

Stabilometric Biofeedback Training in Cognitive and Affective Function Improvement. Contribution of the Russian Scientific School. Part II

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Abstract—This review is the second part of the critical analysis of recent papers of Russian and other authors devoted to the study of the stabilometric parameters in postural control biofeedback training and rehabilitation, associated with psychological functions. The review presents the studies of postural control features in chronic pain syndrome, chronic fatigue syndrome, Parkinson’s disease, multiple sclerosis, and depression. The leading role of Russian researchers in the development and application of stabilometric biofeedback in the training of optimal functioning, rehabilitation, and correction of neurological disorders is noted. The paradigm of stabilometric biofeedback training of the cognitive and affective functions is offered.

Keywords: posture control, attention, anxiety, depression, chronic fatigue syndrome, rehabilitation, biofeedback, stabilometry

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The key mechanism of postural control as one of the most common examples of sensorimotor integration is adaptive feedback [1, 2]. Hence it follows that the disruption of the connections between the perception and the processing of information during the execution of motor or cognitive tasks, causes disorders of central genesis. This determines the fundamental significance of studying the interrelationship between the impairments of perception (vestibular, visual, proprioceptive and support afferentation) and CNS (cognitive and affective functions) of postural control processes. In the past 30 years the study of this relationship has gained new relevance due to the development of informative technologies presupposing the use of more and more electronic gadgets in everyday life, which leads to a reduction in physical activity and changes in the pattern of cognitive activity [3]. In addition to the negative consequences of sedentary lifestyle, long-term sitting position or weakened support afferentation per se impairs not only physical musculoskeletal [4, 5], cardio-respiratory and vegetative [6], but also cognitive [7–9] and psychoemotional functions [10–12]. At the same time, if we take into account the negative effects of high-frequency electromagnetic waves caused by electronic devices and gadgets [8, 9], which are also associated with cognitive and psychoemotional disorders and even with the appearance of depressive symptoms as early as in the childhood and adolescence [13], the study of tech-

niques for correcting impaired postural control as a result of weakened support afferentation in sedentary lifestyle becomes particularly important [4]. In addition, the relevance of studying the interrelationship between stabilometric and psychological parameters is due to the fact that balance training and posture control can be highly effective for elderly people, the relative number of which has been steadily increasing over the past 20 years, and the problem acquires global significance [14–81]. Finally, in the recent two years of the COVID-19 pandemic, a new need has arisen to investigate the interrelationship between impaired postural control (as a result of sedentary lifestyle), being a consequence of isolation and a complication of neurochemical processes in the brain after coronavirus infection [19, 20].

It is known that one of the most efficient approaches to neurophysiological nonmanipulative rehabilitation of impaired regulatory processes is to use the biofeedback technology as learning to recognize the state of optimal functioning [21]. Stabilometric biofeedback (BFB) presupposes postural control training with the involvement of feedback from the parameters of the center of pressure deviations (CoPD). We assume that stabilometric BFB will favor the correction and rehabilitation of not only biomechanical functions of equilibrium but also the cognitive and affective functions associated with impaired

sensorimotor integration. However, the problems of using the objectively measured stabilometric characteristics of sensorimotor integration as BFB aimed at overcoming psychoemotional disorders and cognitive deficit have not yet been sufficiently investigated.

The present article continues the review of research into the psychophysiological mechanisms of postural control. The second part of this review presents the published data on the relationship between the impairments of postural stability and the disorders of psychological functions in chronic pain syndrome (such as fibromyalgia), chronic fatigue syndrome, multiple sclerosis, depressive states and disorders of cognitive functions. The review includes the currently known data on the efficiency of using stabilometric BFB aimed at the correction of neurological disorders and affecting psychoemotional functions.

Literature on the impact of impaired postural functions rehabilitation, as well as influence of postural control training with stabilometric biofeedback, on psychological characteristics was searched for by the following keywords: “postural control,” “stabilometry,” “sensorimotor integration,” “afferentation,” in combination with the words “cognitive functions,” “memory,” “attention,” “anxiety,” “depression,” “biofeedback,” “training,” and “rehabilitation.”

