INFLUENCE OF PSYCHO-EMOTIONAL LOAD AND BIOFEEDBACK ON THE ACTIVATION OF CEREBRAL CORTEX AND AUTONOMIC REGULATION OF HEART RATE IN FEMALE STUDENTS

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Background: *To investigate the features of activation processes and vegetative status of the female students in a situation of emotional stress and after a course of biofeedback game.*

Materials and methods: *The research was involved 22 students aged between 18 to 21 years. Registration of physiological parameters was carried out with the informed consent of the participants. Were used methods of omegametry, variation cardiointervalography, biofeedback game on heart rate.*

Results: *In the situation of emotional stress 50% of students were discovered a suboptimal level of activation of the frontal cortex, manifested as excessive expression or the reduction of total indicators of DC-potential. From the side of the autonomic system were increased sympathetic influences on cardiac function compared to baseline values, the structure of heart rate revealed the predominance of central regulation contour. Expressed tension of regulatory mechanisms was noted in 82% of subjects. After a course of 10 sessions of biofeedback in all students were observed normalization of activation effects on the cerebral cortex and autonomic regulation of heart rate.*

Conclusion: *The individual characteristics of activation and autonomic regulation of heart rate are important indicators of the functionality and success of adaptation in a situation of emotional stress.*

Keywords: *activation processes; DC-potential; autonomic regulation of heart rate; psycho-emotional stress; adaptation mechanisms; biofeedback.*

Period of study at the University accompanied by increased information and emotional pressure, which is playing role of a strong stress factor

[1]. In some cases, individual response to difficulties reaches such a level that there is a real threat of breakdown of adaptive mechanisms and the development of psychosomatic disorders [2]. This is especially true for female students in comparison with male students, associated with their higher level of anxiety and emotion sensitivity. Nervous tension during exams may be reason for female students of sleep disorders, digestive disorders, and menstrual cycle disturbances of cortical-thalamic genesis [1].

The activation processes are one of the elements determining the state of adaptive reserves of the organism [3]. It was shown that the exchange of nutrients and metabolic products depends on the activity of mutually modulating influences of the cortex and subcortical structures of the brain, which significantly affects the effectiveness of the process of learning [4, 5, 6]. The integral index of activation level of systems of wakefulness, higher mental functions and behavior is value of sustainable potential (DC-potential) of millivolt range, frequency from 0 to 0.05 Hz [7, 8, 9]. The background magnitude of the DC-potential is a reliable indicator of fatigue, reflects the wakefulness level, local and general energy consumption [10, 11, 12].

One of the methods of stress resistance training and reducing the level of anxiety is the technology of game biofeedback (BF) [13]. The main aim of biofeedback is learning of self-regulation skills. Feedback makes available information, a man in normal condition does not perceive [14, 15]. It has been noted the high efficacy of the heart rate control biofeedback to improving the quality of operators performance [16], in sports, rehabilitation of patients with hypertension, PTSD and other psychosomatic disorders [17].

In regard to the above, the assessment of the physiological features of individual reaction to stressful situation and formation of self-regulation skills in female students seems highly relevant.

The aim of the research was to investigate features of the activation processes of the frontal cortex and autonomic regulation in female students during the intersessional period, during the exams and after the course of biofeedback in the frequency of heartbeats.

Materials and methods

Our experiments involved 22 full-time female students. The average age of the subjects was 20.4±0.8 years. Surveys were carried out with the informed consent of the all subjects.

To register the integral parameter of activation levels of the frontal cortex of the brain, we have used the computer-hardware complex "Omega-tester OT-2" [18]. Distinguished three activation levels for the right and left hemisphere:

I level: value of DC-potential from 0 to 20 mV;

II level: value of DC-potential from 20 to 40 mV;

III level: value of DC-potential from 40 mV to 60 mV [19].

The characteristics of the heart rhythm were estimated by the method of cardiointervalography at rest with the recording of 128 R-R intervals using the psychophysiological testing device UPFT-1/30-"Psikhofiziolog". Recorded the following parameters of the statistical and spectral characteristics of heart rhythm: heart rate (HR), tension index of regulatory systems (SI), total power (TP), very low frequency oscillations (VLF); low frequency oscillation (LF); high frequency oscillations (HF); the balance of sympathetic and parasympathetic influences on heart rate (LF/HF), the average duration of R-R intervals (RRNN); the standard deviation of the values of R-R intervals (SDNN), an index of centralization of rhythm control (IC).

With the aim of teaching students of self-regulation skills we used hardware-software complex "BOS-pulse professional." The BF course consisted of 10 sessions with a total duration of 20–30 minutes each.

Validation of the differences between dependent samples was carried out using the Wilcoxon's T-test and the χ^2-test. The mathematical and statistical processing of the data has been performed with software package Statistica 6.0 and MS Office Excel 2010.

Results

The study of levels of activation of the cortex (Table 1) showed that during the intersessional period, the majority of students (81.8%) was

characterized by an optimal level of activation of the frontal lobes of the brain (29.96 ± 2.02 mV of the left hemisphere and 33.03 ± 2.52 mV of the right hemisphere), at 18.2% of cases detected low average level of DC-potential. Over-expression of activation was not observed. It noted a significant ($p < 0.05$) difference between the average level of DC-potential in the background and before to exam. Before the exam in 45.5% of the students the value of DC-potential was at a low level in the range of 10–20 mV, at 4.5% an increase to the level of DC-potential of 40 mV and higher, which may be an indicator of significant stress and the breakdown of adaptive mechanisms [9]. The optimal level of activation during exams was observed in half of the students. An important change after the sessions of BF is the lack of both insufficient and excessive activation of the Central nervous system. After the BF sessions all students matched optimal level of activation, an average of 28.54 ± 2.30 mV for the left and 32.11 ± 3.08 mV to the right hemisphere.

