of maladaptation states that may be premonitory signs of many pre-pathological and pathological conditions. The objective of the research was the study of monitoring indices of the cardiorespiratory system in students during their adaptation to various physical activities when studying at the faculty of physical education. The research consisted in studying physical development, physical fitness, heart rate and functional characteristics of the circulatory system using the healthExpress computer software and hardware complex. As a result of the research, the valid trend to lower heart rate and arterial blood pressure in students has been found in follow-up examination, which gives evidence about the development of the cardiovascular system mechanisms of adaptation to various physical activities.

Keywords: monitoring, adaptation, cardiorespiratory system, students, sport specialization, physical activity.

1 Introduction

The current conditions of life place high demands on the level of physical development, working capacity and defenses of the human body. The analysis of functional status of the body and physical fitness of children and young students shows that over the recent decade, the number of students scoring low on physical fitness has tripled reaching 50,8% in young men, and 58,8% in young women (Pozharova & Elaeva, 2016).

In schoolchildren, physical state and working capacity change under the impacts of the environment and learning events. Meanwhile, timely checking and assessing the schoolchildren's fitness allow building the educational process sensibly and identifying its efficiency. It takes schoolchildren immense expenditure of the internal energy, physical effort, and emotional tension to pass from general education to higher school.

In young students, adaptation to new social conditions, particularly in their first years of study, triggers active mobilization of the body. With regard to this, the system of measures for protecting students' health and rehabilitation during their learning at higher educational institutions has to be improved (Yakimova et al., 2014).

In the recent decade, a negative trend has been noted in students' medical status, which is due to the social and economic situation, natural environment worsening, and, as a consequence, material welfare and people's level of life decreasing.

At the same time, the country has seen reforms of the higher school system, which was accompanied by students' having to absorb a larger volume of the learning material against the background of insufficient knowledge and skills of the healthy way of life, emotional stress, hypodynamia, and the relatively weak physical development. This hindered adaptation of young students, especially of the first-year ones, to the educational process, with adverse deviations in the body ensuing. In its turn, this led to worse health, reduced mental and physical working capacity of the young students (Baevskiy & Berseneva, 1997).

According to Order of the President of the Russian Federation dated May 7, 2018 No. 204 "On the national objectives and strategic tasks of development of the Russian Federation for the period of up to 2024", one of the priority focus areas of scientific and technological, social and economic development of the Russian Federation is promotion and protection of health, as well as increase of the percentage of citizens leading a healthy way of life. Special attention should be paid to health of the rising generation. As of today, the situation associated with students' health needs more careful control, which is confirmed by Resolution of the Government of the Russian Federation No. 916 dated 29/12/2001 "On all-Russian system for monitoring physical health of the population, physical development of children, adolescents, and young people".

Creation and implementation of all-Russian physical health condition monitoring is the state task in social policy; this monitoring ensures finding the cause-and-effect links between people's physical status and life environment factors, identifies the influence of social and psychological, sport and pedagogical, natural environmental factors on the quality of life, and contributes to making substantiated managerial decisions in health promotion (Pozharova & Elaeva, 2016).

2 Literature Review

At the adolescent age, adaptation processes are formed under the effects of age-related particularities of the body, puberty processes, and environmental conditions (Pozharova et al., 2016; Yakimova et al., 2014). Long-term adaptation develops under multiple repetitions and summing up of physical actions. This stage is associated with numerous morphofunctional changes occurring in the body. First of all, the transformations pertain to the cardiorespiratory system which is the indicator of development of adaptation mechanisms (Ignatyeva et al., 2016; Kawabata et al., 2008). Studies of many authors have shown that the circulatory apparatus (and heart in particular) is one of the most important limiting elements in adaptation to exercise of various types (Golyshenkov et al., 2004; Matalyghina, 2009; Petrukhin et al., 2013; Koreneva, 2016).

Certainly, it is on the level of tension of regulatory mechanisms as well as on the stability margin that the cardiovascular system functioning economization and efficiency, the vegetative and energy supply of muscular activity depend (Sauer et al., 2007).

