BIOFEEDBACK – A PROMISING NON PHARMACOLOGICAL TOOL OF STRESS – RELATED DISORDERS

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Abstract

Biofeedback is a therapeutic method of obtaining better awareness of physiological functions based on principles of operant conditioning and learning in general. While patient observes changes in physiological parameters in real-time (e.g. blood pressure, heart rate variability, temperature, electrodermal activity, etc.), he/she learns how to manipulate them at will. By means of this technique, individuals can improve their mental, emotional, and physical health. Clinical biofeedback training becomes popular for treating a variety of medical conditions, management of disease symptoms, and improvement of overall health through training of stress management. There is no center or group to systematically deal with biofeedback methods in Slovakia, except the Slovak Institute of CBT (cognitive-behavioral therapy) that teaches biofeedback as a therapeutic method. However, biofeedback and its opportunities have a relatively long history of exploration and practice, which is the best precondition for positive changes in this area. The review article aims to provide an insight to biofeedback training as a non-pharmacological therapeutic tool in stress management and stress-related diseases and disorders. The article also describes biofeedback modalities and efficacy on various medical conditions.

Key words: biofeedback, autonomic nervous system, self-regulation, non-pharmacological therapy

INTRODUCTION

Central nervous system can memorise, analyse and interconnect obtained knowledge, model and evaluate critical situations. Recent technological advances in microelectronics, computer technology, and biosensors allow to monitor, record, and display information about physiological functions in real-time (1, 2).

In the 1950s, in the USA, biofeedback started to evolve as a scientific discipline by convergence of experimental and neurophysiological findings, psychological and clinical experiences. The work *"A factor of encouragement in the feedback regulation of learning and activities of five-year-old children"* (in Czech language) by Hlavsa et al. published in 1966 presents the first mention about biofeedback in Czechoslovakia (3). In the upcoming years, biofeedback was proclaimed as a universal method for treating a wide variety of diseases and symptoms, often without underlying scientific studies, resulting in extreme disapproval of a large part of scientific public and massive temporary interest of general public. Today, the training centers provide biofeedback methods at a good professional level and the Slovak Institute of CBT (cognitive-behavioral therapy) that teaches biofeedback as a therapeutic method (4, 5).

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Biofeedback, as a therapeutic method, represents an interconnection of technological possibilities, scientific knowledge, and the power of human thought. Biofeedback training is defined as the way of control of mostly unconscious physiological functions using modern technical equipment. It is based on a principle of learning and operant conditioning. During biofeedback training, patient gradually learns how to modify the activity of the autonomic nervous system (ANS) through real-time information about changes in physiological parameters (1,3). The aim of the review is to present methods of biofeedback training, its modalities, and practical application of the biofeedback trainings under physiological and pathological conditions.

Autonomic nervous system

The autonomic (or vegetative) nervous system is a primary regulatory system maintaining homeostasis, flexibility and adaptability of an organism while resting and in response to stress-related stimuli. The term "autonomic" refers to a relative independence of its functions from central nervous system (1). The ANS controls all of the life-sustaining body processes. This includes regulation of homeostasis, functions of internal organs, innervation of smooth muscles, heart and glands, metabolism, and vital physiological functions (6, 7). The ANS consists of neurons of the central and peripheral nerves (7, 8). Cells of the ANS are located in the brain and in the spinal cord ganglia. Its nerves consist of at least two neurons and they form visceromotor systems starting from the central nervous system (CNS). Unlike sympathomotor nerves, they do not exceed directly from the CNS, but they are linked to other neurons in ganglia – this explains why we distinguish preganglionic and postganglionic neurons (7, 8). Despite the fact that the autonomic body functions are not under voluntary control there are centers associated with voluntary control that play an important role in the control of the autonomic nervous system. The ANS is controlled by subcortical centers (hypothalamus, brain stem, spinal cord, etc.) as well as cortical centers (cerebral cortex) (9, 10).

