ANALYSIS OF THE ORGANISM ADAPTIVE RESERVES OF DIFFERENT AGE GROUPS

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Abstract. The article discusses the organism`s adaptive capabilities of different age groups in the population with the use of cardiointervalography and hemodynamic parameters. There was a decrease in the total power of the heart rate variability spectrum and the power of all spectral parameters with an increasing age. In age groups 1 and 2, LF, % and VLF, % were more pronounced, there was a significant predominance of VLF, % in group 2, which reflected an increase in the level of the sympathetic link regulation activity. A more significant increase in the power of very low frequency oscillations indicates an increase in the influence of the central circuit of regulation along with an increase in the cerebral ergotropic influences. Assessment of oxidative metabolism by fluorescence spectroscopy showed an increase in the indicator in group 2, with a tendency to decrease in group 3 as compared to the values of group 1. The performed analysis of the frequency-amplitude spectrum revealed changes in the reactivity of the structures of the microvasculature depending on age. An increase in the volume of blood entering the microcirculation system was recorded, but the regulatory effect on microcirculation was different: group 2 was dominated by central mechanisms of regulation, in group 3 there was a predominance of local regulatory mechanisms. Thus, with age, there is a decrease in the adaptive reserves of the body with a tension in the regulatory vegetative homeostasis and a transition from nervous mechanisms of regulation to a lower level of humoral mechanism.

Keywords: adaptation, age, cardiointervalography, microcirculation.

List of Abbreviations

VLF – very low frequency range
LF – mid-frequency range
HF – high-frequency range
TP – total power of the spectrum
HRV – heart rate variability
LF/HF – index of vagosympathetic interaction
Amo – mode amplitude
IVB – index of vegetative balance
Ae – endothelial component
An – neurogenic component
Am – myogenic component
Ar – respiratory component
Ac – heart rate component
ST – stress index
M – microcirculation index
IOM – indicator of oxidative metabolism

Introduction

The level of health is determined by the degree of adaptation of the body (Baevsky & Ivanov, 2000). Adaptive processes that carry out the adaptation of the body to changing conditions of the external and internal environment are determined by the reserve capabilities of the body (Musabekova *et al.*, 2016). The higher the level of functional reserves, the lower the degree of tension of these mechanisms necessary for adaptation. A decrease in the adaptive capabilities of the body causes the transition from a state of health to illness and determines a decrease in the ability to adequately respond not only to social and labor, but also to ordinary daily stresses (Meerson, 1981; Deryugina *et al.*, 2019).The deterioration in the health of the population of our country and the resulting increase in morbidity and mortality rate are the result of many factors, among which the leading role is played by: a decrease in the adaptive capabilities of the body (a decrease in resistance to adverse effects, a decrease in the body's defenses); a sharp deterioration in the environmental situation (sanitary and hygienic, industrial, social factors) (Baranov *et al.*, 2004).

In connection with the above, it is necessary to analyze the adaptive capabilities of the organism because a system for predicting the state of health and working capacity can be built only on the basis of their assessment. It is advisable to evaluate the state of the body's adaptive-compensatory mechanisms by changes in the electrophysiological properties of cardiomyocytes, determined by the method of cardiointervalography (Gimaev *et al.*, 2009) because the regulation of the function of the heart is closely associated with the work of various neurohumoral circuits.The activity of such circuits is manifested in heart rate variability (HRV), which reflects the processes of various homeostatic functional systems' self-regulation (McCraty & Shaffer, 2015; Thayer & Lane, 2009). At the same time, the appearance of negative characteristics in cardiointervalography can surpass changes in the clinical and laboratory parameters (Egorova *et al.*, 2015). Pronounced deviations of cardiointervalography values are the first signs of tension in adaptive-compensatory mechanisms (Vlasova, 2016).

Taking into account the physiological mechanisms of adaptation processes, one should not forget that not only does the characteristic changes of the cardiac activity occur, but also the compensatory changes in hemodynamics and microcirculation may develop, which differ depending on the state of the body (Kosovskikh *et al.*, 2013).

At the same time, the microcirculatory bed provides timely adequate blood supply to the corresponding structures of the body (Baevsky, 2006). Analysis of microcirculation parameters and its relationship with cardiac rhythmogenesis is a potential approach to studying the characteristics of the adaptive activity of people of different age groups.

The aim of the work was to compare the characteristics of cardiointervalography and hemodynamic parameters in people of different age groups, to identify their possible differences in order to study the mechanisms of the adaptive capabilities of the organism of different age groups of the population.