Assessment of functional status of the body is of immense importance in pre-nosological diagnosing (Baevskiy & Berseneva, 1997). Alongside studying the pattern of physiological parameters over time characterizing adaptation processes, one of the important methods is that of mathematical analysis of cardiac rhythm (Sazontova, 1997). This allows judging about the capacities of vegetative influence on the cardiorespiratory system and obtaining further information about functional status of the body even if there is no trend data on the main physiological indices (Pozharova & Elaeva, 2016; Neustadt et al., 1994).

3 Research Methodological Framework

The objective of this research consisted in monitoring several indices of the somatic health of students and their functional capacities of the circulatory system representing the development of adaptation of the body in response to various physical activities. The research tasks included studying the trend of indices of students' physical development and physical fitness in the course of study at the PE faculty, as well as finding out the effects of exercise of various types on the cardiorespiratory system.

The studies were conducted in the academic year of 2018-2019 on the base of the Regional scientific and practical center for physical education and healthy way of life of M. E. Evsevyev Mordovia State Pedagogical Institute (Saransk). All indices were taken twice during the day (before the start of classes and after their completion), twice a week (on Mondays and Fridays), and twice during the academic year (in October – term I; in March –

term II). The authors examined 25 students of the first year and 26 students of the third year of the faculty of physical education of M. E. Evsevyev Mordovia State Pedagogical Institute. The following parameters were studied: physical development; functional characteristics of the cardiovascular system; physical fitness of the students. Using the software of the healthExpress integrated computer diagnostic machine, the following anthropometric and physiometric measures of all the students were taken (in the relative physiological rest condition): height (cm), body weight (kg), chest circumference (CC), heart rate (HR), and the arterial blood pressure (ABP) (Ryabova, 2012; Pozharova et al., 2016). The statistical parameters of cardiac rhythm were studied by the variation histography technique on 100 cardiac cycles. Histographic analysis of 100 cardiac cycles in R-R-intervals according to R. M. Baevskiy (Antonov & Burov, 2010; Baevskiy & Berseneva, 1997) with the calculation of mode (Mo), mode amplitude (AMo), variation range (MxDMn), and tension index (TI) was performed using the Varicard-Express hardware and software complex designed for assessing the index of activity of regulatory systems of the body based on the HRV analysis.

The mathematical analysis was performed using the EScreen computer software for ECG recording and analysis. This software automatically recorded ECG with further analysis of the intervals between complexes and plotted cardiointervalograms. These were processed in the mathematical unit of the software, and a number of figures characterizing the trend parameters of cardiac rhythm were output. Based on the histographic analysis, the statistical indices of cardiac rhythm were evaluated. For comparing the response types with the initial TI values, Pearson criterion was calculated (χ^2).

Physical fitness of the students was assessed by finding out the pattern of development of some physical qualities – speed and endurance – over time. Motor tests of 100-meters and 1000-meters races were conducted. The 100-meters race to test the level of development of speed was conducted on the stadium track. At the "Ready!" command, the tested ones stood at the starting post in the crouch start position. Simultaneously with the "Go!" command, a visual signal for time-keepers standing at the finish mark was given. During the tested ones' covering the distance, they were watched so that they did not reduce the pace of running before the finish. Only one attempt was allowed. In a round, two and more tested students took part, but for each one, their timing was recorded against the stopwatch with an accuracy to 0,1 second. The test was conducted in such weather conditions under which the tested ones could show their usual, comparable results. The 1000-meters race characterizing endurance development level was conducted on the stadium track, too, with a standing start, and the time of running was recorded.

4 Results and Discussion

At the first stage, the research consisted in studying physical development, physical fitness, and functional characteristics of the circulatory system, as well as their trends throughout the academic year, in students of years I and III of the physical education faculty who had a significant volume of exercise in sport subjects combined with track and field athletics training (races of various distances).

The comparative analysis of anthropometric and physiometric measures in students of years I and III of the physical education faculty at the beginning of the academic year has found valid distinctions in height, weight, and chest circumference. The pattern of morphofunctional indices representing physical development level and the change of physical qualities development level (the latter was assessed by special tests in the first- and third-year students during the academic year) plotted against time (Table 1) is of a great interest.

