Effect of motor activity on heart rate in adolescent children

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Abstract. The study of heart rate variability parameters in adolescent children was carried out. Heart rate, cardiac cycle duration and several parameters of rhythmic activity of the heart at rest and after a short-term exercise test were studied. It was found that in adolescent children short-term physical load causes statistically significant changes in almost all studied parameters of cardiac activity. One of the most important indices characterising the rhythmic activity of the heart, the stress index in adolescents after motor exercise increased significantly. Its values indicate an increase in the activity of the sympathetic link of the autonomic nervous system after the load. At the same time, the values of the stress index of heart rate variability after the load did not exceed the values characterising overstress in the central nervous mechanisms of regulation of rhythmic activity of the heart.

1 Introduction

Heart rhythm is regulated by various mechanisms - humoral and nervous. A special place is occupied by central nervous mechanisms of regulation of rhythmic activity of the heart. The study of the state of central nervous mechanisms of heart rhythm regulation allows us to answer the question: whether there is an overstress in the nervous regulation of heart work, which of the links of autonomic nervous regulation is under stress. The analysis of central nervous mechanisms of heart work became possible due to electrocardiographic studies of cardiac activity. To study HRV parameters it is necessary to record a long ECG, on which there is a continuous series of cardiac cycles. Through the analysis of this series, a number of HRV parameters can be calculated [6]. Among the frequently analysed parameters of the rhythmic activity of the heart, the important ones are mode, mode amplitude, variation sweep and stress index [6].

The method of studying heart rate variability parameters has proved to be a useful approach in assessing the response of the adult organism, including children, to physical activity. During physical exertion, as a rule, there is an increase in the activity of the nervous system regulating the activity of the cardiovascular system and the rhythmic activity of the heart [2]. The nature of the response from the central nervous mechanisms of regulation can be assessed by analysing the above parameters of HRV. In adolescent children, the mechanisms of neural regulation of resting heart rhythm are generally similar to those of adults. Although there may be peculiarities associated with endocrine

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restructuring of the child's organism and instability of the nervous system during adolescence. When presented with a physical load, the organism of adolescents may react differently than the organism of an adult. Therefore, studies of the reaction of the cardiovascular system, central nervous mechanisms of regulation of the rhythmic activity of the heart are relevant. The aim of this work is to study the parameters of heart rate variability to motor load in adolescent children.

2 Materials and Methods of the Study

Electrocardiographic study was conducted with adolescent children - 11-15 years old. Adolescent schoolchildren -15 girls and 15 boys were studied. Adolescent children without cardiovascular system complaints were selected for the study of ECG and HRV parameters.

ECG study in children was carried out in the morning hours. ECG registration was performed using an electrocardiograph ArMaSoft-12-Cardio (ArMaSoft-12-Cardio). This electrocardiograph is fully automated. The electrocardiograph is connected to a computer. Software for quantitative analysis of recorded electrocardiograms is installed on the computer. In order to calculate HRV parameters, it is necessary to record sufficiently long ECG recordings in the subjects. Therefore, long ECG recordings were made in children to obtain a series of approximately 100 cardiac cycles. ECG recordings in children were made at rest and immediately after performing 20 squats for 30 seconds. This motor exercise is referred to as the Martinet test. The following HRV parameters were calculated individually for each child: mode, mode amplitude, variation spread and stress index. The quantitative data of the experimental study were processed using the statistical programme "Biostatistics". The paired Student's criterion was used as a criterion.