A literature search was conducted according to the recommendations of “Preferred Reporting Items for Systematic Reviews and Meta-Analyses” *PRISMA* and relied on the literature search described in the *RELISH (RElevant LIterature Search)* consensus [22]. The following databases were used: *Web of Science*, *PubMed*, *Scopus* and *RSCI* (to report on the results of Russian studies). The present review includes the results published in the articles with DOI (*digital object identifier*), completely corresponding to the keywords (Table 1). The review does not include the results of studies without psychological measurements or investigating individual cases without the control, as well as those published as abstracts only.

Psychophysiological Mechanisms of Postural Control Impairment

One of the methodological techniques used in the framework of cognitive neurosciences to study psychophysiological mechanisms is to compare the postural control variables under the normal conditions and their values in patients with CNS disorders [23–26] or dysfunction of sensory inputs [27], as well as with the borderline mental [28], phobic [29], anxiety and depressive disorders [30, 31].

Chronic pain syndrome and chronic fatigue syndrome. Chronic pain syndrome and chronic fatigue syndrome are overlapping and can influence disease etiology by involving the same regulatory mechanisms in CNS [32, 33]. This may have an effect on the central mechanisms, because motor learning requires the

maintenance and renewal of internal psychomotor models [34]. Pain and fatigue perception can interfere with postural control. For example, the problems with maintaining balance have been found in patients with fibromyalgia and/or chronic fatigue syndrome [35, 36]. In patients suffering from chronic pain and fatigue, cognitive problems are combined with postural deficits [35–37]. Such patients often complain that they have to make more efforts to perform the common cognitive tasks [38, 39]. The possible consequences of chronic pain and fatigue with respect to motor functions are often underestimated but must be taken into consideration. In particular, E. Peper et al. and W.C. Tsai et al. have noted that the maintenance of correct upright posture with the support on the feet is associated not only with reduction of painful sensations in the neck, shoulders and back, but also with mood improvement, confidence, greater strength compared to the hunched sitting posture, which is associated, in addition to painful and unpleasant bodily sensations, with depressive state and negative emotions [40, 41].

In the work of O. Rasouli et al., the effects of adding cognitive task performance to the maintenance of the upright posture were compared in the groups of patients with chronic fatigue and fibromyalgia, as well as in the healthy participants group [42]. In patients, the frequency of CoPD proved to be lower compared to the control, demonstrating predominance of the involuntary component of postural control. While performing a competing cognitive task, the patients showed worse postural control parameters compared to healthy persons: the higher amplitudes and the lower frequencies of CoPD. At the same time, the differences in stabilometric parameters in the chronic fatigue compared to the control group were more marked [42]. The fact that the present study has revealed correlations between fatigue and postural control, but not pain, suggests the predominance of psychological but not reflex mechanism of impaired postural control in the chronic fatigue syndrome.

Attention deficit. Attention is an important factor in adequate motor commands organization, in particular, while maintaining balance [43]. This fact is confirmed by the proven deterioration of postural control in children with attention deficit [44]. The role of voluntary attention in postural control is studied using the “separated attention” models with the addition of a competing cognitive task, e.g., conversation while walking [45]. It would be logical to assume that the addition of a cognitive task while maintaining the upright posture will enhance the load of information processing in the CNS [46] and thereby reduce the ability to control balance. Such effect has been demonstrated in the study of elderly people with the increased risk of falling (the increase in the area of CoPD while performing a competing cognitive task) [47]. The increase in energy demand for simultaneous (motor + cognitive) tasks performance demon-

Table 1. Description of the studies included in assessment of the efficiency of stabilometric balance control for the correction of cognitive and affective functions