Table 1 Comparative data of physical development, physical fitness, and functional indices of the circulatory system in the students of the physical education faculty (M±m)

Indices	Research stage (term)	Years	
		I	III
Height, cm	I	176,7±1,057	178,4±1,070
	II	177,1±1,059	178,5±1,075
Weight, kg	I	71,5±1,425	76,0±1,676
	II	72,3±1,490	75,8±1,726
CC, cm	I	92,7±1,178	96,7±0,933
	II	95,1±1,095	97,1±1,099
Testing			
100 m race, sec	I	13,0±0,099	12,9±0,108
	II	12,9±0,105	12,0±0,125
1000 m race, min	I	4,02±0,011	3,03±0,045
	II	3,09±0,049	2,59±0,046
Relative rest condition			
Systolic blood pressure, mm Hg	I	118,09±1,250	111,31±1,003
	II	116,07±1,230	110,03±0,020
Diastolic blood pressure, mm Hg	I	74,31±1,300	71,12±1,051
	II	72,04±0,901	69,05±0,964
HR, bpm	I	70,22±1,707	66,56±1,007
	II	70,03±1,123	67,43±1,087
After exercise			
Systolic blood pressure, mm Hg	100 m	128,08±1,350	116,32±1,003
	1000 m	114,08±1,230	109,01±0,040
Diastolic blood pressure, mm Hg	100 m	73,33±1,300	70,62±1,051
	1000 m	72,06±0,901	69,05±0,964
HR, bpm	100 m	125,02±0,907	120,06±1,003
	1000 m	132,43±0,596	123,71±1,201

Source: Pozharova G. V., Elaeva E. E., 2018-2019

Interpreting the table data, one can note that higher speed qualities and endurance figures are observed in the senior years' students. According to the authors' observation, such physical qualities as speed (100 m race) and endurance (1000 m race) are validly higher in the students of the year III, which is, clearly, owing to consistent learning and training events in sport subjects during the three years of studying at the faculty of physical education. In particular, by the end of the academic year, the 100-meters race indices characterizing speed qualities have improved by 0,9 sec (9,3%) on average, and there has been an 8,4% increase in the 1000-meters race figures representing the development of endurance.

One of the highly informative indices of cardiac factors adapting to continuously changing extracorporal conditions is the arterial blood pressure (ABP). The data shown in Table 1 represent a clear downward trend of the ABP both at rest and after exercise. So, on average, the students' systolic blood pressure indices are 9,4% lower (119,3 mm Hg in the first-year students and 111,6 mm Hg – in the third-year ones). At rest, HR in the first-year students is 70 beats per minute on average, and 67 – in the third-year ones, i.e. the difference amounts to 10%. A downward trend can be traced in the HR after exercise, too. In the first-year ones, its value is 132 beats per minute, while it is 123 in the third-year students, which is 9,3% less.

As a rule, this gives evidence about the growing training level and adaptation of the cardiorespiratory system to physical activities.

HR is known to be a keen indicator of neuro-humoral regulation of the heart and adaptation capacities of the body (Elaeva et al., 2018). In particular, the analysis of HR in students of various years demonstrates a valid trend for its reduction with age. It is common knowledge, too, that heart rate slows down with the development of adaptation capacities of the body owing to stronger effects of the vagus nerve centers on the heart function. It can also be thought that in students of the first years who are less adapted to exercise, essential shifts of regulatory mechanisms are noted towards the sympathoadrenal regulation mechanisms prevailing significantly.

For finding out the change in vegetative regulation of the cardiovascular system during adaptation to learning and physical activities in most detail, the authors have conducted the analysis of cardiac rhythm parameters in the same tested students in the years I and III. This analysis has shown that it is over the training day and over the academic year that the patterns of change in regulation of chronotropic function of the heart are the most essential (Table 2).

