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FEATURES OF THE CARDIAC ACTIVITY REGULATION IN ADOLESCENT BOYS IN CONDITIONS OF DISTANCE LEARNING

G.S. Bobkov, M.V. Zvereva, S.N. Bobkova

Moscow City University, Moscow, Russia

Key words: distance learning, cardiovascular system, adolescence, physical inactivity, cardiointervalography.

Annotation. The aim of the study was to analyze the features of the cardiac activity regulation in adolescent schoolchildren of graduating grades who are on distance learning. The article presents the results of assessing heart rate variability of 32 schoolchildren of medical classes of secondary schools in Moscow who do not have chronic diseases, in conditions of full-time and distance learning at rest and with dosed physical activity. As a result of the survey, it was revealed that a significant proportion of boys (60%) after completing distance learning had a state of functional tension of regulatory systems, a shift in the balance of the vegetative nervous system towards its sympathetic division.

Introduction. A need for movement is inherent in a human at birth. It is especially important for a growing and developing organism of a child. Modern schoolchildren experience significant psychological loads related with educational activity, there is a steady tendency of a decrease in their physical and functional fitness [1]. To a large extent, this includes schoolchildren of graduating grades, 64-75% of whom have a low motor activity [2]. A forced sedentary lifestyle related to the educational activity became worse after a transition to distance learning due to the SARS-Cov-2 pandemic. It is known that the cardiovascular system (CVS) is the most important for adapting the organism to environmental influences. Being an indicator that shows the state of the organism, the CVS supports a level of its functioning that would correspond to an adequate work of the blood circulation system. The vegetative nervous system plays a leading role in its adaptation to changing conditions of functioning. [3]

Reduced motor activity, being one of the risk factors for the child's organism, is undoubtedly demonstrated on the functional state of the CVS. At the age of 14-15 years, the processes of puberty are still continuing, accompanied by substantial loads on the central nervous system, expressed in disturbances of autonomous regulation and a decrease in the activity of the parasympathetic division. Disturbances in regulating vegetative functions lead to limiting functional capabilities of the CVS. It

is known that boys are less resistant to stress due to learning loads and a new form of learning (distance) during the period of preparing for the main state exam [4]. One of the methods that allow evaluating a level of the CVS's vegetative regulation, degree of its adaptation to physical inactivity and stress, predict a development of possible pathological state of the organs and systems of the child's organism, is a method of cardiointervalgraphy.

Taking the aforementioned into account, there is a need for a closer study of changes in the CVS's state of schoolchildren of graduating grades in conditions of physical inactivity during distance learning. That is the reason why the aim was to evaluate the CVS's functional state in male adolescent schoolchildren of graduating grades who are on distance learning.

Methods and organization. The study was carried out in the Center of Project Creativity "Start PRO" of the Moscow City University. It involved 32 boys aged 14-15 years who did not have any chronic diseases. Their physical development corresponded to age and gender norms. According to medical records, they belonged to the main medical group (I-II groups of health). They were all students of the final ninth grades of secondary schools in Moscow and were on distance learning from October 2020 to January 2021. A degree of the CVS's adaptation was evaluated with a cardiointervalgraphy method, for which we used the Varicard 2.51 device. This method is non-invasive and allows evaluate comprehensively not only the state of the vegetative nervous system, but also segmental and suprasedgmental divisions of the central nervous system. We evaluated following indicators: heart rate (HR), indicator of activity of regulatory systems (IARS), stress index (SI). To evaluate the total effect of regulation of the CVS's work by the vegetative nervous system (VNS), we assessed indicators of the time analysis: mean square derivation (SDNN) (ms) (standard derivation of normal intervals); activity of the parasympathetic division according to RMSSD (ms); pNN50 (%) – a measure of the heart rate variability (HRV) with a short cycles' duration, expressed in relation to RR-intervals; mode amplitude (AMo) (%) – a share of intervals that correspond to the Mo value. We also assessed indicators of the frequency spectral analysis: TP – total spectrum power (ms^2), HF (%) – high-frequency component of the spectrum, LF (%) – low-frequency component, VLF (%) – very-low-frequency component that characterizes the sympathetic division's activity [5]. All measurements were taken during full-time learning and after the course of distance learning. The vegetative tone was evaluated according to a ratio of spectral analysis indicators HF/LF. At the beginning and at the end of the study, in order to assess the CVS's adaptation to physical loads, we used the Martinet-Kushelevskij test. The results obtained were processed using standard methods of mathematical statistics.