Source	RCT/SGT/CCS	Sample, average age (years)	Number of groups, subjects (women)	Measured STG parameters (equipment), feedback signal	Type and frequency of training/rehabilitation/testing	Estimated psychological function	Significance level of results
Bofanova, 2013 [89]	RCT	Patients with traumatic brain injury (TBI): E, 48 ± 4; and healthy subjects: C, 48 ± 4.8	E = 40 (0) C = 30 (0)	oCOP_AP_ML, STG area, CoPD rate (MBN-Stabilo), feedback from CoPD position	Stabilotrainers: “soap bubbles,” 2–3 min; “target,” 2–3 min; “shooter,” 2–3 min; “bee,” 5–7 min; daily for 10 days	Neuropsychological examination	In the E group, CoPD ML ↓ by 18%, oCOP AP ↓ by 16%, STG area ↓ by 40%, CoPD rate ↓ by 22% than in the TBI group without STG training
Tauil, 2021 [78]	Cross-section study	Patients with multiple sclerosis with (E2) and without (E1) symptoms. E1, 36.5, E2, 35.9	E = 26 (24) E1 = 15 (0) E2 = 11 (2)	oCOP rate (<i>AccuSway Plus, AMTI Inc.</i> , United States)	Three attempts by 30 s with a 60-s pause between them	Anxiety and/or depression (Beck Scale, Hospital Anxiety and Depression Scale (HADS)). Subjective reported fatigue (Borg scale)	CoPD rate (unstable support) accounts for 21% of variation by Beck Scale and 24% of variation by HADS
Aftanas, 2018 [31]	CCS	20–55	E = 24 C = 26	Energy consumption index (ST-150 (MEPA))	Tasks: (1) quiescent posture maintenance in the upright position while standing on a stabiloplatform, (2) dual task of maintaining posture and finger movement, (3) dual task of maintaining posture and imagining finger movements	Depression: Hamilton Scale, Beck Scale, <i>Ruminative Responses Scale</i>	Performance of a competing real or imaginary movement (fine motor activities of fingers) with EC redistributes attention resources and distracts from rumination

Table 1. (Contd.)

Source	RCT/SGT/CCS	Sample, average age (years)	Number of groups, subjects (women)	Measured STG parameters (equipment), feedback signal	Type and frequency of training/rehabilitation/testing	Estimated psychological function	Significance level of results
Mesquita, 2015 [84]	RCT	Elderly women. E1, neuromuscular proprioceptive development. E2, Pilates group. C, no exposure	E1 = 20 E2 = 20 C = 18	oCOP amplitude in the frontal and sagittal planes, mean rate of oCOP, oCOP area (<i>electronic baropodometer (S-PLATE)</i>)	Sessions in experimental groups were conducted by 50 min three times a week for 4 weeks	Pain and chronic fatigue	In the group of neuromuscular development (compared to the control): ↓ total spread of oCOP, ↓ oCOP area, ↓ mean rate of oCOP, ↑ points by the <i>functional reach test</i> and <i>TUG test</i> . In the Pilates group: ↑ points by the <i>functional reach test</i> and <i>TUG test</i>
Rasouli, 2018 [42]	CCS	Young and middle-aged women with chronic fatigue syndrome (CFS) and fibromyalgia. E1, CFS, 34.0 ± 8.9; E2, fibromyalgia, 38.6 ± 8.0; C, healthy, 34.4 ± 7.9	E1 = 25, E2 = 25, C = 25	Amplitude and frequency parameters of slow and fast oCOP (<i>Kistler force plate</i>)	Two tasks by 60 s while standing on a solid platform: 1, quiescence; 2, quiescence + sequential subtraction of 7 from 150	Pain and fatigue—subjective assessment by inventories	In CFS compared to the control: ↑ ampl. of slow (in both directions) and fast (only in the ML direction) oCOP components. In patients compared to the control: ↓ oCOP frequency in both directions, both in quiescence and during cognitive task performance, correlations between fatigue and oCOP but not pain

Table 1. (Contd.)

Source	RCT/SGT/CCS	Sample, average age (years)	Number of groups, subjects (women)	Measured STG parameters (equipment), feedback signal	Type and frequency of training/rehabilitation/testing	Estimated psychological function	Significance level of results
Hassan, 2014 [279]	SGT	Patients with Parkinson's disease. E, 67 ± 9	E = 37 (13): 1, reduced apathy (E1 = 17), 2, improved postural control (E2 = 20)	oCOP area platform (4060-10, Bertec Corp., Columbus, OH)	Three attempts of quiet standing, 20 s each	Apathy, Beck Depression Inventory	Patients with apathy compared to patients without apathy: ↑ total estimate for Parkinson's disease, ↑ points by Beck depression scale, ↑ oCOP area
Ozgen, 2016 [83]	RCT	Multiple sclerosis patients	E = 20, C = 20	Fall risk index (from 0 to 100). Tetrax interactive balance system (Sunlight Medical Ltd., Ramat Gan, Israel)	Vestibular rehabilitation program for 8 weeks	Quality of life: Multiple Sclerosis Quality of Life-54 Beck Depression Inventory	↑ All estimated parameters compared to the control group (except for Tandem Romberg with EC and standing on an unstable support with EO)
Harvey, 2020 [88]	CCS	Healthy men and women, average age 21.9 ± 2.9	E = 13, C = 13	Stabilometry was not performed	UpRight gadget is fixed on the back in the area of the lower cervical vertebra, feedback as vibration in case of changing posture (hutching). Is carried for no less than 15 min per day throughout 4 weeks	The Quality of Life Scale, SF-36 Health Survey (8 scales)	↑ Parameters of the quality of life, ↓ stress level, and ↑ self-confidence (based on self-reports)

Table 1. (Contd.)