Table 2 Characteristics of cardiac rhythm pattern in students over the academic year (the average values for the entire group)

Indices		Mo, sec	A_{Mo},%	MxDMn, sec	TI, rel. units
Year I					
Test period					
October	before classes	0,64±0,02	36,7±0,9	0,24±0,02	116,8±4,1
	after classes	0,74±0,01	31,9±1,1	0,30±0,01	73,6±3,8
March	before classes	0,76±0,01	35,5±1,3	0,29±0,01	90,2±3,1
	after classes	0,83±0,01	30,2±0,7	0,33±0,01	58,6±2,9
Year III					
October	before classes	0,71±0,01	39,1±0,9	0,21±0,01	145,3±7,4
	after classes	0,82±0,01	32,5±1,1	0,30±0,01	82,1±7,2
March	before classes	0,75±0,01	31,7±0,9	0,29±0,01	89,9±3,6
	after classes	0,83±0,01	28,9±1,3	0,34±0,01	87,9±2,3

Source: Pozharova G. V., Elaeva E. E., 2018-2019

Analyzing the data of Table 2, it can be concluded that throughout the academic year on average for the group, especially in the first-year students, the initial (before classes) functional status of the cardiovascular system is changed. At the beginning of the academic year, a quite high level of sympathetic effects (Mo = 0,64-0,65 sec, MxDMn = 0,22-0,26 sec) and the central regulation (TI>110) was registered that characterize the condition of "mobilization readiness" for work.

In the research representing the third-year students' cardiac rhythm variability, it is seen that the level of sympathetic effects and central regulation on the activity of the heart is much lower in the initial condition, and parasympathetic effects get stronger: MxDMn goes up, while TI goes 20–30% down ($p<0,01$).

During the training day throughout the year, a steady response of the body to training activities has been noted in the students. The response was characterized by stronger parasympathetic effects (a valid increase in Mo and MxDMn) and by a reduced level of the central regulation (a valid decrease in TI). The intensity of diurnal changes in regulation of chronotropic function of the heart is well illustrated by the adaptive value calculated according to the integral index (TI) as the ratio of the difference of the index value before and after classes to the initial level (in percent).

The first-year students' adaptive value (V_{Ad}) is 36-37% on average and it does not change throughout the academic year. In the third-year students, V_{Ad} amounts to 49% in the first study (before classes) and it is much lower (27%) in the second one (after classes). A steady response of the body to the daily learning activity can be considered as a response of self-adjustment having formed during adaptation to the learning activity.

A lower level of sympathetic effects and stronger parasympathetic effects, a lower level of the central regulation of activity of the heart in the second study both in the students of year I and III give evidence about the overall reduction of the cardiovascular system activation level.

For identifying the influence of the total of learning events, each tested one's level of functioning and pattern of responding to exercise was analyzed according to the behavior of statistical parameters of cardiac rhythm. For this assessment, gradations of the functional status according to the values of TI – the integral value characterizing the balance of regulation levels ensuring the optimum activity level of the heart – have been suggested: TI>180 – tension, TI=180-60 – adaptive regulation, TI<60 – a reduced level of activation of the cardiovascular system. According to the said gradation, in all studies, TI has shown their valid redistribution during the day: in year I, the distribution according to groups did not change during the year, while it did significantly from term I to term II in year III. In the first year, 28% of the students start their training day at a reduced level of activation of the cardiovascular system, and the number of such students validly increases up to 57% ($p<0,01$) by the end of the learning events. In 26% of the students, tension of the cardiovascular system is registered before classes, and their number is not higher than 10% by the end of the classes ($p>0,05$). The number of students whose heart response ranges within the adaptive change zone goes from 46% down to 33% during the day ($p>0,05$).

In the third year, a similar daily pattern has been found: the number of students having a reduced cardiovascular system activation level increases from 22% to 67% ($p<0,01$) from the beginning to the end of classes in October, and in the second study, in term II, their numbers increase both before classes (52%) and after classes (71%). Therefore, over half of all the students of years I and III complete their training day with a lower level of activation of the cardiovascular system which is characterized by a sharp decline in the tone of sympathetic effects, stronger parasympathetic effects, and decentralization of cardiac rhythm control.

5 Conclusion

Finally, the authors would like to note once again that the status of the cardiovascular system is one of the critical factors limiting physical capacities of the body. It follows from that that assessment of blood circulation indices can be an important tool for controlling the efficiency of provision of the body with oxygen and, as a consequence, for prevention of various diseases.

The monitoring survey of anthropometric and physiometric figures, as well as physical fitness results of students of years I and III of the physical education faculty presented in this research has shown essential differences in the level of their physical development and physical fitness against time. First of all, the fact of development of adaptation capacities of the cardiovascular system is of interest, which was manifested in saving its activity both at rest and after exercise. This is a measure of the favorable influence of physical training on the heart, it points to gaining a higher functional reserve of the system and contributes to prevention of pre-pathological and pathological phenomena developing in the cardiovascular system.