3 Results of the Study and Discussion

Any motor loads on the human body cause significant shifts in the work of the cardiovascular system, the heart. When studying the effect of two types of motor loads - dynamic and static - on the work of the heart, it was found that there are significant changes in the work of the heart. First of all, there is an increase in HR [2]. Moreover, the more intense the load, the higher the increase in HR. As can be seen in Table 1 and figure 1 of the data of HR before and after the load Table 1, Figures 1, its value increased significantly after the motor load. The children's HR was 78.2 beats per minute before and 106.4 beats per minute after the exercise. In percentage terms, the increase in HR was 26.5%. According to the literature, the increase in heart rate during exercise can range from 20 to 40%. The increase in HR depends on the intensity and duration of physical activity. If there is a too high increase in HR after dosed motor loads, it may indicate poor adaptation of the cardiovascular system to physical activity. Our adolescents have a moderate increase in HR.

Table 1. Heart rate and cardiac cycle duration in adolescent children after the motor test

ECG parameters	Tranquillity	Sample
HR, beats/min	78,2±2,61	106,4±3,55***
Cardiac cycle (R-R), s	0,77±0,026	0,56±0,019***

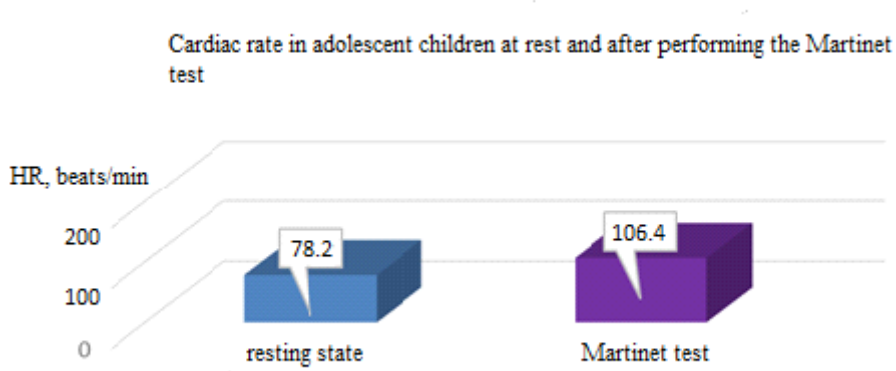

Fig.1. Effect of short-term physical activity on adolescent heart rate

The duration of the cardiac cycle after the test in adolescent children significantly shortened Table 1, figure 2. The duration of the cardiac cycle depends on HR. With increasing HR, the cardiac cycle shortens.

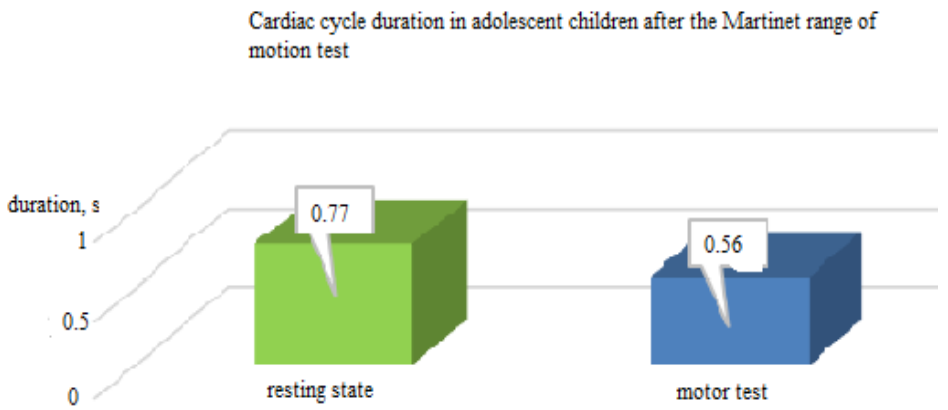

Fig. 2. Change in cardiointerval duration as a result of short-term physical work performance

The electrocardiogram parameters studied in adolescents at rest did not exceed the normative limits [3].