Source	RCT/SGT/CCS	Sample, average age (years)	Number of groups, subjects (women)	Measured STG parameters (equipment), feedback signal	Type and frequency of training/rehabilitation/testing	Estimated psychological function	Significance level of results
Hebert, 2011 [85]	CCS	Patients with multiple sclerosis. E, 46.8; C, 42.6; waiting list, 50.2	E = 12 (9), C = 13 (11). Waiting list = 14 (11)	Sensory organization test: upright posture maintenance under 6 different conditions (parameter, <i>Sensory Organization Test</i> , <i>SOT</i> , %), device, <i>The Smart Balance Master System</i>	Exposure phase, 6 weeks. Delayed effect phase, 4 weeks. Experimental, vestibular rehabilitation; control, training on a stationary bike and stretching exercises	Chronic fatigue syndrome— <i>21-item Modified Fatigue Impact Scale (MFIS)</i> , Beck Depression Inventory	Experimental group of 6-week vestibular training: ↑ <i>SOT</i> , ↓ fatigue, ↑ balance, ↓ vertigo-related difficulties compared to the group performing only physical exercise. The changes persisted for at least 4 weeks
Melnikova, 2018 [90]	RCT	Patients with diagnosed axial spondyloarthritis, coxarthrosis, gonarthrosis. E, 58.3 ± 14.3; C, 67.1 ± 9.2	E = 104 C = 24	CoPD rate, CoPD area ML_AP. Stabilotaining with BFB, device <i>Prokin, TechnoBody</i> (skiing computer game no. 10)	All—therapeutic exercise. E patients: stabilotaining no. 10 by 20 min daily	Pain intensity by the visual analog scale	In Group E: ↑ muscle strength, ↓ pain intensity, ↓ standard deviation of CoPD, ↓ mean rate of CoPD, ↓ the area of the ellipse, ↓ excess perimeter

Table 1. (Contd.)

Source	<i>RCT/SGT/CCS</i>	Sample, average age (years)	Number of groups, subjects (women)	Measured STG parameters (equipment), feedback signal	Type and frequency of training/rehabilitation/testing	Estimated psychological function	Significance level of results
Krivoshey, 2008 [28]	CCS	Healthy persons (C) and patients with non-psychotic disorders (E). C, 34.9; Ex, 36.7; EA, 31.4; EB, 38.8; EC, 29.2	C = 37 (34), E = 127, Ex = 49 (10), EA = 27 (6), EB = 22 (13), EC = 29 (21)	The Romberg Quotient (QR); CoCOP rate (V), mm/s; CoCOP area <i>Stab</i> , %. “MBN-STABILO”	Exposure of subgroups: C—, Ex—without BFB; EA—SB (12 procedures); EB—Balance therapeutic exercises; EC—CB + Balance therapeutic exercises	Hamilton Depression Rating Scale (HDRS), Hospital Anxiety and Depression Scale (HADS)	After completion of therapy in the control group of patients: CoPD shifted backwards, ↑ CoPD area. In the E groups (trend-level): ↓ STG area, ↓ depression, ↓ anxiety. Comparison between Ex and E A, B, C: Romberg quotient in EA > Ex. CoPD rate with EC in EC < Ex. CoPD area in EB and EC < Ex. Depression in EC < Ex

CoPD, the center of pressure; CoPD, center of pressure deviations of foot; CG, the center of gravity; E, energy for balance maintenance; EC, eyes closed; EO, eyes open; RMS, the root-mean-square value of the COP-CG oscillation range; MPPF, median power frequency; SB, stabilometric biofeedback; RCT, randomized controlled test; SGT, single group test; CCS, case-control study.