Results and discussion. This study is continuation of the work on the assessment of the functional state of adolescents and young people exposed to loads of various directions [6].

When conducting a five-minute express evaluation of the heart rate variability (HRV) at relative rest in male adolescents who were on full-time learning, average HR indicators were within limits of normal values. There were no significant changes in indicators of time and spectral analysis of the HRV. However, there was a dispersion of indicators inside the group and an upward trend in indicators showing the predominance of the sympathetic curve (SDNN, VLF). It can be related to age features of the vegetative nervous regulation among adolescents, hormonal influence on the VNS, as well as to the fact that after staying at home from March to June 2020, they did not manage to adapt to loads of various direction (table 1). Nonetheless, the spectrum structure remained within limits of the norm, which indicated a moderate predominance of the cardiac activity's autonomic regulation.

After the repeated survey (when distant learning had ended), we revealed an increase in a share of adolescents with a predominance of the sympathetic link of CVS's regulation. Distribution of adolescents according to a description of the autonomic nervous regulation against the background of different learning modes is presented on the figure 1.

Thus, there were 12 boys (37,5%) with a predominance of the sympathetic link of regulation at the beginning of the study, 11 boys (34,4%) – with the parasympathetic link, 9 boys (28,1%) had the balanced regulation of the heart rate. After the course of distance learning, a percentage of adolescents with a predominance of the sympathetic curve increased – 59% (19 people). A number of normotonics (by 33%) and vagotonics (by 8%) decreased.

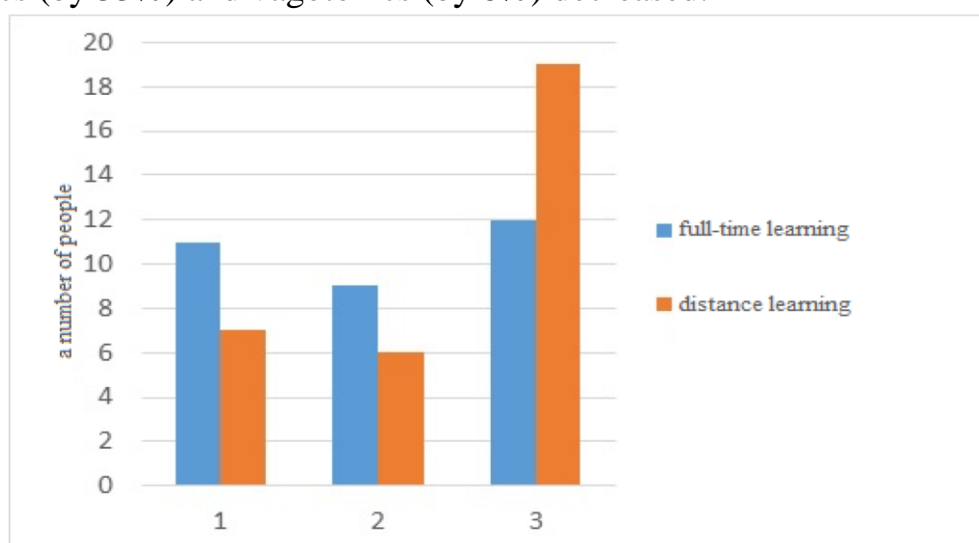


Fig. 1. Analysis of vegetative balance of male adolescents (n=31) in case of full-time and distance learning

Note: 1 – vagotonics; 2 – normotonics; 3 – sympathotonics

Table 1

Evaluation of the CVS's functional system with the HRV method among male adolescents (n=32) at rest in case of full-time and distance learning (M±m)