As it was mentioned above, as a result of motor activity, HR and cardiac cycle duration change. Based on these data, we should expect changes in the parameters of heart rate variability. The issue of the relationship between heart rate parameters and physical activity was investigated in [7, 8]. It was shown that some HRV parameters can change under the influence of physical load. Our study in adolescent children shows that all three HRV parameters - mode, mode amplitude, variation range - change after the Martinet test Table 2, figure 3, 4, 5. The duration of variation span and mode decreased after the load Table 2, figure 3, 4, and the amplitude of mode, on the contrary, significantly increased Table 2, figure 5.

Table 2. Heart rate variability indices in adolescents when performing the Martinet test

HRV	Fashion (Mo), s	Fashion amplitude (AMo), %	Variation spread (X), s
Rest	0,76±0,025	35,5±1,18	0,27±0,009
Sample	0,49±0,016	43,8±1,46	0,22±0,007
p	***	***	***

Figure 3 shows a rather sharp shortening of the mode duration. Decrease of the mode value after the test is equal to 36%. It should be assumed that this shortening is caused by increased sympathetic influences on the sinus pacemaker. Modes are the most frequently occurring values of the cardiac cycle during heart work for a certain period of time.

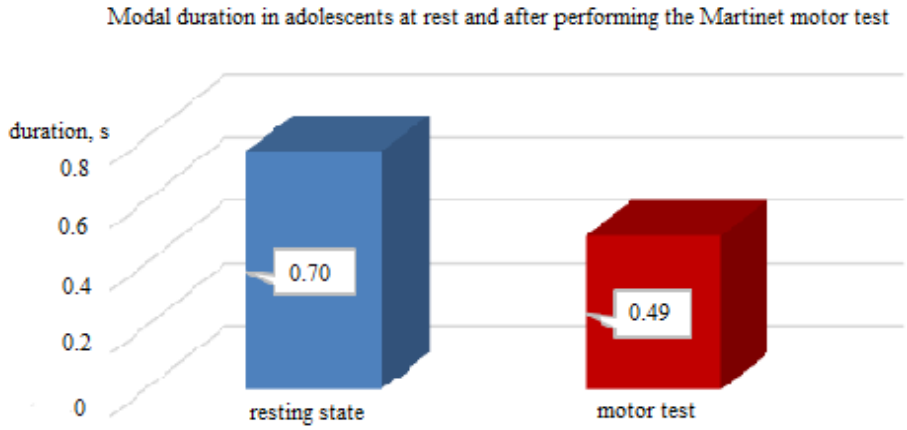

Fig. 3. Fashion duration in adolescent children depending on the functional state of the organism

Decrease in the duration of variation span after the test was 18.5% figure 4. The duration of the variation range reflects to a greater extent the influence of the parasympathetic nerve branch on the heart work. Here we see that the width of the variation span significantly decreased after the load.

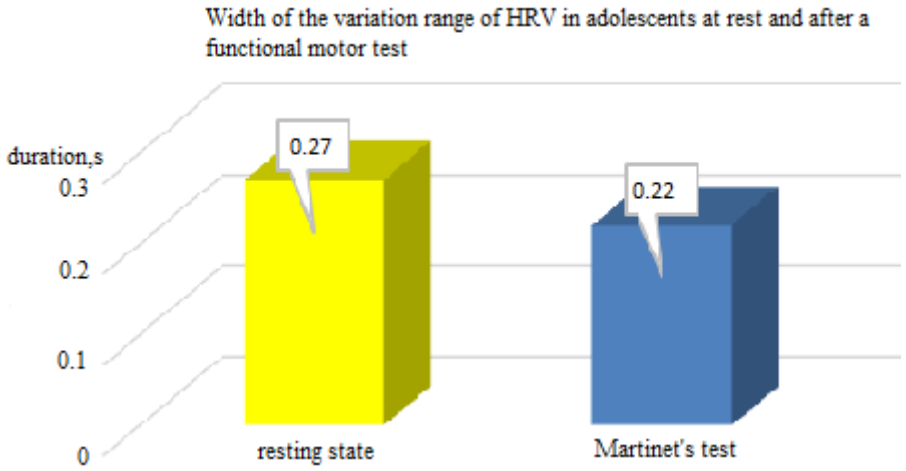

Fig. 4. Variation spread (X) in adolescent children after short-term physical activity

