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USE OF PORTABLE BIOFEEDBACK DEVICES FOR CORRECTION OF THE FUNCTIONAL STATE OF AUTONOMIC NERVOUS SYSTEM

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Summary: The influence of deep diaphragmatic breathing in biofeedback mode using handheld computer devices StressEraser ("Helicor", USA), EmWave2 ("Heartmath", USA) and MyCalmBeat (USA) on heart rate variability in healthy young men was investigated. It was established that breathing exercises lasting of about 15 minutes significantly affect the functional state of the autonomic nervous system (ANS). According to the heart rate variability, the deep breathing increases the overall tone of ANS activity and redistributed the relationship between its central and peripheral parts. The most effective influence on the functional state of ANS provides the device StressEraser.

Key words: autonomic nervous system, heart rate variability, diaphragmatic breathing, breathing exercises, biofeedback devices

Formulation of the problem. It is known that breathing and regulation heart rate is closely connected with physiological processes [6, 8, 11, 21]. Their delicate coordination is a necessary condition for adaptation of the human to the metabolic needs. One of the most striking manifestations of this coordination is sinus respiratory arrhythmia (SRA) - physiological fluctuations of cardiac cycle duration connected with respiratory periodicals [9, 25]. When we inhale, the sympathetic link of autonomic nervous system (ANS) is activated, which leads to the increase of frequency of heart rates (FHR). When we exhale, conversely, the tone of the parasympathetic link of autonomic nervous system (ANS) is intensified that is the course of slowing heart rate. Such fluctuations of the frequency of heart rates are making a significant contribution to the general heart rate variability (HRV), including the high-frequency part of its spectrum in the range of 0.15-0.4 Hz (HF). In connection with this, the spectral energy of curve of the heart rate variability in this frequency range is usually used as a noninvasive marker of parasympathetic link activity of the autonomic nervous system (ANS) [1, 10, 15, 16, 23]. Several studies have shown that the severity of sinus respiratory arrhythmia (SRA) is positively correlated with the tone of the parasympathetic link of autonomous nervous system (ANS) and can modulate the physiological reactions to mental stressors [4, 18, 20-25]. Therefore, the search of non-medical methods for the increasing of heart rate variability and, in particular, its high-frequency component, in order to better adaptation of the body to various stressors, especially in terms of pathology, is psychologically quite reasonable.

Analysis of recent researches and publications. In recent years, particular interest in this context challenges breathing exercises in the mode of reverse biological connection with heart rate variability (HRV) [3, 9]. Deep breathing, which is consistent with the natural fluctuations in heart rate, can significantly enhance both sinus respiratory arrhythmia (SRA) and general heart rate variability (HRV). This is especially effective coordination which can be achieved by using portable computer devices that visualize heart rate variability (HRV) and let independently

correct the frequency and depth of breathing for obtaining maximum effect. One such device that has proved itself as a means of biological reverse connection, is device called StressEraser (TM, Helicor, USA). With it, the person who trains may choose individual optimal frequency and depth of breathing, which provides the most harmonious relationship between the cardio-respiratory system and the autonomic nervous system (ANS). Several studies have shown that such harmonization increases the tone of the parasympathetic link of autonomic nervous system (ANS), causes psychological relaxation and increases the resistance to stress factors [21, 24]. Portable devices for breathing exercises in the mode of reverse biological connection with heart rate variability (HRV) are widely advertised and relatively affordable. However, they are positioned by the developers, primarily as a means of psychological relaxation.

The formulations of the objectives. We set out to find out whether these devices are able to use the recommended mode influence significantly on heart rate variability (HRV) for healthy young people. For the study were used three devices: StressEraser ("Helicor", USA) (Picture1), EmWave2 ("Heartmath", USA) (Picture 2), MyCalmBeat (USA). The last of them is a software package that can be run on a

Picture 1. Device StressEraser ("Helicor", USA)

personal computer or smart phone, and its hardware is represented only a clip with the photoelectric transducer that responds to the degree of blood filling of the auricle.

Presentation of the main research material. The research involved 30 males, aged from 18 to 20, who were randomly divided into 3 equal groups in number with 10 persons in each of them. All participants of the experiment did not show complaints of health, had no abnormalities on physical examination data and did not professionally engaged in sports. Members of the first group were doing breathing exercises with the use of a portable device of reverse biological connection StressEraser, the second used EmWave2 device, and the third - hardware and software system MyCalmBeat. Each session lasted from 10 to 15 minutes. There were held 10 sessions daily in the morning.