Literature:

1. Antonov, A. A., Burov, N. E.: *Systemic Hardware Monitoring*. Annals of Critical Care, 3, 2010. 8-12 pp.
2. Baevskiy, R. M., Berseneva, A. P.: *Assessment of Adaptation Capacities of the Body and Diseases Development Risk.* Moscow: Meditsina, 1997.
3. Elaeva, E. E., Komarova, N. A., Yakimova, E. A.: *The Possibility of Using Amino Acids for Adjusting Functional Status of the Cardiovascular System.* Proceedings of V. I. Vernadsky Crimea Federal University. Series: Biology. Chemistry: Scientific Journal, 2, 2018. 57-64 pp.
4. Golyshenkov, S. P., Melnikova N. A., Tairova M. R.: *The Influence of Exercise on the Aggregation Activity and Lipid Peroxidation of Platelets.* Human Physiology, 6, 2004. 96-102 pp.

5. Ignatyeva, L. E. Elaeva, E. E., Kireeva, Yu. V., Kairova, A. S.: *A Study of Individual "Vegetative Profile" and Functional Status of Cardiac Muscle in Young Biathletes.* Physical Culture and Health: Scientific and Methodological Journal, 5, 2016. 19-24 pp.
6. Kawabata, M., Hirao, K., Takeshi, S., Sakurai, K., Inagaki, H., Hachiya, H., Isobe, M.: *Torsades de Pointes Related to Transient Marked QT Prolongation Following Successful Emergent Percutaneous Coronary Intervention for Acute Coronary Syndrome.* J Electrocardiol, 41, 2008. 117-122 pp.
7. Koreneva, N.: *Dynamics of the Functional State of Sportsmen According to the Heart Rate Variability.* International Journal of Economics and Education, 2(2), 2016. 41-47 pp.
8. Matalyghina, O. A.: *On Diagnosing Functional Reserves of the Body.* Bulletin of St. Petersburg Medical Academy of Postgraduate Studies, 2, 2009. 42-48 pp.
9. Neustadt, B. R., Smith, E. M., Nechuta, T. L.: *Mercaptoacyl Amino Acid Inhibitors of Atriopeptidase. Structure-Activity Relationship Studies of Methionine and S-Alkylcysteine Derivatives.* J. Med. Chem, 15, 1994. 2461-2476 pp.
10. Petrukhin, V. A., Pogrebnyak, Yu. O., Ruzov, V. O.: *Monitoring of Functional and Adaptive Reserves of the Human Body.* Computer Mathematics, 2, 2013. 105-114 pp.
11. Pozharova, G. V., Elaeva, E. E.: *Functional Adaptation to Learning in Students of the Faculty of Physical Education.* Theory and Practice of Physical Culture, 8, 2016. 26-28 pp.
12. Pozharova, G. V., Elaeva, E. E., Yakimova, E. A.: *Particularities of Runners' Training on the Basis of Consideration of Blood Circulation Types and Bioenergetic Profile.* Modern Problems of Science and Education, 4, 2016. 68-70 pp.
13. Ryabova, N. V.: *Mordovian Basic Teacher Training Center as an Innovation Structural Unit of the Institute.* The Humanities and Education, 2, 2012. 41-45 pp.
14. Sauer, A. J., Moss, A. J., McNitt, S., Peterson, D. R., Zareba, W., Robinson, J. L., Goldenberg, I., Hobbs, J. B., Ackerman, M. J.: *Long QT Syndrome in Adults.* J Am CollCardiol, 49, 2007. 329-337 pp.
15. Sazontova, T. G.: *Forming the Higher Resistance of Calcium Pumps of Sarcoplasmic Reticulum of Myocardium in the Dynamics of Adaptation to Stress Actions.* Bulletin of Experimental Biology and Medicine, 3, 1997. 272 p.
16. Yakimova, E., Gryzlova, L., Elaeva, E.: *Seasonal Features of the Clotting Reactions to Physical Load.* Advances in Environmental Biology, 8, 2014. 313-317 pp.

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