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DIAPHRAGMATIC BREATHING IN BIOLOGICAL FEEDBACK MODE FOR CORRECTION OF THE PSYCHOPHYSIOLOGICAL STATE IN MEDICAL STUDENTS

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ABSTRACT
The aim: The current study aimed to examine the possibility of correction of the psychophysiological state of the undergraduate students by diaphragmatic breathing sessions in the biological feedback mode utilizing heart rate variability.
Materials and methods: The study enrolled 86 students 18 to 20 years old. Assessment of the functional state of the ANS was performed bycardiointervalography (CIG) and analysis of the spectral indices of HRV by the hardware-software complex "Cardiolab" (KAI Medica, Ukraine). A complex assessment of the autonomic homeostasis was performed using IARS calculated by a special algorithm. Assessment of the psychophysiological state of students was performed by questionnaires.
Results: Among the examined population, 45% of students were in the state of satisfactory adaptation, 43% – in the state of functional tension, and 12% – in the state of unsatisfactory adaptation. Students with poor level of adaptation and depletion of regulatory mechanisms had higher heart rate, systolic and diastolic pressure, and RR compared to the students in the state of satisfactory and strained adaptation.
Conclusions: The findings suggest that the average intensity of psychosomatic complaints has significant differences between groups with varying degrees of tension of regulatory mechanisms.

KEY WORDS: diaphragmatic breathing, biological feedback, psychophysiological state, autonomic nervous system

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INTRODUCTION

A continuous intensification of the educational practices in institutions of higher education is a complex and long-lasting process that significantly affects the psychophysiological parameters of a young person's organism. High levels of psycho-emotional and intellectual tension, increased demands towards the quality of knowledge, and low levels of physical activity all negatively affect the functional capabilities of the students' bodies and result in the stress of the mechanisms of central adaptation [1]. As a result, adaptive reserves are reduced, mechanisms of autonomic regulation are disrupted, and preconditions for the emotional stress and psychosomatic disorders develop [2,3]. The physiological basis of such conditions is the excessive activation of the sympathetic branch of the ANS, inadequate hormonal background, and energy deficit of the cerebral cortex. Therefore, the search for non-pharmacological methods of correcting autonomic imbalances is an urgent medical problem.

To diagnose the functional state of the autonomic nervous system (ANS), the analysis of heart rate variability (HRV) is now actively used in practice [4,5,6]. Another commonly used tool is an integral indicator of the adaptive capacity of the organism – the Indicator of the Activity of Regulatory Systems (IARS), proposed by R.M. Baevsky [7].

Recently, there has been a growing interest in the use of IARS in clinical and restorative medicine [4,8,9], because it allows to characterize not only the degree of stress of the adaptation mechanisms and the initial functional state of the organism, but also its adaptive capacity in changing environmental conditions. Furthermore, it enables comprehensive evaluation of the stressful effects of unfavorable factors on the human body.

Our previous study found a tight relationship between the psychophysiological indicators of medical students and the degree of the ANS tension involving IARS [10]. This allowed us to put forward a working hypothesis that the normalization of the functional state of the ANS in this group of students can cause positive changes in their psychophysiological state.

One of the methods for correction of the functional state of the ANS is the diaphragmatic breathing in the biological feedback mode utilizing heart rate variability.

THE AIM

The study aim was examination of the possibility of correction of the psychophysiological state of the undergraduate students by diaphragmatic breathing sessions in the biological feedback mode utilizing the heart rate variability.

MATERIALS AND METHODS

The study involved 86 students 18 to 20 years old who did not deviate from the norm according to a physical examination and did not play sports professionally. The studies were conducted in the part of an academic term not involving tests or exams (October-December).

The assessment of the functional state of the ANS was performed by cardiointervalography (CIG) including the analysis of the spectral indices of HRV by the hardware-software complex "Cardiolab" (KAI Medica, Ukraine) (Fig. 1).

Data recording and computer analysis of HRV were performed in accordance with the accepted international standards for analysis of heart rate variability [8,9], as well as according to R.M. Bayevsky [7]. The following HRV spectral parameters were determined: TP, ms^2 – the Total Power of the HRV spectrum; VLF% (Very Low Frequency) – the activity of higher supersegmental centers of autonomic regulation and humoral-metabolic effects; LF% (Low Frequency) – the activity of sympathetic modulators; HF% (High Frequency) – an indicator of vagal influences; LF / HF – sympathetic-vagal balance; IC – centralization index.

