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NORMALIZATION OF STUDENTS' FUNCTIONAL STATE DURING ACADEMIC WORKLOAD

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The changes of students' heart rate parameters during daily academic load, as well as the possibility of their correction with classical music were investigated. It was established that daily academic load leads to disturbance of the sympathetic-parasympathetic balance through an increased activity of parasympathetic mechanisms and development of fatigue. Classical music neutralizes negative effect of daily academic load on the students' organism functional systems, improves physical and mental efficiency of work, promotes the activation of compensatory-adaptive mechanisms, giving the so-called Mozart effect.

***Keywords*:** autonomic nervous system, music, heart rate variability, academic load.

Introduction. Modern educational process is characterized by higher informative and emotional strains, hypertension of physiological and psychological functions, which are combined with hypodynamia, have a negative impact on the students' physiological state and lead to the decrease of efficiency and the quality of the educational process [1]. It is known that the chronic impact of social-environmental factors exceeding the organism's functional and adaptive capabilities may contribute to the shifts of homeostasis constants, changes the regulatory-adaptive status of the organism [2].

Among the factors leading to the students' physiological and psychological tension, the academic load is one of the strongest. According to the data including in modern scientific literature, academic load negatively affects on the students' mental and physical working capacity, leads to a decrease of arterial pressure and heart rate, as well as to the development of vegetative homeostasis disorders and fatigue [1, 3–5].

In this context the non-pharmacological methods (music, aromatherapy, physical exercises) are becoming increasingly important for correcting functional changes, which can be observed under the influence of social-environmental factors. The therapeutic effects of music therapy are being recognized more and more in the field of rehabilitation medicine. Listening to music is a complex phenomenon, involving psychological, emotional, neurological and cardiovascular changes with behavioral modifications of breathing. Psychosocial, educational and

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physical benefits have also been widely reported in planned, structured sessions. A great deal of literature documents, ascertain the efficacy of music in the modulation of attention, emotions, cognition, treatment of various diseases and disorders, increase of organism's adaptive-compensatory mechanisms [6–8].

Heart rate changes are known to be a universal part of the body's response on the influences of the external and internal medium and reflect the numerous regulatory effects on the cardiovascular system. The hierarchy of the regulatory levels comprises the nervous apparatus of the heart, the sub-cortical nervous centers, the higher autonomic centers and, perhaps, the cerebral cortex. A non-invasive method for investigation of the cardio-vascular system is the heart rate variability (HRV), which describes the oscillations of the intervals between consecutive heartbeats. Examination of HRV is indicated to offer relevant information regarding adequate function of the autonomic nervous system (ANS) in heart rhythm regulation process. It is used for cardiovascular system control investigation in healthy subjects, adult patients with different diseases and for the diagnosis of autonomic dysfunctions [9, 10].

Therefore, the goal of this research was the investigation of the effect of musical auditory stimulation on students' HRV parameters in condition of academic load.

Materials and Methods. 30 students (at the age of 19–22) have been investigated. They were studied in 3 experimental situations: 1 – in physiological norm; 2 – before classes (8^{30}–9^{30}); 3 – after classes (14^{30}–16^{00}). Examinees were divided into two groups: 15 – control group, 15 – experimental group.

The examinees of the experimental group had 20 *min* period of music therapy in 12^{30}–12^{50}. The fragments of rhythmic, classical compositions were used. Musical taste is a highly subjective area. Thus, the study used a questionnaire to identify mood before and after exposure to an individual piece of music. Used musical fragments were evaluated positively by all examinees.

All tests were carried out in comfortable temperature, humidity and light. All procedures necessary for the data collection were explained to the individuals and the subjects were instructed to remain at rest and not to talk during the data collection.

The electrocardiogram (ECG) was registered in the 1^{st} standard lead. The registration and analysis of ECG was carried out by the variation pulsometry method of R. Baevski with the specially designed hardware-software complex, including portative Bio-Art 001 electrocardiograph, a personal computer, automated registration and analysis program, which provides the calculation of more than 30 parameters of heart rate.

Baseline recordings of ECG were taken for 3 *min*. The analysis of ECG was carried out in accordance with the instructions of European Society of Cardiology and the North American Society of Pacing and Electrophysiology.

The main statistical parameters of students' HRV were investigated: root-mean-square difference between the duration of the neighboring R–R intervals (RMSSD); number of R–R intervals that differ by more than 50 *ms* (pNN50).