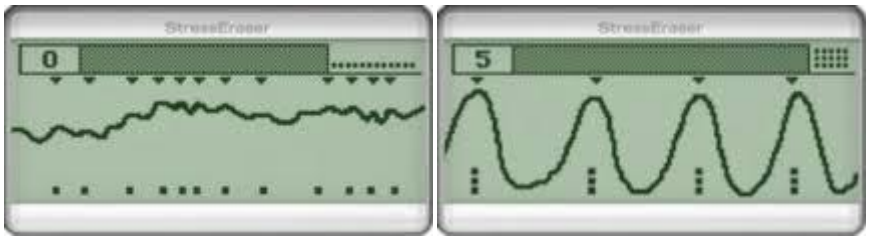
During the training, each participant of the first group changed respiratory rate in accordance with the visual signals of the device StressEraser. The wave structure of heart rate was calculated according to the device with the help of photopletismographic sensor that detected pulse blood filling of the index finger.

The appearance of the marker in the triangular form at the top of the screen gave the signal for the expiration. In the case of harmonization of the wave structure of heart rate with the rate of respiration, the device indexed accrued points for each successful act of breathing with the help of squares at the bottom of the screen (Fig. 3, a, b). 3 squares are evaluated at 1 point by the device. The session

Picture 2. Device EmWave2 ("Heartmath", USA)

lasted to set t 30 points.

Breathing gymnastics in the second group of participants using the device EmWave 2 was realized through audio and visual correction of breathing patterns during 15 minutes. The device generated the operating stimuli based on uninterrupted registration of photoelectric sensor of the pulse of the auricle. In particular, in the case of achieving coherence of breathing with cardiac activity, the indicator in the top right corner changed its color from Picture 3.



Picture 3. The visualization of doing breathing exercises on the device display StressEraser
a – 1 minute of training; b- 15 minutes of training

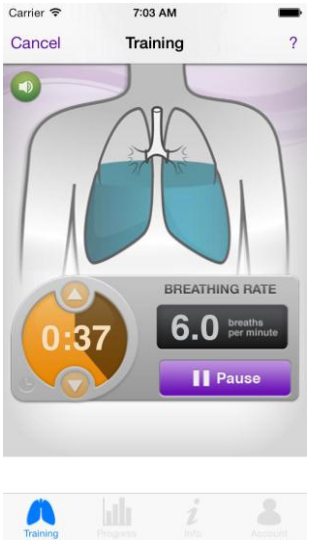
red to blue or green depending on the degree of its coherence. At the same time device gave sound signal, which increased the efficiency of correction rate of breathing in patient.

The participants of the third group used pulse metric sensor for reverse biological connection, which detected pulse in the auricle similar to the registration of pulse in the second group of participants. However, the principle of correction of breathing with the use of software MyCalmBeat was somewhat different. During the first two minutes of training hardware and software complex on the basis of free patient breathing counted individually optimal respiratory rate, and in the next 15 minutes the device gave visual instructions on beginning of inhalation and exhalation on the screen of smart phone according to this frequency (Picture 4).

Heart rate variability was registered by remote heart rate monitor Polar RS800CX and software Polar ProTrainer5. For calculations of heart variability rate indexes were used 5-minute stationary area of the curve of the 1st electro cardio graphic (ECG) according to the recommendations of the European and North American Cardiologist Association (1996) [16]. As indicators of heart rate variability were used mean squared deviation of cardio intervals duration (SD, ms) which reflects the general variability of heart rate; the square root of the mean squared differences of values of consecutive pairs of cardio intervals (RMSSD, ms), reflecting mainly the influence on the parasympathetic part of autonomic nervous system; the number of pairs of successive intervals R-R, which differ in duration more than 50 ms (rNN50), which reflects the activity of the peripheral parts of autonomic nervous system (ANS). In addition, were determined spectral parameters of heart rate variability, as TP (ms^2) - the total power of the frequency spectrum of heart rate, reflecting the general effect on heart rate of all regulatory systems; HF (ms^2) - the high-frequency component of heart rate spectrum in the range of 0,15-0,4 Hz, reflecting mainly vagus influence on the heart rate connected with breathing; LF (ms^2) - the low-frequency component of heart rate spectrum in the range of 0,04-0,15 Hz, reflecting mainly the influence of the sympathetic part of autonomic nervous system on heart rate, including the activity of vascular-motor center and VLF (ms^2) – very low frequency component of heart rate spectrum in the range 0,003-0,04 Hz, which reflects the total activity of above segmental parts of autonomic nervous system and neurohumoral influences on heart rhythm. Additionally was calculated the index of sympato-fluctuation balance (LF / HF) and percentage contribution of each from the frequency components of total power spectrum (HF% / LF% and VLF %).