strates that walking or maintaining postural stability requires the involvement of considerable cognitive resources in healthy elderly people [48] and/or in case of mental disorders with the early Alzheimer's disease [49]. In the meantime, B. Kerr et al. [50] have established that postural control is impaired only when solving a spatial task but not a working memory task. These results suggest that the cognitive processing of precisely spatial tasks depends on the neuronal mechanisms of the vestibular but not on the nonspecific cortical activation in postural control [50]. The results of our study in patients with major depressive disorder [31] also showed that performance of a dual postural–psychomotor task not associated with spatial imagination was accompanied by postural control improvement with respect to the parameters of energy demands for balance maintenance, while in healthy persons it was unchanged or even reduced in case of task complication. It can be supposed that, in case of depression, the attention required to maintain balance was focused on the process of rumination (“preoccupation with negative thoughts”) instead of postural control; when performing a simple cognitive task, the attention was switched over to task performance, while balance was maintained automatically [31]. We assume that such attention switching technique can be useful for balance training in order to overcome depressive rumination.

Affective disorders. The studies with the involvement of psychiatric patients and patients with the vestibular disorder report the high comorbidity of vestibular dysfunctions and the symptoms of agoraphobia [51], panic attacks [52], and anxiety [53]. The results of M.S. Redfern et al. show that patients with anxiety disorders, especially with the space and motion phobia, are more dependent on visual afferentation while maintaining balance than in the absence of phobia [54]. This subgroup of patients can be exposed to the therapy with the involvement of stabilometric biofeedback, which uses visual inputs as a feedback signal.

The studies of the role of vestibular afferentation make it possible to reveal, at least partially, various neuronal mechanisms. C.D. Balaban et al. assume that the area of the parabrachial nucleus receiving afferent inputs from vestibular receptors contains the cells that respond to rotation of the body relative to the force of gravity. The parabrachial nucleus, with its reciprocal relationships with the central nucleus of the amygdala, the infralimbic cortex and the hypothalamus [53], is an important node in the primary network that processes the convergent vestibular, somatic and visceral information in order to mediate avoidance conditioning, anxiety and conditioned fear responses [55].

The noradrenergic and serotonergic projections of vestibular nuclei also have parallel connections with the pathways of anxiety. The ceruleovestibular pathway originates in the locus coeruleus (LC) and pro-

vides regionally specialized noradrenergic input to the vestibular nuclei, which probably mediates the effects of alerting and vigilance on the sensitivity of vestibule–motor circuits. Both serotonergic and nonserotonergic pathways from the dorsal raphe nucleus also project differentially to the vestibular nuclei, while 5-HT (2A) receptors are expressed in amygdaloid and cortical targets of the parabrachial nucleus. It is proposed that the dorsal raphe nucleus pathway contributes to both the tradeoff between the motor and sensory (information gathering) aspects of responses to self-motion and the calibration of sensitivity of affective responses to aversive aspects of motion [56]. F. Mast et al. believe that the described neurophysiological model is a synthetic scheme for studying the neuromorphological and neurochemical bases of comorbidity of balance and anxiety disorders. Spatial transformations affect the parietal regions, body representation is associated with the somatosensory regions, and affective processes involve the insular and cingulate cortex, each of them receiving a vestibular signal [57]. Under certain circumstances, visual, vestibular and postural interactions act as a signal causing fear, similarly to what takes place in motion sickness, which then may be associated with particular stimuli or a situation, creating an association (e.g., phobia), or without association with any particular concomitant event (e.g., panic) [58]. Following this rationale, C.M. Coelho and C.D. Balaban have proposed to consider this subcategory of anxiety disorders as the one induced by visual-vestibular disorders and fears in the framework of *DSM-V* diagnostic criteria [59]. In the meantime, in spite of establishing the broad range of various vestibular cortical projections, their functions have yet been poorly studied.

Depression. The relationship between postural control and depression deserves special attention, as it was noted long ago that the major depressive disorder has a negative effect on the entire organism but not only on the psyche. Among the most severe manifestations of depression, there are motor symptoms; nevertheless, they are often ignored both in research and in clinical practice [60]. In spite of the fact that motor disorders attract much less attention in the assessment of depression, often they are a self-sufficient factor independent of affective, cognitive and neurovegetative components of this disorder [61–63]. The existing estimates of motor symptoms usually rely on subjective judgments made by physicians on the basis of observed or recalled behavior [64, 65]. In some studies, they begin to use more objective tools such as *Timed Up and Go Test (TUGT)* or dual motor-cognitive tasks [66–68].