The geometrical parameters were analyzed: mode, the value of the most frequently occurring R–R interval (*Mo*); the amplitude of the mode-the proportion of such R–R intervals (*AMo*); and the range of deviation (ΔX); the index of regulatory systems strain (*SI*), the index of autonomic balance (*IVB*), the index of the adequacy of regulatory processes (*IARP*), the autonomic index of rhythm (*VIR*).

Spectral analysis of heart rate variability was also performed. Spectral analysis opens up new opportunities for the investigation of higher centers of the autonomous nervous system, because heart rate fluctuations are caused by the actions of certain brain structures that regulate the heart. The following spectral parameters were investigated:

• heart rate fluctuations (*HF*, ms^2, %) occur in the 0.15–0.4 *Hz* range and are designated as high-frequency oscillations. They are related to the respiration rhythm and are determined by the activity of vagal center.

• Low-frequency oscillations (*LF*, ms^2, %) lie in the 0.04–0.15 *Hz* range. These waves are supposed to be similar to the slow Traube–Hering waves, found in the arterial pressure tracings, the plethysmograms and reflects the level of sympathetic circuit activation.

• Very slow waves (*VLF*, ms^2,%) with the frequency range from 0.003 to 0.04 *Hz*. *VLF*-oscillations reflect the cerebral ergotropic effects on the underlying brain levels and are closely related to anxiety or to some other types of psycho-emotional strain.

• Total specter power (*TP*, ms^2) characterizes the level of heart rate variability. Activation of parasympathetic circuit leads to the increase of *TP* and activation of sympathetic mechanisms gives an opposite effect.

To compare changes in variables among the three experimental conditions, the data were analyzed via a program of "Statistica 10". Statistical analysis of experimental results included calculation of the mean and its error ($M \pm m$). Evaluation of the reliability of investigated parameters of situational shifts were carried out according to Student's *t*-test, $p<0.05$ was considered to be statistically significant.

Results and Discussion. According to the obtained results no significant differences were observed between the control and the experimental groups HRV parameters in norm and before the classes (Table).

After classes *SI* was reduced by 27.71% ($p<0.001$) in the control group, whereas in the experimental group *SI* level was only slightly increased (by 11.07%, $p<0.01$). Many investigators found that *SI* is a very sensitive indicator of fatigue, stress caused by various factors, such as the necessity of resolving mathematical problems under the condition of time deficiency cardiovascular disease and mental workload [11].

The decrease of *SI* in the control group is mainly ensured by the decreased activity of sympathetic circuit of ANS in condition of activation of parasympathetic mechanisms of heart rate regulation.

In the control group the decrease of *SI* after classes compared with its level before classes is accompanied with the decrease of *AMo*, *IV*B, *VIR*, *IARP* (respectively by 15.35%, $p<0.05$; 26.88%, $p<0.001$; 18.30%, $p<0.05$; 38.81%, $p<0.01$), also indicating the reduction of the sympathetic mechanisms tonus.

The levels of *AMo*, *IVB*, *VIR*, *IARP* in the experimental group are fluctuated in the range of their baseline. The maintenance of the sympathetic circuit normal activity in the experimental group after classes proves the toning effects of the rhythm, classical music on functional systems of the organism, as well as the increase of body's compensatory-adaptive capabilities in condition of the impact of various negative factors [12–15].

Corrective effect of music on students' heart rate parameters in condition of daily academic load

	Control group			Experimental group		
	norm	before classes	after classes	norm	before classes	after classes
SI	173.74±55.97	176.79±59.44	127.81±45.37***	150.03±89.83	154.06±80.34	171.11±91.78**
AMo	73.98±17.12	75.01±17.92	63.49±10.84*	67.84±15.76	68.12±16.42	66.31±12.31
IVB	270.27±89.53	274.33±92.41	200.58±61.85***	231.26±117.04	240.87±126.31	248.70±115.97
VIR	5.06±1.62	5.19±1.69	4.24±1.58*	4.43±1.53	4.62±1.71	5.01±1.98
IARP	94.71±21.36	96.85±22.41	79.26±14.19**	88.32±25.59	85.90±25.97	88.65±23.22
Mo	0.76±0.11	0.76±0.12	0.81±0.12*	0.77±0.12	0.78±0.09	0.76±0.11
Δ*X*	0.28±0.05	0.27±0.05	0.34±0.09***	0.31±0.07	0.30±0.08	0.29±0.09
RMSSD	29.41±8.23	27.87±7.69	39.81±10.31*	32.31±10.49	30.81±11.18	31.12±12.08
pNN50	16.42±7.39	14.95±4.34	18.59±11.26	21.20±6.35	19.52±7.08	14.58±4.34
TP	1764.01± ±800.11	1655.33± ±1014.83	2353.33± ±774.47*	2456.87± ±1189.79	2331.88± ±1199.41	2066.87± ±970.02
VLF	15.31±8.39	14.23±6.75	16.55±8.71	17.77±12.49	18.39±10.54	17.24±9.28
LF	53.27±11.96	56.33±12.68	50.53±12.89	59.75±15.42	58.88±12.56	59.56±12.45
HF	31.93±15.74	29.27±11.96	32.86±14.13	22.49±11.87	21.88±9.61	23.12±7.63