Table 1.

The values of DC-potential levels of the students in the background, before exams and after the biofeedback training

N=22	The value of DC-potential in the left and right hemisphere (mV)					
	low		medium		high	
	LH	RH	LH	RH	LH	RH
Background (1)	12.63±2.34 n=3	16.08±0.78 n=5	28.84±1.44 n=17	29.75±1.41* n=16	42.60±3.39 n=2	40.12 n=1
Exam (2)	12.63±1.19 n=10	11.68±1.06 n=10	26.97±1.31** n=11	25.85±1.50 ** n=11	41.15 n=1	57.13 n=1
After BF (3)	-	-	27.1±1.09 *** n=20	29.7±1.78 *** n=20	-	-

Note: Statistically significant differences ($p < 0.05$): * – between 1 and 2, ** – between 2 and 3, *** – between 1 and 3.

Analysis of HRV (Table 2) showed increase of sympathetic influences in the situation of psycho-emotional stress and parasympathetic nervous system after BF training. A rising of values of heart rate ($p<0.001$) in subjects at rest (79.38 ± 1.94 bpm) and emotional stress

(84.75 ± 4.51 bpm) was observed. Significantly reduce HR after the course of the BF (72.50 ± 1.69 bpm), even to compared to background values. The values of R-R intervals (RRNN) and their standard deviation (SDNN), also show a decrease in the heart rate variability rhythm in a tense situation and a noticeable increase in her after the training of self-regulation.

Table 1.

Indicators of heart rate variability of the students in the background, before the exam after the biofeedback training

Parameter	Background (1)	Exam (2)	After BF (3)
HR, bpm	79.38 ± 1.94 *	84.75 ± 4.51 **	72,50 ± 1.69 ***
RRNN, ms	758.75 ± 5.61	723.87 ± 14.76**	829,00 ± 18.73***
SDNN, ms	57.63 ± 5.76	57.25 ± 6.11	70,75 ± 11.21
TP, ms ^{2}	4131.63 ± 9.71	3261.38 ± 8.82 **	5976,75 ± 7.04***
VLF, ms ^{2}	1470.38 ± 4.91	985.88 ± 2.07	1754,00 ± 4.41
LF, ms ^{2}	1654.38 ± 5.20	1604.38 ± 5.43	1788,25 ± 3.28
HF, ms ^{2}	1131.63 ± 2.93	660.50 ± 2.60 **	2434,63 ± 1.83***
VLF, %	33.00 ± 2.50	34.88 ± 4.56	28,13 ± 3.34
LF, %	37.75 ± 2.40	44.25 ± 3.40 **	28.75 ± 1.91
HF, %	29.25 ± 1.19	20.62 ± 2.32**	43.25 ± 2.20***
LF/HF, conv. units	3.18 ± 1.17	3.52 ± 1.57 **	0.93 ± 0.28 ***
SI, conv. units	95.63 ± 7.91 *	141.38 ± 11.28 **	69.00 ± 5.72
IC, conv. units	5.67 ± 1.59	6.91 ± 2.63**	2.68 ± 0.71

Note: Statistically significant differences ($p < 0.05$): * – between 1 and 2, ** – between 2 and 3, *** – between 1 and 3.

Analysis of the ratio of LF and HF power and LF/HF index allowed to note the shift in the balance of autonomic regulation in the direction of sympathic in the exam compared to background ($p < 0.01$). Before the test, students had an increase in the percentage shares of LF, VLF and the index of centralization (IC), this indicating predominance of activity of the central contour of regulation over the autonomous. After the BF training most of the subjects recorded a predominance of

vagal influences on the heart activity, which is the most efficient and optimal mechanism of neuroautonomic control.

It was found, that on the exam there was a decrease of the regulatory systems tension index to below 60 conventional units in 23% of subjects. In this category of students the autonomic index of the rhythm (SI) was shifted towards predominance of parasympathetic regulation, which may indicate trophotropic orientation of their activities as a result of chronic fatigue or overexertion [20, 21].

A comprehensive assessment of the functional state of the subjects showed that 78.6% of subjects with low and 50% high level of activation of the frontal cortex mainly characterized by a pronounced tension of regulatory systems. In the group with an optimal level of activation 80% of subjects had optimal and moderate tension of regulatory systems. In General, during the intersessional period was observed signs of suboptimal response in 68% of subjects, during the exams this figure reached 82%, after biofeedback training this figure dropped to 52%.

Conclusion

Thus, it can be concluded, that the shift of activation influences towards non-optimal values (both low and high) under the influence of psycho-emotional load is an indicator of the overload and breakdown of regulatory mechanisms of an organism of female students. Learning self-regulation skills has a significant effect in normalizing the relationship of the cortical-subcortical mechanisms of regulation of the wakefulness level and indicators of autonomic regulation of the cardiovascular system, leads to improved functional state of the organism and mental activity. The results can be applied to identify risk groups of non-adaptive students and planning of preventive measures to prevent them.

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