Materials and Methods

The study involved volunteers from Nizhny Novgorod divided into three age groups. Group 1 – individuals up to 35 years old, group 2 – from 35 to 50 years old, group 3 – 50 years and older. All patients were informed and consent was taken to be included in the study. The study was complies with the Helsinki Declaration of the world medical Association «Recommendations for doctors engaged in biomedical research involving people», and by the Local Ethics Committee of Institute of Biology and Biomedicine «Lobachevsky State University of Nizhny Novgorod».

Cardiorhythmogram registered by a standard methodology (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Heart rate variability. Standards of measurement, physiological interpretation and clinical use. Circulation. 1996; 93:1043–56). ECG was recorded using the «Reo-spectrum» device (Neurosoft, Russia). Analysis of cardiointervalography, spectrograms, histograms was carried out in the «Poly-Spectrum» program. Vegetative tone was examined in the supine position. Recording of ECG signals with their analog-to-digital conversion and the storage of data in the computer memory was performed after 10-minute of adaptation of the subjects in the supine position for 5 minutes (at least 300 cardiointervals were analyzed).

From the characteristics of HRV, the indicators of the spectrogram and histogram were evaluated (Vlasova *et al.*, 2016). The functional state of the vegetative nervous system was assessed based on the power of the frequency components of the heart rate spectrum: very low frequency range (slow waves of the second order) – VLF (0–0.033 Hz); mid-frequency range (slow waves of the first order) – LF (0.033–0.11 Hz) and high-frequency range – HF (0.11–0.5 Hz).

When evaluating cardiointervalography, the following were analyzed: TP – the total power of the spectrum of heart rate variability (HRV) (the total absolute level of regulatory systems activity and the general functional state of the body); LF/HF – relative activity of the subcortical sympathetic nerve center, index of vagosympathetic interaction; ST – stress index – the index of tension of regulatory systems, which characterizes the activity of the mechanisms of sympathetic regulation, most fully informs about the degree of tension of the body's compensatory mechanisms; Amo – mode amplitude – is the number of interval values corresponding to Mo, and is expressed as a percentage of the total number of cardiocycles of the array, determines the state of activity of the sympathetic division of the autonomic nervous system; IVB – index of vegetative balance.

The state of microcirculation was assessed by skin laser Doppler flowmetry (LDF), which was carried out using a laser analyzer of capillary blood flow «LASMA ST» (OOO NPP «LAZMA», Russia) , which allows for a comprehensive assessment of microcirculation. Initial LDF-grams were recorded for 5 minutes at rest, at a temperature of 21-22 ºC from the skin of the distal phalanges of 2nd finger of both hands (in the sitting position).

When analyzing the amplitude-frequency spectrum, we analyzed the normalized characteristics of the rhythms of blood flow oscillations: endothelial (Ae), neurogenic (An), myogenic (Am), respiratory (Ar) components, and heart rate (Ac). We also assessed the microcirculation index (M) – perfusion and POM – an indicator of oxidative metabolism.

Experimental data was processed statistically using Microsoft Excel. Parameters such as the arithmetic mean of the sample population and the standard deviation according to Student's criterion were calculated. Differences were considered significant at $p < 0.05$.

Results

When comparing vegetative system balance parameters in the studied groups, a clear dependence of the decrease in spectral parameters on age was revealed, in particular, TP decreased in group 2 by 60%, in group 3 by 68% relative to group 1, respectively (Fig. 1).

At the same time, the distribution of the heart rate spectrum was dependent on the age group. In group 1 (up to 35 years old), LF- and VLF-fluctuations prevailed, which amounted to 36.29% and 38.54% of the total power of the spectrum (Fig. 2). In group 2, the same trend was seen in the distribution of frequency characteristics, but with a greater severity of the VLF component, which reached 64.18%. In the 3rd age group, there was a decrease in the VLF fluctuations as compared to the 2nd group and the approach of this indicator to the values of the 1st group: VLF fluctuations amounted to 43.34% of the total power of the spectrum.

Against the background of a decrease in the power of VLF oscillations in group 3, a decrease in LF oscillations to 23.3% and an increase in the HF component to 33.4% of the total power of the spectrum were recorded. In addition, in the 3rd age group there was a decrease in the LF / HF coefficient by 2 times as compared to the 1st group and 3 times in comparison with the 2nd group, while in the 2nd group this indicator increased relative to the 1st group (Fig. 3).