The obtained numerical data were processed by methods of variation statistics using Student's criterion with significance level

of p <0, 05. The dynamics of heart rate variability indexes under the influence of diaphragmatic breathing was assessed by the method of paired comparisons. And intergroup differences were assessed by the method of single fact dispersion analysis.



Picture 4. Visualization of doing breathing exercises on the smart phone screen with the use of software MyCalmBeat

In order to clarify the influence of diaphragmatic breathing in the mode of reverse biological connection on the indexes of heart rate variability was registered the 1st electro cardio graphics (ECG) in all examined persons by the remote heart rate monitor Polar RS800CX in sitting position after 10 minutes adaptation to the registration conditions. Last 5 minutes of adaptation period were used for background indexes of heart rate variability. In the next 15 minutes lasted the session of diaphragmatic breathing, after its completion was continued the registration of electro cardio graphic for another 5 minutes. The effectiveness of session of breathing on heart rate variability was judged by comparing the first and second five-minute period. The results of this comparison are presented in Table 1.

According to the presented results, in all three groups of examined was observed similar dynamics of heart rate variability (HRV), but its intensity was different. Common integral effect of diaphragmatic breathing with the use of all three devices of reverse biological connection was a substantial increase of heat rate variability (HRV) as according to statistical and also to spectral indexes. Thereby, SD in the groups of StressEraser, EmWawe2 and MyCalmBeat grew respectively to 10.2 + 1.2; (p <0,01); 8.1 + 2.3; (p <0,02) and 6.5 + 2.4; (p <0,05) ms. Analogical increase of PNN50 in these groups was 4.2 + 0.4; (p <0,001); 3,8 + 0,6 (p <0,01) and 3.3 + 0.7; (p <0,01). Index of RMSSD, characterizing parasympathetic part of autonomic nervous system, statistically significantly increased only in the first and second groups, respectively to 12.2 + 1.4; (p <0,01) and 14.2 + 1.8; (p <0,05) ms (See Table 1).

The increase of general variability of heart rate is confirmed by spectral indexes, including TP, which increased in all three groups according to 1002 + 145 (p <0,01); 875 + 177 (p <0,02); and 645 + 189 (p <0,05) ms2. The advantage of spectral analysis of heart rhythm gives the opportunity to find out the dynamics of individual parts of autonomous nervous system under the influence of diaphragmatic breathing. дихання. In particular, in all three groups, the major shifts were observed in low frequency spectrum of spectral curve LF, which according to the generally accepted interpretation reflects the activity of the sympathetic part of the autonomic nervous system and vascular-motor centre. The increase of power of LF in StressEraser, EmWawe and MyCalmBeat groups was respectively 1107±123 (p<0,01); 892±136 (p<0,02); and 709±109; (p<0,05) ms^2 (See Table 1)

However, in the cases of deep diaphragmatic breathing, its frequency in all participants was in the range of 5-7 breaths per minute, which correlates with frequency characteristics of LF waves of heart rate spectrum (0.1 Hz). Therefore, in these conditions, the LF power range is characterized not so much the activity of the sympathetic part of autonomic nervous system (ANS) but reflects respiratory frequency. For the same reasons, the increase of LF / HF

coefficient in all three groups respectively to 0,9 + 0,16 (p <0,05); 1,1 + 0,17 (p <0,05) and 0,8 + 0,18 (p <0,05) should not be interpreted as the increased activity of the sympathetic part of the autonomic nervous system (ANS). There were no reliable index changes of HF in all three groups. The power of waves of very low frequency (VLF) spectrum, reliably decreased only in the first group to 237 + 56 (p <0,05) ms² (See Table 1).