The autonomic nervous system consists of two functional groups:

- **Pars sympathica (thoracolumbar system)** – its nuclei in CNS, also known as nuclei intermediolaterales, are located by sides of C8-L3 segments of the spinal cord. Sympathetic division of the ANS prepares an organism for attack or escape reaction – fight-or-flight response (7, 8).
- **Pars parasympathica (craniosacral system)** – its nuclei are located near cranial nerves (cranial parasympathicus) and are by the sides of S2-S4 segments of the spinal cord (sacral parasympathicus). Parasympathetic nervous system maintains relaxed state of an organism postprandially and during rest – rest-or-digest (7, 8).

Sympathetic and parasympathetic division of the ANS interacts together to coordinate the organism functions at rest as well as to maintain adequate allostatic response during stress (9, 11). The autonomic state resulting from these complex interactions is termed as "sympathovagal balance" (10). Sympathetic and parasympathetic nervous system usually tend to act against each other; however, there are exceptions (10). The body processes related to relaxation (lower body temperature, lower heart rate, higher glandular secretion and peristalsis, miosis) are regulated by the parasympathetic nervous system. Sympathetic nervous system plays a crucial role in the stress response and in endurance situations resulting in increased heart rate, blood pressure and temperature, tachypnoe, mydriasis, lower glandular secretion and peristalsis) (7, 9).

Stress, stressor

Stress represents a complex response of the organism to stressor from the external or internal environment of an organism that affects all organs and tissues of the organism

(11,12). However, the definition of stress is still discussed because it is very hard to define something that defies any definition due to its high degree of subjectivity (12,13). Various stimuli of the internal or external environment leading to the activation of compensatory mechanisms to retain homeostasis and to prevent organism from damage are termed stressors (14). The intensity of these stimuli varies from mild (noise, pollution, traffic), to very strong (death of a child, divorce, unemployment) (13,14). In case the intensity of stimulus is too high to retain homeostasis utilizing common compensatory mechanisms, the stress reaction is activated. Sometimes, stimuli deprivation can also act as a stressor (14). Short time activation of stress reaction is an evolutionary mechanism of coping with stressful situations (12, 13). In this case, stress has positive implications and is necessary for our survival, helping us to handle difficult situations and achieve high performance of organism even out of our comfort zone. However, when stress reaction is activated for too long or in inadequate intensity, it can lead to exhaustion of compensatory mechanisms and, therefore, to participation on physical and mental health damage or/and on serious illnesses development (14, 13). Recently, as the group of mental stressors (caused by social, professional and personal demands) predominates, the attention turns to non-pharmacological therapeutic interventions such as biofeedback (13, 15).

In general, there are several kinds of stressors:

- physical – usually accompanied by pain, often interrupt the integrity of body surface tissues, e.g. extreme environment temperature, vibrations, noise, changes in light conditions, etc;
- metabolic – hypoxia, hypoglycemia, oxidative tissue damage;
- biological – viruses and bacteria, toxins;
- mental – typical for human population, these stressors play an important role especially in modern population and represent the cause of psychosomatic disorders, e.g. death of wife/husband, divorce, wedding, pregnancy, moving, etc;
- social – children in orphanages, unemployment, retirement;
- cultural – interruption of behavioral norms;
- influencing more body systems – immobilisation, chronic illnesses, jet lag syndrome (14,16,17).

Sometimes, the same stressor can be attached to more than one of the groups above. Another classification separates stressors to individual (hospitalization, public presentation, etc.), group (family, school environment, etc.), and social (retirement, employment, etc.) (18).

BIOFEEDBACK – MODALITIES AND EFFICACY

It is well-known that physiological functions are usually not conscious, thus not controlled and optimalized by will. It is also true that emotions and feelings experienced during stress reaction do not always correspond to the usual physiological reactions. The importance of stress reaction monitoring is based on the finding that stress-related somatic and mental symptoms can be activated and modified by changes of physiological functions (19). As defined by Faber in 2017, biofeedback represents a new therapeutic intervention how to control and improve physiological functions (20). This method allows defining client's stress profile and reactivity of physiological systems. Biofeedback training includes measuring and monitoring of changes of ANS functions in real-time and their presentation to the patient (21). At the beginning of the procedure, electrical biosensors are connected to specific areas of patient's body. The placement and the type of sensors depend on the type of monitored signal. During the session, the therapist guides the patient through mental exercises (relaxation, breathing, visualisation, or meditation techniques) (22). The patient performs these activities and receives information about physical response from the measurement unit (1). The duration, number, and frequency of biofeedback trainings sufficient to attain maximum benefit from biofeedback procedures is highly variable, depending on many factors such as type of applied biofeedback, compliance of patient, treatment goals, and others (1,2). From methodological aspect, monitoring of several physiological functions such as heart rate, respiration, blood pressure, temperature is used. According to the observed physiological function, the biofeedback modalities are differentiated (19, 21).