A complex assessment of autonomic homeostasis was performed using IARS, which was calculated by a specific algorithm [7].

Based on IARS, there are three functional states of health, which are also called the "traffic light" system: the green zone – a normal state or a state of satisfactory adaptation; the yellow zone – a strain or an extreme strain of adaptation mechanisms; and the red zone – a failure of adaptation.

Assessment of psychophysiological state of students included determination of the level of situational and personal anxiety by the Spielberger-Hanin test method, assessment of the level of stress resistance [11], and investigation of the psychosomatic conditionality of somatic ailments according to the Giesener Beshwedebogen (GBB) questionnaire [11]. The Giesener Beshwedebogen Questionnaire is designed to identify the subjective perception of an individual's physical ailments. Four major and one additional scale were evaluated:

Scale 1. "Exhaustion" (E) – characterizes a non-specific factor of exhaustion, indicating the total loss of vital energy and the need for assistance.

Scale 2. "Gastric complaints" (G) – reflects the syndrome of nervous (psychosomatic) gastric ailments.

Scale 3. "Rheumatic Character" (R) – reflects the patient's subjective suffering of a spastic nature.

Scale 4. "Cardiac Complaints" (C) – indicates that the patient attributes his or her ailments mostly to the cardiovascular area.

Scale 5. "Complaint intensity" or "Pressure" (P) – characterizes the overall intensity of complaints.

Respiratory rate (RR), heart rate (HR) and blood pressure (BP) were measured in all subjects.

The StressEraser device ("Helicor", USA) was used to modulate the functional state of the ANS by diaphragmatic breathing in biological feedback mode with heart rate variability. During the training with the StressEraser, each participant in the experiment adjusted the breathing rate according to the visual signals of the device (Fig.2). The wave structure of the heart rhythm was calculated by the device according to the photoplethysmographic sensor, which detected the pulse of the index finger. The appearance of a triangle marker at the top of the screen signaled the beginning of exhalation. In the case of harmonization of the wave structure of the heart rhythm with the respiratory rhythm, the instrument awarded points to the participant. The session lasted until 30 points were reached, with an average duration of 15-20 minutes during a month.

All obtained digital data were analyzed for differences between groups by Student's t-test at a significance level of $p<0.05$.

RESULTS

Among the examined population, 45% of students were in the state of satisfactory adaptation, 43% were in the state of functional strain, and 12% were in the state of unsatisfactory adaptation (Fig. 3 Distribution of students by IARS).

In the next stage of the study, students with different adaptive capacities were evaluated for a number of psychophysiological parameters (Table I).

Students with the unsatisfactory level of adaptation and depletion of regulatory mechanisms had higher heart rate, systolic and diastolic pressure, and RR compared to students in the state of satisfactory and strained adaptation. Students with unsatisfactory levels of adaptive capacity had a higher level of personal anxiety and low levels of stress resistance compared to the group of satisfactory adaptation.

Analysis of the results of the intensity of psychosomatic ailments according to the Giesener Beshwedebogen questionnaire (Table II) showed that significantly higher mean values of psychosomatic ailments on all scales were found in the group of students with unsatisfactory adaptation.

The results obtained in this study show that the average intensity of psychosomatic complaints is significantly different between groups with varying degrees of tension of the regulatory mechanisms. Thus, the mean values of psychosomatic complaints were significantly higher in individuals with unsatisfactory adaptation on all scales, with $p<0.05$ on the "Gastric", "Rheumatic", and "Cardiac" scales and $p<0.01$ on the "Exhaustion" and Pressure" scale.

In the next phase of our study, a course of diaphragmatic breathing sessions was conducted in the biological feedback mode with heart rate variability using the StressEraser device (Helicor ", USA) in order to optimize the functional state of the ANS in students with the strain of regulatory mechanisms (group 1) and failure of adaptation (group 2).

Dynamics of HRV indicators in the examined groups after the 30-day course of breathing exercises is presented in Table III. After completing the course, a redistribution of activity of the peripheral ANS in favor of a significant increase in HF was noted in two groups. Thus, the relative contribution of the high-frequency part of the spectrum

Figure 1. Computer processing of the rhythmocardiogram of student B. using the Cardiolab device.