The activation of parasympathetic mechanisms in regulation of heart rate in the control group after classes is also testified by the increase of pNN50 and RMSSD levels respectively by 24.35% and 42.84% ($p<0.05$) respectively. The correlation of these parameters with the conventional markers of the activity of the autonomic system (the heart rate, the systolic and diastolic arterial pressure and some other physiological parameters) confirms the existence of close relations between *SI* and the activity of the sympathetic nervous system, also between pNN50 and RMSSD parameters, and the activity of the parasympathetic system.

The increase of other markers of parasympathetic mechanisms activity (*Mo*, Δ*X*) was also registered. The changes of *Mo* and *ΔX* in the control group reached to 6.58% and 25.92% ($p<0.001$) respectively.

In the experimental group the levels of the markers of parasympathetic nervous system activity (RMSSD, *Mo*, Δ*X*) are fluctuating in the range of norm. pNN50 was the only exception, the level of which was decreased by 25.31% after classes. The latter proves the maintenance of the sufficient tone of sympathetic mechanisms during a daily academic load, which is ensured by the modulating effect of music.

According to the literature, the most completely elaborated model of the hierarchic structure of the brain centers that regulate the cardiac activity is the model proposed by R. Baevski [16]. This model comprises two regulation circuits: autonomic and central. The working elements of the autonomic regulatory circuit include the sinus node, the vagus nerves and their nucleus in the medulla oblongata. The central circuit comprises three levels including the cortical centers, which provide the rearrangement of the functional activity of the body in response to environmental changes; the higher autonomic and sub-cortical centers, which provide homeostatic interactions of various physiological systems of the body; and the vasomotor centers, which put in equilibrium different hemodynamic parameters inside the system [11].

The increase of *TP* by 42.17% ($p<0.05$) was observed in control group, compared with its level before classes, while in the experimental group *TP* slightly decreases (11.36%, $p<0.05$).

In the control group the change of *TP* after classes was conditioned by the increase of *VLF*, *HF* oscillations respectively by 16.30% and 12.26%, while the level of *LF* oscillations was reduced by 10.29%. These shifts indicate the dominating impact of parasympathetic and central mechanisms in regulation of heart rhythm in condition of a daily academic workload.

In the experimental group the statistically significant shifts of *VLF*, *LF* and *HF* oscillations were not observed after classes. The change of *TP* after classes was ensured by the weak activation of sympathetic mechanisms, which hinders the disturbance of sympathetic-parasympathetic balance during academic load. For many years, the sympathetic and parasympathetic interactions of the nervous system have been of a deep interest to physiologists, who study the activity of the autonomic system and to physicians, who encounter different manifestations of cardiovascular diseases with the leading role of autonomic disturbances. Their effects are not simply antagonistic, but are complex reciprocal interactions, which highly depend on the exact type of the adaptive activity of the body [11].

Conclusion. Our study presents that the academic load has a negative impact on students' functional state. It leads to the decrease of ANS parasympathetic circuit activity and development of inhibitory processes in CNS, conditioned by fatigue. Musical processing encompasses brain mechanisms in musical perception, recognition and emotion. Musical perception requires the decoding of a musical stimulus within the primary auditory cortex in Heschl's gyrus and the association cortex in the superior temporal gyrus. The primary auditory cortex is connected to the hypothalamus, thalamus, medial geniculate nucleus, which in turn are connected through networks to the association cortex, mesolimbic systems and other multi-sensory cortices [17, 18].

In conclusion, musical influence neutralizes the negative effect of daily academic load on students' organism functional systems, improves physical and mental performance, promotes the activation of compensatory-adaptive mechanisms, giving the so-called Mozart effect.

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