Indicators	Full-time learning (n=32)	Distance learning (n=32)
HR, beats/min	77,4±3,4	85,7±7,4
SDNN, ms	53,7±9,1	44,2±4,4*
SI, c.u.	101,8±16,3	147,2±29,6*
RMSSD, ms	52,8±6,8	41,5±4,1*
pNN50, %	34,1±9,5	25,5±6,8*
AMo, %	32,8±6,7	43,3±6,1*
TP, ms ²	3841,6±322,4	2328,3±202,6*
HF, %	46,4±6,6	37,8±4,3*
LF, %	30,2±4,7	42,9±6,1*
VLF, %	14,2±4,3	19,5±4,2*
IARS, points	3,2±1,6	4,9±2,7*

Note: * – difference between measurements is significant if $p < 0,05$

When evaluating the influence of distance learning on the CVS's functional state, we discovered a HR increase by 10,7% in average for the group, but its values did not exceed the age norm. The HRV indicators changed. Thus, we noted a significant ($p < 0,05$) decrease of means in following time indicators: SDNN (by 23%), RMSSD (by 21,4%), pNN50 (by 25,1%), and a significant increase in mean AMo values (by 32,1%). Reduced values of RMSSD and pNN50 can be related to an increase in the activity of central mechanisms of the VNS's regulation.

When assessing spectral characteristics of the cardiointervalgraphy (table 1), we revealed significant differences ($p < 0,05$), including: an increase of mean values of the VLF-wave's share (by 37,3%), indicating a state of energy deficit and also characterizing activity of the sympathetic division; of the LF-wave (by 29,6%), indicating an involvement of the vasomotor center in processes of regulation; a decrease on median indicators of the VLF-wave's share (by 18,5%), indicating a reduced parasympathetic influence from the VNS and activation of the sympathetic division. Decrease of the TP's mean values (by 39,4%), showing a total effect of the heart rate's vegetative regulation and SDNN presents involvement of central mechanisms of regulation and suppression of autonomic, accompanied by an increase of the mean SI in the group (by 69%) and the IARS integral indicator by 53%.

An important indicator of the CVS's adaptive capabilities is the IARS, the mean value of which in the group was exceeded the norm initially and also increased after the course of distance learning. The figure 2 presents distribution of children depending on the IARS level in case of full-time and distance learning.

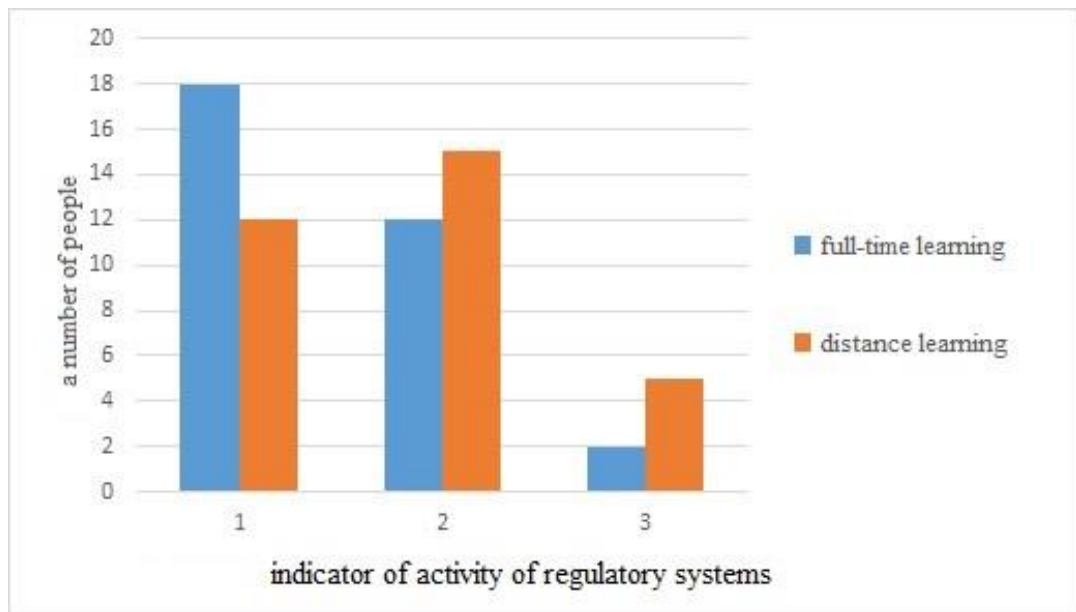


Fig. 2. Distribution of male adolescents (n=32) according to the indicator of activity of regulatory systems (at relative rest) in case of full-time and distance learning