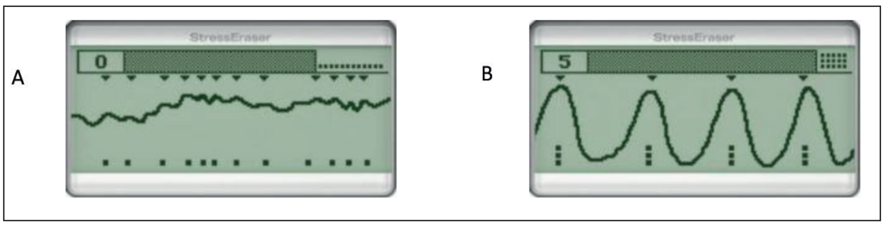

Figure. 2. Visualization of breathing exercises on the StressEraser display
a - during the 1st minute of training; b- during the 15th minute of training.

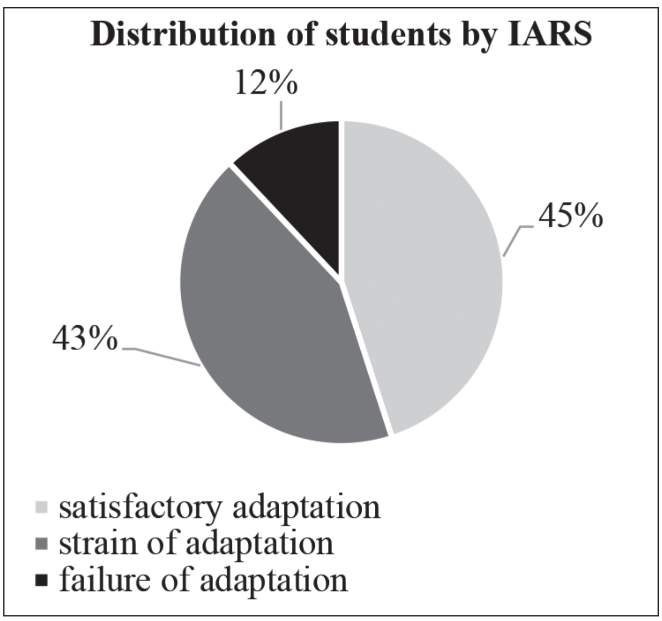

Figure 3. Distribution of students by IARS.

(HF%) to the total heart rate variability increased by 13.3% (p <0.01) and 13.6% (p <0.01), respectively.

A repeat analysis of the results of the intensity of psychosomatic ailments according to the Giesener Beshwedebogen questionnaire after a 30-day course of respiratory gymnastics revealed a significant decrease in the average values of psychosomatic ailments on most scales in two groups of students (Table IV). Thus, the largest change was noted on the "Exhaustion" scale – from 8.8 ± 2.1 to 5.4 ± 0.5 (p<0.01) in the first group and from 12.5 ± 2.5 to 6.3 ± 0.9 (p<0.01) in the second group. Another positive result was a decrease in personal anxiety, which is considered an integral component of adaptive self-regulation.

DISCUSSION

Personal anxiety is considered to be a stable individual feature of a person that characterizes one's tendency to perceive a certain range of indifferent situations as threatening and dangerous to self-esteem. Highly anxious individuals tend to perceive the threat to self-esteem and vitality and respond with pronounced anxiety. Increased anxiety is the main mechanism of non-adaptive behavior. However, a certain level of anxiety is a natural and a necessary feature of human productive activity. Self-control and self-evaluation of this condition is an essential component of adaptive self-regulation, since heightened anxiety is the leading "obligatory mechanism" of maladaptive disorders.

After a course of diaphragmatic breathing in the biological feedback mode a redistribution of activity of the peripheral ANS in favor of a significant increase in HF was noted in two groups. According to a number of authors,

Table I. Psychophysiological parameters depending on the functional state of students' regulatory systems (M ± m)

Indicators	Satisfactory adaptation (n=45%) 1	Strain of adaptation (n=43%) 2	Failure of adaptation (n=12%) 3
HR. beats per minute.	74±2.3	83±3.1	95±6.5**
SAP. mmHg	119.54±3.3	125±4.3	134.±5.3*
DAP. mmHg	72.7±1.4	79.4±2.5	84.3±4.5*
RR. per minute.	15.2±0.7	17.2±0.9	19.7±1.9*
Personal anxiety	31.7±4.4	46.1±4.2	52.7.2±5.3**
Stress resistance	18±3.7	32±4.3	47±4.8**

Notes: * - probability of the difference in indicators between groups 1 and 3, p<0.05; ** - probability of the difference in indicators between groups 1 and 3, p <0.01.