Analysis of Amo, IVB and SI showed an increase in these parameters depending on the age group. The maximum indicators were recorded in the 3rd group. The severity of changes in these indicators was significant between groups 1 and 2, while between groups 2 and 3 the difference in indicators was less pronounced (Fig. 4).

The values of microcirculation indicators are shown in Fig. 5. In groups 2 and 3, a significant increase in the microcirculation index was observed, 31% and 40% relative to the values of group 1, respectively.

The amplitude of neurogenic oscillations (An) significantly decreased in both the groups 2 and 3 by 16% and 39% relative to the values of group 1, respectively (Fig. 6). In the 2nd group, the values of the amplitude of the endothelial rhythm (Ae) significantly increased by 128%, while in the 3rd group this indicator decreased by 50% relative to the values of the 1st group. Only in group 3 the amplitude of myogenic fluctuations (Am) decreased by 42% relative to the values of group 1. Blood pressure values were comparable in all groups. The values of the heart rate amplitude (Ac) decreased by 38% in the 2nd group as compared to the values of the 1st group.

Evaluation of oxidative metabolism by fluorescence spectroscopy showed an increase in the indicator by 30% in group 2, with a downward trend in this indicator in group 3 relative to the values of group 1 (Fig. 7).

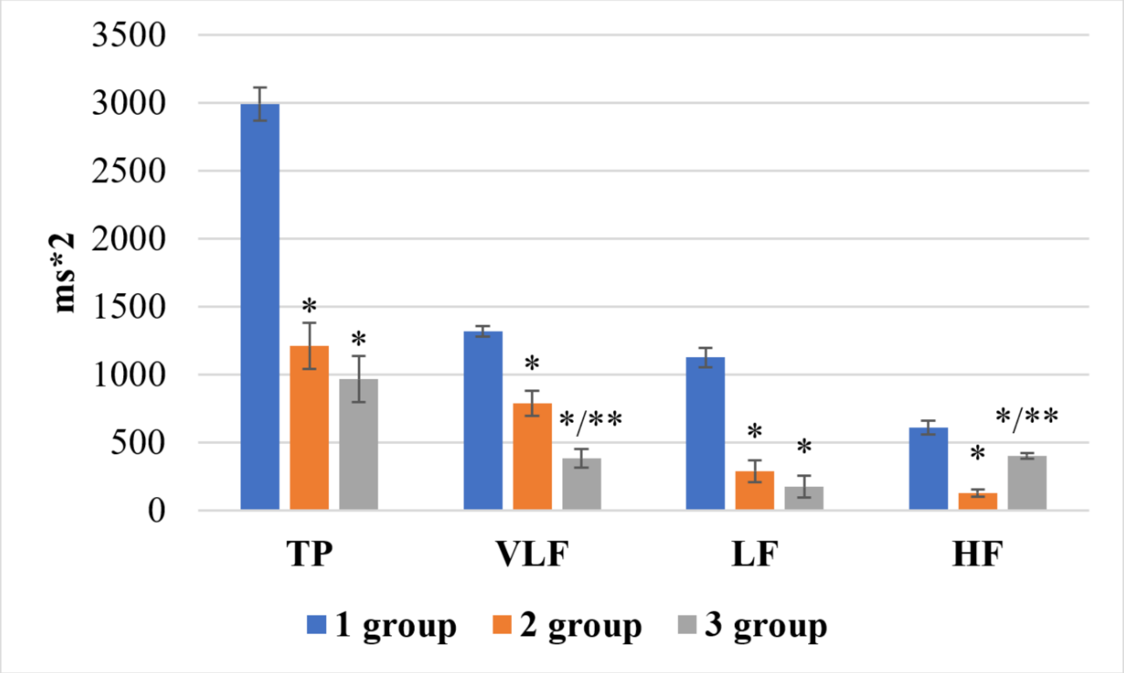

Fig. 1. Indicators of TP, VLF, LF, HF (ms*2) of different age groups
Note: * – statistical significance in relation to group 1 ($p < 0.05$);
** – statistical significance of indicators of group 3 to group 2 ($p < 0.05$)