After the motor test, the amplitude value increased by approximately 19% Table 2, figure 5. The mode amplitude reflects the proportion of cardiac cycles closest in duration to the average duration of

the cardiac cycle. Higher amplitude values mean stronger sympathetic influences on the heart rhythm. For example, at rest in adolescents the value of mode amplitude was 35.5%, and this value was in the interval of normotonia (eutonia) - 32-41% [6], and after exertion it increased to 43.8%, which according to the same literature source corresponds to sympathicotonia (>41%).

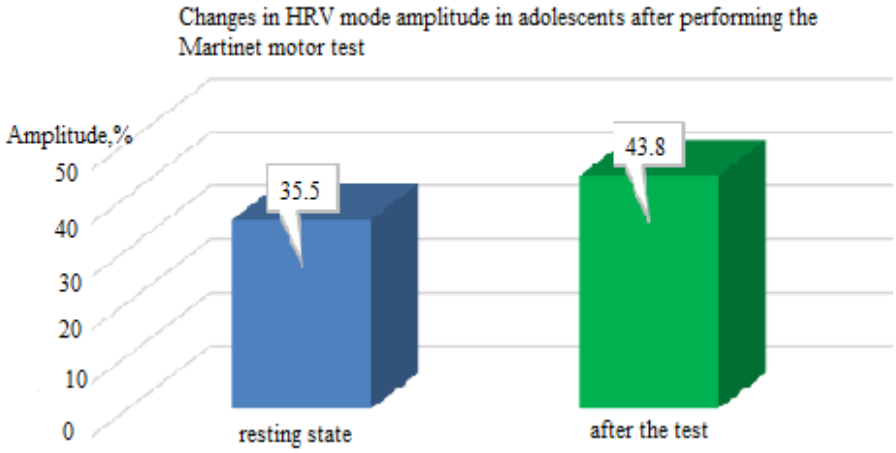

Fig. 5. Effect of physical activity in adolescents on the amplitude of heart rate variability mode

Thus, after physical exercise, HRV parameters changed significantly. The changes in all three HRV parameters indicate that the adolescents after the test increased the influence of sympathetic nervous regulation on the rhythm of HRV.

Indices of the rhythmic activity of the heart after performing the Martinet test in adolescents also changed. Heart work, activity of its excitable elements (sinus node, atrioventricular node, bundle of Hiss, Purkinje fibres, cardiomyocytes) are regulated by humoral and nervous mechanisms [4]. Nervous mechanisms play a key role in the regulation of cardiac excitability. In particular, two links of the autonomous nervous system - parasympathetic and sympathetic. They provide adaptation of heart function to the influence of external and internal factors, including physical load. The influence of nervous regulation on the heart work is reflected by HRV indices. They can indicate: whether there is an overstress in the work of the heart, in which of the branches has a predominant influence on the work of the heart. Among HRV indices, the tension index most fully reflects the influence on the heart work of each of the links, the balance of two links of the autonomous nervous system. As can be seen from Table 3 and Figure 6, at rest the values of HRV indices in adolescents corresponded to the norm [1, 6]. According to the data of different authors, the value of IN, for example, in resting standing is 71-120 c.u. [6] or 80-150 c.u. [6] or 80-150 c.u. [1].