Table II. Intensity of psychosomatic complaints in students depending on the functional state of regulatory systems (M±m)

Indicators	Satisfactory adaptation (n=45%) 1	Strain of adaptation (n=43%) 2	Failure of adaptation (n=12%) 3
Exhaustion	5.3±0.6	8.8±2.1	12.5±2.5**
Gastric complaints	1.8±0.3	2.7±1.3	4.7±1.3*
Rheumatic complaints	4.4±1.4	5.5±1.5	8.7±3.5*
Cardiac complaints	2.4±0.7	2.9±0.9	5.5±1.9*
Pressure	11.7±3.4	21.1±4.2	32.2±4.3**

Notes: * - probability of the difference in indicators between groups 1 and 3, p<0.05; ** - probability of the difference in indicators between groups 1 and 3, p <0.01.

Table III. Dynamics of HRV indicators in the study groups

Indicator	The first group (strained adaptation) (n=37)		The second group (failure of adaptation) (n=10)	
	Baseline	After a training course	Baseline	After a training course
TP. ms^2	3963.9±474.1	4215±363	1727.9±746.9	2423.9±525
HF. ms^2	1073±55.8	1687±134*	244.2±63.8	673.3±84*
HF. %	27.1±1.3	40.4±2.16**	14.1±3.3	27.7±3.1**
IARS	5.9±1.4	4.2±1.6*	8.8±0.6	5.4±1.2**

Notes: * - statistically significant change from baseline (p <0.05), ** (p <0.01)

Table IV. Dynamics of psychosomatic complaints intensity and the level of personal anxiety in students

Indicator	The first group (strained adaptation) (n=37)		The second group (failure of adaptation) (n=10)	
	Baseline	After a training course	Baseline	After a training course
Exhaustion	8.8±2.1	5.4±0.5**	12.5±2.5	6.3±0.9**
Gastric	2.7±1.3	1.7±0.3	4.7±1.3	2.8±0.5*
Rheumatic	5.5±1.5	4.5±1.5	8.7±3.5	5.1±1.4
Cardiac	2.9±0.9	2.1±0.5	5.5±1.9	2.3±0.7*
Pressure	21.1±4.2	12.8±2.6*	32.2±4.3	15.6±3.6*
Personal anxiety	46.1±4.2	33.4±3.1*	52.7.2±5.3	38.7±4.3*

Notes: * - statistically significant change from baseline (p <0.05), ** (p <0.01)

such restructuring of the autonomous regulation creates a favorable background for modulating psychophysiological responses to mental stressors [7,9,10].

A repeat analysis of the results of the intensity of psychosomatic ailments according to the Giesener Beshwedebogen questionnaire after a 30-day course of diaphragmatic breathing in the biological feedback mode showed a significant decrease in the average values of psychosomatic ailments on most scales in two groups of students. These results suggest that the use of controlled breathing in the biological feedback mode to increase the variability of heart rate, and its high-frequency components in particular, leads to the optimization of the reflex response to mental stressors and is sufficiently sound physiologically. This method is based on the use of physiological mechanisms of sinus respiratory arrhythmia. It leads to a more complete harmonization of the respiratory cycles with the wave structure of the heart rhythm due to the ability to observe one's own HRV curve and to correct the frequency and depth of breathing. Respiratory training in the biological feedback mode with cardiac activity leads to a significant increase in HF in students with strain and failure of regulatory mechanisms' adaptation and regression of psychosomatic manifestations.

CONCLUSIONS

1. Investigation of the HRV indices in the conditions of normal educational load among students revealed different functional states according to the integrated activity index of the regulatory systems. Depending on the functional reserves, the regulatory systems operated with varying degrees of strain from optimal level to failure. As the strain of adaptation mechanisms increased, the activity of sympathetic influences was enhanced and the influence of respiratory periodicity was reduced.
2. It was established that students with an unsatisfactory level of adaptation and depletion of regulatory mechanisms had significantly higher levels of personal anxiety, low stress resistance, and an increased level of psychosomatic manifestations.
3. Deep breathing in biological feedback mode with heart rate variability shifted the sympathetic-vagal balance towards the parasympathetic branch of the autonomic nervous system and created the optimal background to optimize the response to mental stress.
4. Respiratory gymnastics using portable biological feedback devices can be used to prevent psycho-emotional stress in the education of medical students.

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