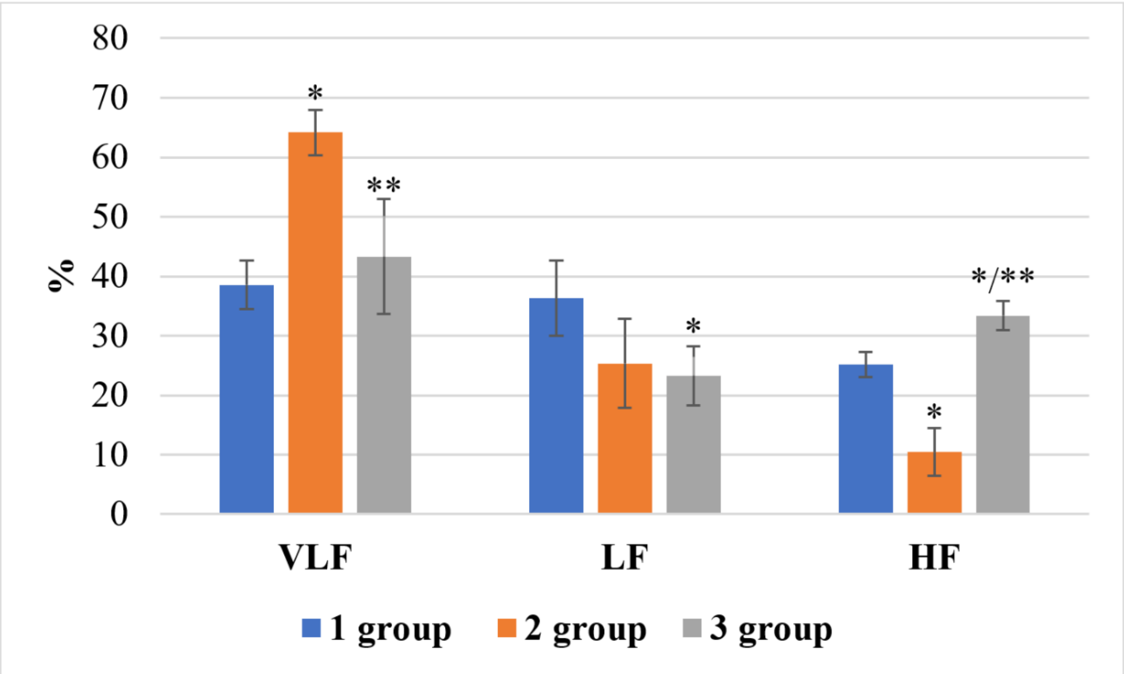

Fig. 2. Indicators of VLF, LF, HF (%) of different age groups
Note: * – statistical significance in relation to group 1 ($p < 0.05$);
** – statistical significance of indicators of group 3 to group 2 ($p < 0.05$)