Table 1

Dynamics of heart rate variability indexes under the influence of a single session of diaphragmatic breathing

Index	SressEraser (n=10)		EmWave2 (n=10)		MyCalmBeat (n=10)	
	Background	After session	Background	After session	Background	After session
SD, ms	52,5±6,2	62,7±2,6*	48,9±5,4	57,0±6,1*	54,9±5,4	61,4±5,6*
RMSSD, ms	34,3±4,3	46,5±3,8*	35,7±4,1	49,9±5,2*	37,1±4,2	43,2±6,6
pNN50, %	18,6±1,5	22,8±1,8*	17,8±1,6	21,6±2,2*	16,5±1,3	19,8±1,6*
TP, ms²	3797±345	4799±433*	3868±301	4743±345*	3944±401	4585±434*
HF, ms²	762±108	894±144	763±138	777±153	725±223	764±156
LF, ms²	1781±223	2888±216*	1862±218	2754±249*	1955±225	2664±301*
VLF, ms²	1254±176	1017±198*	1243±145	1212±163	1264±257	1157±232
LF/HF	2,3±0,21	3,2±0,23*	2,4±0,22	3,5±0,24*	2,7±,22	3,5±0,24*
HF, %	20,1±4,4	18,6±3,7	19,7±3,7	16,4±3,3	18,4±4,7	16,7±3,9
LF, %	46,9±5,2	60,2±4,9*	48,1±4,6	58,1±4,7*	49,6±3,6	58,1±3,9*
VLF, %	33,0±3,5	21,2±2,9*	32,1±3,1	25,6±2,8*	32,0±3,3	25,2±2,9*

Note * - statistically probable change in relation to the background index (p < 0, 05).

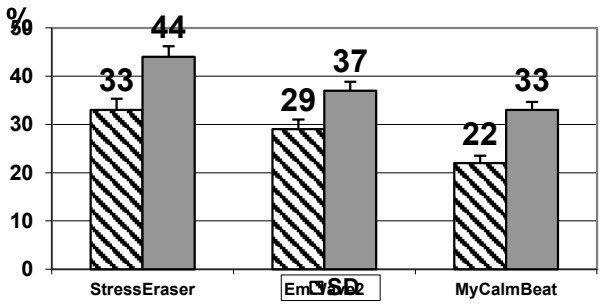
While analyzing the interest spectral structure of heart rate before and after the session of diaphragmatic breathing was established that in all three groups was probable decrease of specific weight of waves of very low frequency VLF% respectively to 11.8 + 2.2%; (p <0,01); 6.6 + 2.8%; (p <0,02) and 6.8 + 2.4%; (p <0,05) (See Table 1). This means that a redistribution of activity between different regulatory components of heart rhythm in favour of the peripheral part of autonomic nervous system, as very low

frequency (VLF), as it was known, reflects the activity of the central part of the regulation.

Comparing the integral influence on heart rate variability (HRV) of diaphragmatic breathing with the use of various portable devices of reverse biological connection according to SD and TP data, we can mention that it was the most distinctive in the first group, which worked with the device StressEraser, slightly lower - in the second group,

which used EmWave2, and the lowest - in the third group, whose members used System MyCalmbea(Picture 5).

The mechanism of the positive influence of deep diaphragmatic breathing on the physiological state of the body recognizes the redistribution of activity of the peripheral parts of autonomic nervous system in favour of



Picture 5. The increase in percentage of heart rate variability indexes in relation to the background meaning in the investigational groups

parasympathetic part, which is examined in increasing the general heart rate variability and in the indexes of indexes parasympathetic link [6, 8]. Our data generally confirm these views, as evidenced by the probable increase of SD and TP in all examined groups. However, when studying the effect of isolated session of deep breathing to the greatest extent increased LF index, which under normal conditions of physiological calm reflects the activity of the sympathetic part. However, in a relatively slow diaphragmatic breathing, frequency of which (5-7 breaths per minute) is close to the low frequency spectrum of heart rhythm LF (0,1 Hz), this index does not reflect the activity of the sympathetic part, but coordination of baroreceptional reflex with the frequency of breathing and heart rhythm.