Basic biofeedback applications:

Electrodermal activity (EDA) biofeedback – represents the oldest method of biofeedback used by Jung (1910) and today it is also the world's most spread modality of biofeedback (19, 23). EDA represents a sensitive peripheral index of sympathetic activity and it is the only autonomic psychophysiological variable with no parasympathetic activity influence (24, 25). From methodological aspect, EDA biofeedback is based on the monitoring of the skin conductance changes influenced by the activity of eccrine sweat glands innervated by the sudomotor cholinergic nerves (10,26). EDA is characterised by two main components – skin conductance level such as slow changes of EDA (representing tonic activity) and skin conductance responses such as fast changes of EDA (representing phasic activity) (25, 27). In psychophysiological research, EDA monitoring can be used to evaluate emotional behaviour, anxiety, and influence of relaxation techniques (21, 25).

Heart rate variability (HRV) biofeedback – is the most common single-modal biofeedback modality for stress-management (2). HRV is an index of central-peripheral ANS integration regulated by input from both divisions of the ANS – the parasympathetic and sympathetic. However, the parasympathetic part of the ANS has the predominant influence by parasympathetic withdrawal or by increased parasympathetic input (28). HRV biofeedback is based on monitoring of continual oscillations of R-R intervals (21). The input signal can be electrocardiogram (ECG) signal or blood volume pulse (BVP) signal (2, 22). Physiological phenomenon of heart rate oscillations according to breathing is termed as respiratory sinus arrhythmia (RSA). The principle of RSA is prolongation of R-R interval during expiration and shortening during inspiration (21). RSA is widely accepted as a peripheral index of cardiac-linked parasympathetic regulation, cognitive and emotional processing (28). From physiological aspect, breathing represents a set of processes leading to gas exchange between blood and environment. Stress reactions activate higher oxygen intake, breathing "pattern" is characterised by shallow breathing associated with higher respiratory rate. Upcoming physiological mechanisms of homeostasis may be misunderstood as possibly threatening and the organism tends to activate the ANS even more rapidly, leading to anxiety and panic attacks. Specifically, multimodal HRV and respiratory biofeedback uses the possibility of conscious changes in breathing patterns leading to changes in HRV to reach quick and effective changes in emotional states (19,21). During biofeedback trainings, patient practices deep, slow breathing to activate parasympathetic system associated with inhibition of sympathetic activity. Application of deep and slow breathing training results in improvement of cardiovascular system functioning including baroreflex. Consequently, the emotional and cognitive processes are trained (1, 19, 21). In psychophysiological research, this biofeedback modality can be used as a potential marker of stress as well as a potential non-pharmacological tool for personal enhancement and for wide range of stress-related disorders (asthma, depression, etc.) (24, 28).

Blood volume pulse (BVP) biofeedback – is based on plethysmography measuring the tonus of smooth muscles in vessels. In particular, peripheral circulation is higher during vasodilation (lower sympathetic activity) and it is lower during vasoconstriction (higher sympathetic activity). Furthermore, the heart rate is continuously evaluated (19).

Temperature biofeedback – peripheral temperature monitoring is frequently used to train methods of relaxation (19). Body temperature regulation is subject to hypothalamic control (7).

It is assumed that better relaxation is associated with higher temperature. However, if the temperature is too high, it can also indicate chronic stress (21).