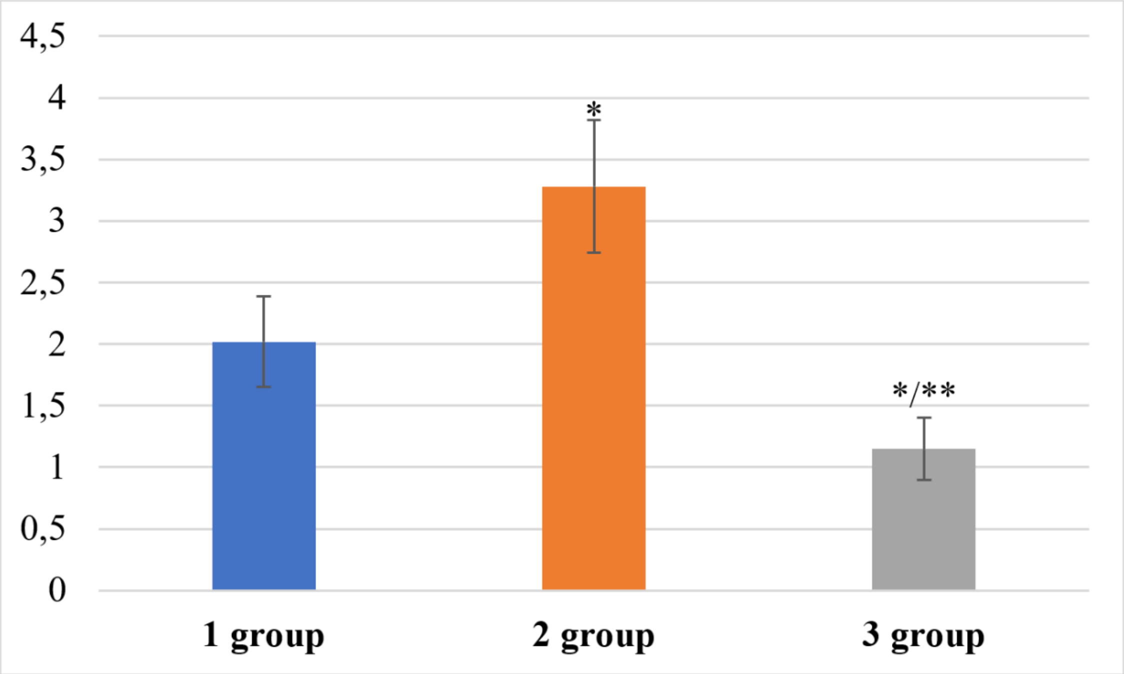

Fig. 3. LF/HF index of different age groups
Note: * – statistical significance in relation to group 1 ($p < 0.05$);
** – statistical significance of indicators of group 3 to group 2 ($p < 0.05$)

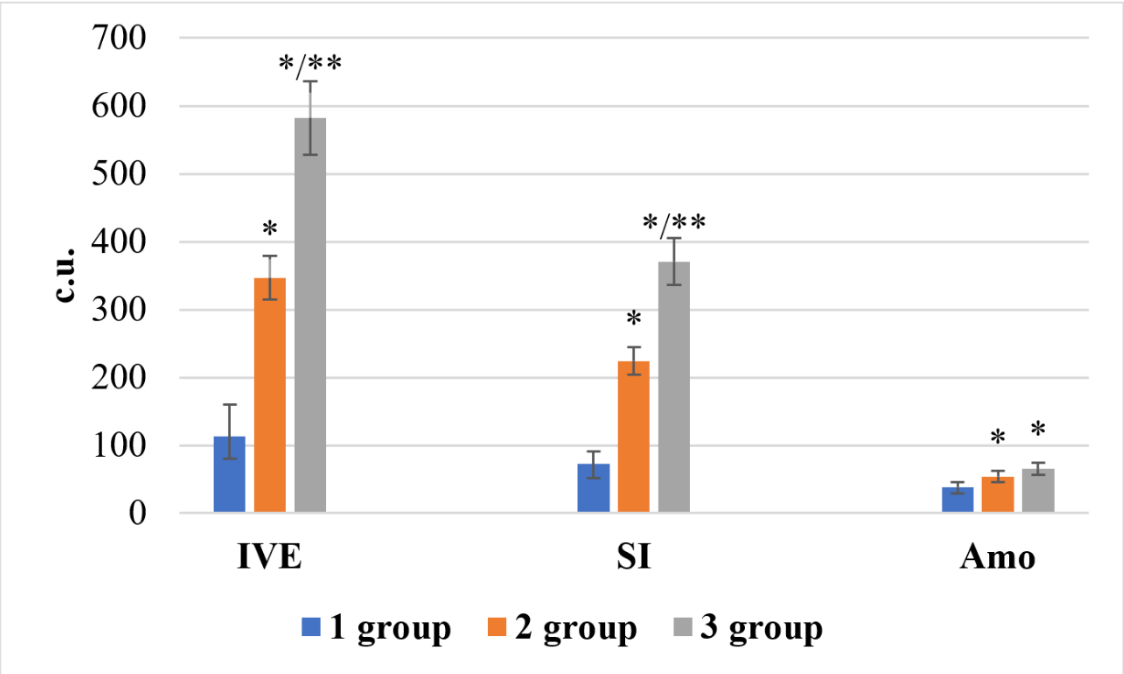

Fig. 4. Indicators of IVE, SI, Amo (c.u.) of different age groups
Note: * – statistical significance in relation to group 1 ($p < 0.05$);
** – statistical significance of indicators of group 3 to group 2 ($p < 0.05$)