Note: 1 – state of norm or satisfactory adaptation; 2 – state of functional stress; 3 – stress of pronounced stress to the extent to overstrain

In 56% (18 people) of children in case of full-time learning, we noted satisfactory adaptation of the CVS, 37,5% of adolescents were in the state of functional stress (12 people), 2 were in the state of overstrain, which can be related to the fact that these children were those who got sick very often. Physical inactivity, to which they were exposed in the period of isolation, affected the VNS's regulatory mechanisms [7]. Distance learning increased a number of children in the risk group (from 2 to 5 people) who were in the state of overstrained regulatory mechanisms. A number of people who were in the zone of functional stress increased from 12 to 15 people. However, it is important to note that there was a predominance of children with a moderate stress of regulatory systems (10 people) in average for the whole group.

When testing with dosed physical loads, the pulse recovery rate in boys at the beginning of the year on full-time learning was less than three minutes in average, which can be considered as a normal reaction of the CVS. The indicator of response quality (RQI) was within limits between satisfactory and good ($0,47 \pm 0,1$ c.u.) response. SDNN, when conducting the Martinet-Kushelevskij test, was also within limits of normal values. Mean IARS values were increased by 36,6% (table 2), which can be related to the fact that children were at home and did not have a chance to adapt to physical loads.

The repeated functional test after the distance learning revealed a significant increase of recovery rate by 29,7%, decrease of the RQI by 37% in average for the

group. A dispersion in the group was within the range from irrational to satisfactory reaction.

Table 2

Results of the Martinet-Kushelevskij test by adolescent boys (n=32) in case of full-time and distance learning, (M±m)

Indicators	Full-time learning (n=32)	Distance learning (n=32)	p
Pulse recovery rate (min)	2,6±0,2	3,7±0,5	<0,05
RQI (c.u.)	0,47±0,1	0,32±0,2	<0,05
IARS (points)	4,1±0,4	6,5±1,4	<0,05
SI (c.u.)	126,7±22,8	182,4±31,6	<0,05
SDNN (ms)	48,2±12,4	33,6±4,2	<0,05

There was also an increase of the mean IARS value by 32%, stress index – by 30,5%, and a decrease of SDNN by 30,3% (table 2). An increasing number of adolescents with a predominant sympathetic link of regulation (60%) after distance learning (fig. 1), which indicates a growing imbalance of vegetative regulation of heart activity, stress of regulatory systems, especially manifesting when performing dosed physical loads, related to reduced physical fitness of test subjects due to compulsory physical inactivity. The results obtained can be related to high learning loads of adolescent schoolchildren in non-standard conditions (distance learning), an absence of physical loads reasonable for this age, which lead to excitation of cortical and subcortical structures with the activation of higher vegetative centers [8].

The most pronounced changes were in schoolchildren who belonged to the II group of health (children who get sick often). Such state of the VNS can be considered as a premorbid state with a possible development of the CVS's diseases.

Conclusion. Therefore, using distance form of teaching adolescents affects the effectiveness of adaptation mechanisms of the CVS's regulation and leads to an enhanced central link of regulation, a shift of vegetative regulation towards the sympathetic link of the VNS. These changes are especially pronounced in adolescents who get sick very often.

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Information about the authors: German Sergeevich Bobkov – Post-Graduate Student of the Department of Adaptology and Sports Training of the Moscow City University, Moscow, e-mail: gornostay22@mail.ru; **Marina Valentinovna Zvereva** – Candidate of Medical Sciences, Associate Professor of the Moscow City University, Moscow, e-mail: mario65@yandex.ru; **Sof'ya Niazovna Bobkova** – Candidate of Medical Sciences, Associate Professor of the Moscow City University, Moscow, e-mail: sonibo@mail.ru.