In clinical practice, for amplification of overall effect, combinations of biofeedback modalities are used frequently (21). Combinations of biofeedback modalities that measure and display two or more types of physiological informations are termed as multimodal biofeedback systems. During multimodal biofeedback training two or more biosignals are monitored. The output might display various physiological information concurrently or based on the analysis of several real-time data, the output can reflect stress level or emotional state (2).

Efficacy

It is assumed that biofeedback is an effective method for treating a wide variety of symptoms with the aim to reduce cognitive and emotional stressors, positively influence stress response, and reverse failure of healthy homeostasis in organism (2,18). The biofeedback trainings give the patient an option to learn skills that moderate the main causes of disorders, sustain the healthy homeostasis restoration, and prevent the large spectrum of diseases. The criteria for evaluation of evidence-based clinical efficacy of biofeedback interventions were designed by the Society for Neuronal Regulation and a Task Force of the Association for Applied Psychophysiology and Biofeedback (29,30):

Level 1: Efficacy not Empirically Supported – Supported only by unofficial proofs and/or case studies without peer-reviews.

Level 2: Possibly Efficacious – without randomised internal assignment, but supported by one study with well-defined outcomes and of adequate statistical power at minimum.

Level 3: Probably Efficacious – evidence based on adequate number of observational clinical and wait-list controlled studies, together with intra- and inter-individual replication studies demonstrating efficacy.

Level 4: Efficacious – fulfilling all of the criteria below:

a. The investigational treatment is statistically significantly superior compared to randomised control group with no-treatment, placebo or alternative treatment, or equivalent to applied treatment of efficient therapy (based on studies of adequate statistical power). A treatment of established efficacy in a study with sufficient power to detect moderate differences;
b. The inclusion criteria of the studies conducted with a population treated for a specific problem are set adequately and clearly;
c. The outcome parameters connected with treated problem are clearly defined;
d. Appropriate analysis of all data;
e. Well defined diagnostic and therapeutic variables and pathways to enable study replication by independent researchers;
f. At least two independent research settings prove the superiority or equivalence of the reviewed modality.

Level 5: Efficacious and Specific – fulfill Level 4 efficacy criteria and there is a statistically proven predominance over placebo, pharmaceutical therapy, or alternative treatment in two independent studies at minimum (21, 29, 30).

Based on the criteria listed above, Yucha and Montgomery in 2008 evaluated various medical conditions according to the efficacy of biofeedback on these conditions. Their categorization is summarised in Table 1 (21, 30).

Table 1. Efficacy ratings for biofeedback training on various medical conditions (according to Frank et al., 2010)

Level 1 **Not empirically supported**	Eating disorders Immune function disorders Spinal cord injuries Syncope
Level 2 **Possibly efficacious**	Asthma Autism Bell's palsy Cerebral palsy Chronic obstructive pulmonary disease Coronary artery disease Cystic fibrosis Depressive disorders Erectile dysfunction Fibromyalgia/chronic fatigue syndrome Hand dystonia Irritable bowel syndrome Post traumatic stress disorder Repetitive strain injury Respiratory failure: mechanical ventilation Stroke Tinnitus Urinary incontinence (children)
Level 3 **Probably efficacious**	Alcoholism/substance abuse Arthritis Diabetes mellitus Faecal incontinence Headache (paediatric) Insomnia Traumatic brain injury Urinary incontinence (males) Vulvar vestibulitis
Level 4 **Efficacious**	Anxiety Attention deficit hyperactivity disorder Chronic pain Constipation (adult) Epilepsy Headache (adult) Hypertension Motion sickness Raynaud's disease Temporomandibular disorder
Level 5 **Efficacious and specific**	Urinary incontinence (females)

CONCLUSION

Biofeedback represents one of the most promising methods of stress-management, offering the possibility to train and, thus, to be prepared to manage upcoming stress reactions. Main advantages and the reason of growing popularity in general population are non-invasiveness, applicability in children, home use (in some modalities), and evidence-based confirmation of efficacy in a wide variety of conditions. On the other hand, there are also disadvantages such as lack of specialists, technical or economic difficulties of some modalities, patient's non-compliance, etc. Importantly, further research in this field could illuminate the pathway linking central control and peripheral nervous system functioning.

Conflicts of Interest

There is no conflict of interest.

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