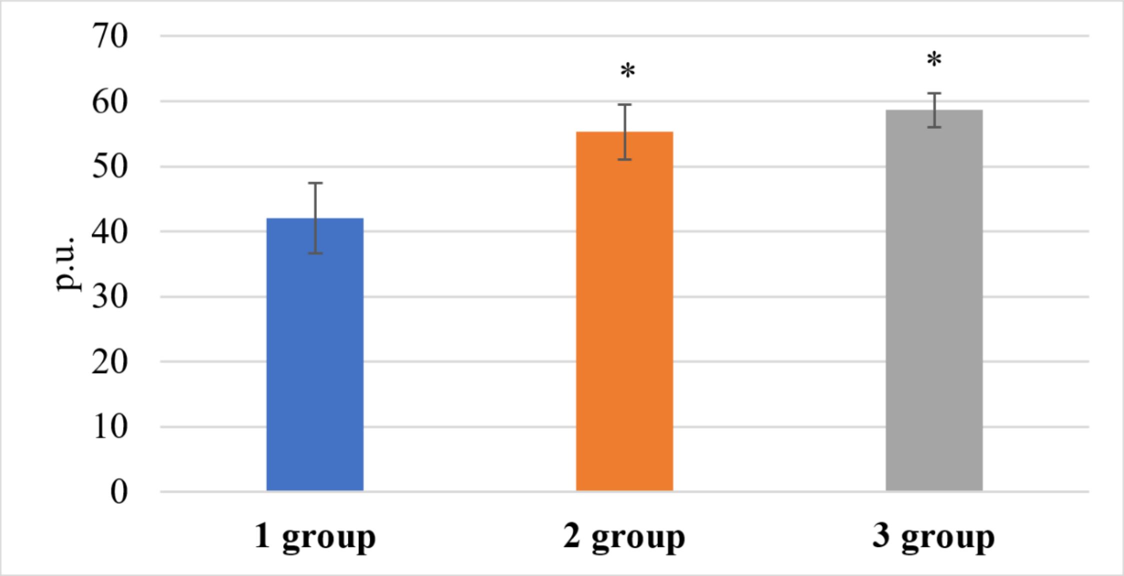

Fig. 5. Microcirculation index (M) (p.u.) of different age groups
Note: * – statistical significance in relation to group 1 ($p < 0.05$);
** – statistical significance of indicators of group 3 to group 2 ($p < 0.05$)

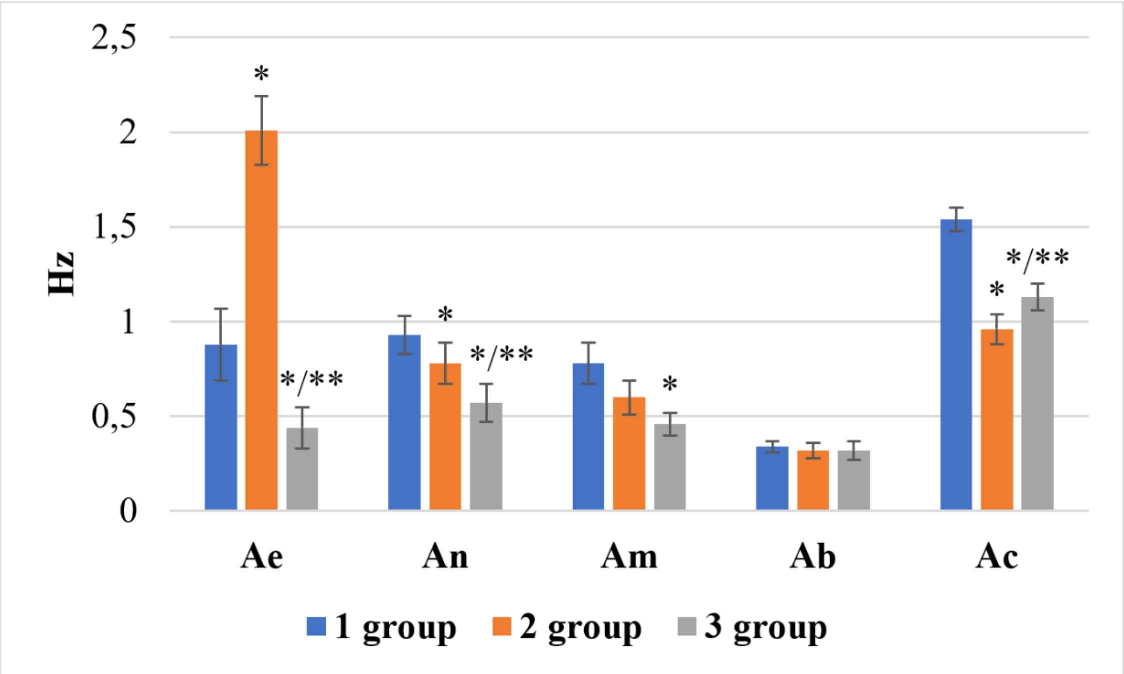

Fig. 6. Indicators Ae, An, Am, Ab, Ac (Hz) of different age groups
Note: * – statistical significance in relation to group 1 ($p < 0.05$);
** – statistical significance of indicators of group 3 to group 2 ($p < 0.05$)