Such frequency of breathing, at which such coordination is achieved, is called the resonant frequency. It is shown that during continuous breath (for about 5 seconds) through the activation of the sympathetic part of the autonomic nervous system, the heart rhythm is accelerated, simultaneously the activation of bar receptors stimulates the heart rhythm to prevent the lowering of blood pressure. During exhalation the processes develop in the opposite direction. Reducing the volume of the chest creates a tendency to high blood pressure, reduces impulses from bar receptors and reflexively activates the parasympathetic part, reducing the frequency of heart rhythm [11, 12, 14]. This explains why during breathing with the resonance frequency of heart rate variability increases. Accurate synchronization of cardiovascular, respiratory and autonomic nervous system creates physiological state of coherence. This term was suggested by Lehrer, who showed that the resonant frequency of breathing is individual and depends on gender and anthropometric parameters [14].

The use of portable electronic devices of reverse biological connection allows a person to observe visually the level of coherence of these systems during training and make the necessary corrections into the patterns of breathing. According to the obtained data, the most effective in this respect was the device StressEraser, which visually displays the coherence of system and provides visual prompts in case of its reduction.

According to the data of Vachillo et al. (2006), the deep diaphragmatic breathing in the mode of reverse biological connection with heart rate variability leads to a significant increase of heart rate variability during several minutes from the beginning of the session and continues up to the end of the session [26, 27]. The breathing on the resonant frequency removes the biggest oscillations of heart rhythm and coordinates these oscillations with the phases of breathing.

In our research was confirmed this effect in all series of observations in the study

of single-session influence diaphragmatic breathing on heart rate variability. Moreover, according to the obtained data the effect of increasing of heart rate variability lasts at least 1 month after a 10-day course of training in the mode of reverse biological connection. We associated this relatively long-term effect of trainings with the increasing of effectiveness of baro reception reflex. In its turn, it was shown that this increase improves the condition of patients with vegetative dysfunctions, especially in patients with bronchial asthma [18], hypertensive states [20], depression [22] and obesity [13]. At the same time, long-term effects of such training are under the question [13]. Obviously, there is a need to continue observation of the effectiveness of training for a longer period. However, more authors agree that the achieved result of training in the mode of reverse biological connection is a higher level of heart rate variability (HRV) at a state of rest improves the patient's chances of recovery [2, 6-8, 21].

On the other hand, the reduced activity baro reception reflex leads to lower heart rate variability and lowers the body's regulatory capacities in adaptation to aerobic loadings, cardiac insufficiency, and anxiety disorders [28]. Some authors consider that the level of heart rate variability (HRV) at a state of rest is correlated with emotional resistance of person [23], the general level of his or her physical and mental wealth [8, 10]. In our opinion, in the analysis of deep breathing effect on the functional state of autonomic nervous system (ANS) should pay attention not only to the general increase of heart rate variability (HRV), but also on its structure. In particular, it concerns VLF index, which in this context, in the available literature was not considered. Although the general physiological interpretation of this index is not fully elucidated, more authors are inclined to believe that it reflects the activity of super segmental centers of regulation of autonomic nervous system (hypothalamus, limbic system), neurohumoral effects on the heart and thermoregulation [2]. However, there is a common opinion that the increase of its index and its specific weight in the spectrum of heart rate (VLF%) means "centralization" of heart rate control and is the feature of reducing the adaptive capabilities of the organism. The data obtained by us, give the opportunity to affirm, that one-off influence of diaphragmatic breathing, and also a 10-day training course reduces the VLF and VLF% in the majority of people on the background of the general increase of heart rate variability. Essentially we are talking about the redistribution of autonomic nervous system activity in favor of its peripheral parts. This, in its turn, can be interpreted as an increase of regulatory reserve of organism [1].

Conclusions. Deep breathing in the mode of reverse biological connection with the use of portable devices StressEraser, EmWave2, and hardware-software complex MyCalmBeat during 15 minutes significantly influences on the functional state of autonomic nervous system , according to the heart variability data. The main changes in the functional state of autonomic nervous system are in the increase of general tone of autonomic nervous system and activity redistribution between the central and peripheral links in favor of the latter. The most effective influence on the functional state of autonomic nervous system was shown by the device StressEraser.

Prospects of further researches. To investigate the effectiveness of breathing gymnastics in the mode of reverse biological connection in patients with vegetative dysfunctions and chronic somatic diseases.

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