Table 3. HRV indices in adolescents during physical activity

HRV indices	Regulatory systems voltage index (RSI), c.u.	Vegetative balance index (VBI), c.u.	Autonomic rhythm index (ARI), c.u.	Indicator of adequacy of regulation processes (RI) c. u.
Rest	86,6±2,89	120,4±4,01	4,87±0,162	47,7±1,59
Trial	203,1±6,77	199,1±6,64	9,27±0,309	89,4±2.98
p	***	***	***	***

After exercise, the IN increased quite significantly, which could indicate a moderate adaptation to exercise of the cardiovascular system and nervous regulatory mechanisms. That is, after the test, the IN value exceeded the normative limits characteristic of the resting state. Its value Table 3, was higher than the literature norm of 120 c.u. [6] and this index corresponded to sympathicotonia. At the same time, motor load in adolescents did not cause overstrain of nervous regulatory mechanisms, as

the value of IN after the test did not exceed 300 u.u. According to Kovyazina O. L. [5], if the value of IN exceeds 300 u.u., it indicates the tension of regulatory systems. The index of IN in the adolescents examined by us did not exceed this limit.

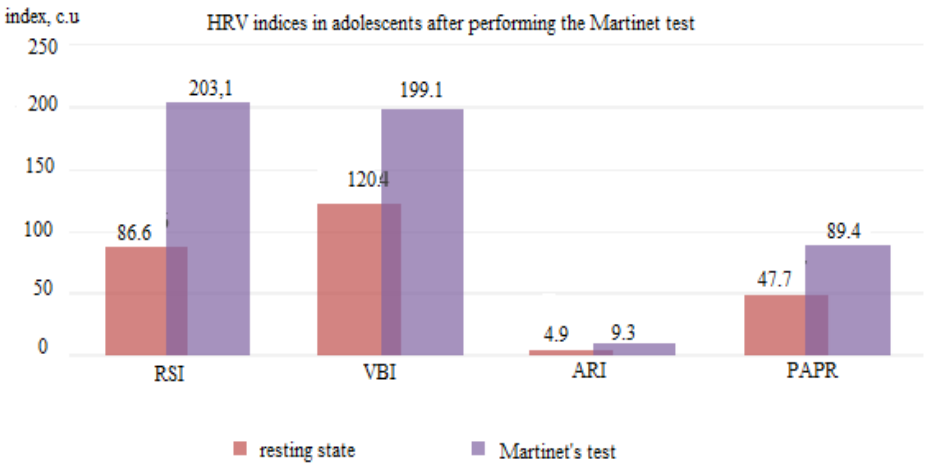

Fig. 6. Influence of motor load in adolescent children on the value of heart rate variability indices

If we compare the reaction of adolescents and children of primary school age to physical load, the value of the stress index in children of primary school age, according to our data, went beyond 300 c.u. Central nervous mechanisms of heart rhythm regulation are not yet fully formed in children of primary school age. In adolescent children, due to the increased influence of vagus on the heart rhythm, there is no overstressing of the mechanisms of nervous regulation of the heart rhythm.

The other HRV indices - HRVR, IVR and PAPR - were normal at rest, but after load they also significantly increased. In contrast to children of primary school age, in adolescents the load did not cause excessive activity of the sympathetic link. In general, we can conclude that adolescents have a moderate adaptation to motor load, as the AN does not exceed the value of 300 uA.

4 Conclusion

Analysis of the central nervous (autonomic) mechanisms of regulation of rhythmic activity of the heart using HRV is a powerful tool for assessing human adaptation to physical activity. Our analysis of HRV in adolescent children shows that at rest their HRV parameters were within the normative limits. At rest, they have a rather low index of stress index (stress index), which indicates a satisfactory state of the regulatory mechanisms of the heart. Based on the results of the study, the following conclusions were made: HR and cardiac cycle duration in adolescents significantly change after motor exercise - HR increases and cardiac cycle shortens; mode duration (Mo) and width of variation range in adolescents significantly decrease after the Martinet test, and the mode amplitude significantly increases; HRV indices - IN, IVR, VPR, PAPR - significantly increase after the Martinet test; the change in HRV parameters after motor exercise is caused by increased activity of sympathetic sympathectomy; the change in HRV parameters after the motor exercise is caused by increased activity of the sympathetic sympathectomy in adolescents.

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