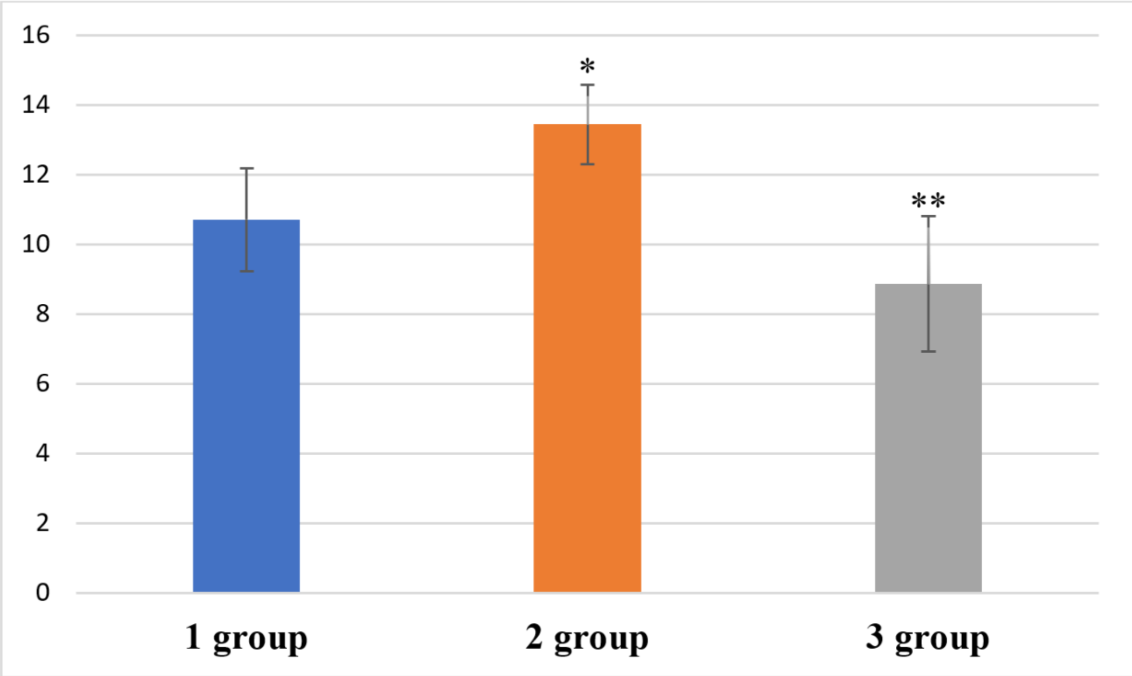

Fig. 7. Oxidative Metabolism Index (OMI) (p.u.) of different age groups
Note: * – statistical significance in relation to group 1 ($p < 0.05$);
** – statistical significance of indicators of group 3 to group 2 ($p < 0.05$)

Discussion

The decrease in spectral parameters depending on age indicates a decrease in the activity of the autonomic nervous system as a whole. At the same time, in group 1 (up to 35 years old) and group 2 (35-50 years old), LF, % and VLF, % prevailed compared to the 3rd age group, with a greater severity of VLF, % in the 2nd group.

This data reflects the influence of the sympathetic division of the autonomic nervous system on heart rate variability and the activity of central ergotropic and humoral-metabolic mechanisms of heart rate regulation (Kotelnikov *et al.*, 2002). This confirms the growth of the vagosympathetic interaction index (LF/HF), which reflects the excess of sympathetic regulation of the heart rate over parasympathetic regulation. At the same time, the increase in VLF power in group 2 can be regarded as an indicator of the activity of suprasegmental ergotropic mechanisms (an increase in the influence of higher vegetative centers on subcortical structures, Vayne *et al.*, 2000). However, a significant increase in the indicator can characterize the depletion of the regulatory systems of the body (Vlasova *et al.*, 2016).

A significant ($p < 0.05$) decrease in the proportion of VLF waves in the 3rd age group indicates an improvement in the state of the autonomic nervous system relative to the 2nd group (Egorova *et al.*, 2015).

At the same time, an increase in the power of high-frequency heart rate oscillations reflects the activity of autonomous parasympathetic mechanisms (Belyavsky, 2008).

In the older age group, there is a decrease in the influence on the myocardium of both sympathetic and parasympathetic (to a lesser extent) influences and a transition from higher (nervous) mechanisms of heart regulation to a lower level.

It should be noted that in the analysis of neurohumoral influences on heart rate, the established progressive decrease in vegetative regulation of heart is probably due to the fact that after 35–40 years the density of adrenergic plexuses of the myocardium decreases, while the density of cholinergic plexuses remains constant (Levy *et al.*, 1994). Morover, with age, there is a change in the baroreceptor zones of the aortic arch, brachiocephalic trunks and carotid sinuses, which can also underlie the decrease in vegetative regulation of heart parameters (Head, 1994). In the older age group, there is a decrease in the influence on the myocardium of both sympathetic and parasympathetic (to a lesser extent) influences and a transition from higher (nervous) mechanisms of heart regulation to a lower level.

Taking into account the growth of such indicators as Amo, IVB and SI depending on age, it should be noted the increase in a certain degree of mismatch of the structural and functional organization of biosystems, there is an increase in the degree of tension of the body's compensatory mechanisms with age (Shpak & Rabinovich, 2008; Stepanova *et al.*, 2017). Analysis of cardiointervalography indicates a decrease in nonspecific adaptive reactions of the body with the tension of regulatory autonomic homeostasis, which, in individuals of group 2, is characterized by a shift in the balance of autonomic tone towards the predominance of the suprasegmental (central) regulation circuit.

Determining the degree of regulatory systems tension is important for assessing the characteristics of the body's adaptation to various loads and the possible development of maladaptation of the body to short-term and strong environmental influences or under the influence of stress (Anopchenko & Agranovich, 2016).

The growth in the increase of the body's reactivity tension confirms the increase in oxidative metabolism in the 2nd age group. It is known that indicators of oxidative metabolism reflect the compensatory capabilities of the body and largely determine its adaptive potential (Baraboy, 2006; Deryugina *et al.*, 2020).

To ensure the intensity of biological oxidation processes and energy -synthetic reactions requires the inclusion of compensatory mechanisms to maintain homeostasis. Such a mechanism can be a change in the state of the microvasculature, involved in transcapillary exchange and providing blood saturation of organs and tissues (Deryugina *et al.*, 2018).

An analysis of the results of the microvasculature determined that in group 2, against the background of a decrease in the amplitude of neurogenic fluctuations, an increase in endothelial fluctuations in blood flow was observed, which indicates an increase in neurogenic tone and a weakening of endothelial function, reflecting the predominance of vasoconstrictor factors, an increase in vasomotor activity of vascular smooth muscle cells (Bokeria & Kuular, 2014). In addition, in group 2, a decrease in the amplitude of cardiac oscillations was observed, which indicates a significant influence of the central regulatory mechanisms. Vasoconstriction caused by an increase in the activity of the sympathetic link of the autonomic nervous system in group 2 increases the speed of microcirculation. It is known that the higher the blood flow rate in the system of metabolic vessels, the more complete the dissociation of oxyhemoglobin and the diffusion of oxygen into the cells of the working organs (Litvin, 2013). In group 3, an increase in the endothelial, neurogenic and myogenic tone was observed, which was combined with a decrease in sympathetic influence and an increase in the volume of microcirculation.

Therefore, in group 3, endothelium-dependent vasoconstriction was observed. In addition, it should be taken into account that an increase in blood flow is a characteristic of an early vascular reaction to tissue hypoxia (Fernyhough & McGavock, 2014; Podkolodny *et al.*, 2016).

Consequently, with age, processes of restructuring of functional activity occur with a dominance of the suprasegmental (central) circuit of regulation and an imbalance of the cerebral ergotropic influences in the 2nd age group. In people of the older age group (group 3), there was a significant decrease in the baroreflex regulation of the cardiovascular system, there was a transition of regulatory mechanisms to humoral.

Conclusion

Thus, the above data discloses the tension of regulatory systems in middle-aged group (35-50 years). It must be taken into account that at this age, an imbalance in the regulatory mechanisms of organs, systems and the body can begin, as well as the adaptive capabilities decreases.

In turn, changes in the autonomic regulation of the activity of the cardiovascular system play a significant role in the mechanisms of changes in the adaptive capabilities of the body. Hemodynamic changes at the level of microcirculation can be considered as an adaptive reaction depending on age to maintain homeostasis of the main vital systems of the body. The average level of tissue perfusion increases with age. At the same time, functional changes in microcirculation are maintained through various mechanisms: in group 2, central regulation mechanisms predominate, in group 3, local mechanisms of microcirculation regulation predominate, which was combined with the direction of autonomic regulation of heart rate variability in individuals of different age groups.

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