At present, it is only known about single studies devoted to the relationship between the severity of depression and stabilometrically measured postural impairments [30, 31, 69]. However, such relationship has its neurobiological basis: postural control, similar to the regulation of emotional state, depends on the

complex mechanisms of sensorimotor regulation involving the dopaminergic pathways, as well as the links between the basal ganglia and the prefrontal cortex [70], and the same mechanisms are involved in the development of major depressive disorder [71]. In addition, recent studies of the consequences of sedentary lifestyle (i.e., the weakened support afferentation) and isolation under conditions of the COVID-19 pandemic demonstrate an increase the number of depressive disorders, probably due to the impaired neurochemical and postural mechanisms of sensorimotor integration, which complement each other [19, 20].

Parkinson's disease. Parkinson's disease is also characterized by a combination of motor and nonmotor disorders, which affect life quality. Nonmotor symptoms such as apathy and depression are associated with locomotion problems, in particular, postural instability [72]. Apathy and depression have a clear anatomical link to cerebral structures and are usually manifested in case of damage to the prefrontal cortical areas and the cingulate gyrus [73]. The neuroanatomical bases of postural instability in Parkinson's disease are less studied. However, all these manifestations (apathy, depression and postural instability) are related actually to the same neuronal pathways as depression. These are the pathways through the basal ganglia associated with dopamine deficiency. These manifestations are usually resistant to the L-DOPA therapy [74, 75]. Other common neurotransmitter pathways involve cholinergic and catecholaminergic fibers [76, 77].

Multiple sclerosis. In patients with multiple sclerosis, locomotor disorders are also combined with anxiety and depressive symptoms. Depression develops in almost half of multiple sclerosis patients at a particular stage of their lives [78]. According to the American Academy of Neurology, the efficacy of antidepressant therapy and/or group therapy in such patients is insufficient [79]. The meta-analysis performed by I. Ensari et al., reporting on the effects of physical exercise in depression, showed that such exposure had a slight but statistically significant effect with respect to reduction of depressive symptoms in multiple sclerosis patients [80]. Later, several reviews presented evidence in favor of the fact that the efficiency of nonpharmacological techniques aimed at an increase in physical activity for rehabilitation and prevention of depressive disorders did not reach a significant level [81, 82].

The available studies show that affective and cognitive disorders are invariably accompanied by impaired balance, posture and gait, when they are assessed by objective stabilometric methods [30, 31]. Impaired postural control probably passes from the main component of affective disorder (among young people) to the epiphenomenon of concomitant physical and cognitive decline (among elderly people).

Thus, disorders of attention, spatial memory, mood, and other cognitive and affective functions,

which could be targets for stabilometric biofeedback, are described in literature as the psychophysiological correlates of impaired postural control. Among the stabilometric indices of these psychological functions, particular attention is focused on the rate of oscillations in the foot center of pressure in high-frequency bands as most predictive, with the possibility of using them for cognitive function training.

The above data suggest that the training of the voluntary element of postural control, i.e., performance of simple cognitive or psychomotor tasks while maintaining balance, can be appropriate for overcoming attention deficit, psychomotor retardation and psychoemotional disorders.

Application of Stabilometry in Affective Disorders Rehabilitation

The previous section of this review demonstrated the interrelationship between stabilometric, psychological and neurobiological characteristics of postural control under normal conditions and in different kind of disorders. However, in rehabilitation, emphasis is usually placed only on one sphere: either motor or emotional. Both Russian and foreign literature sources describe different approaches to postural rehabilitation. Most often, the efficiency of a set of physical exercises is investigated [30, 81–85], while stabilometry is used in combination with other motor tests only for diagnosing disorders.

It is known that the biofeedback technology, due to neurophysiological principles of its organization, is the most efficient technique for regulation impairments correction and for training the optimal functioning [21, 86]. The neurophysiological basis of biofeedback procedure is related to anticipation, considered by Bernstein as a structural element of any human activity organization, which is closely associated with planning or creating a model that can be used in future reality [1, 34]. The result of the execution plan is presented in signs of the visual, acoustic, proprioceptive or even tactile feedback. These signals are a stimulus for training sensory awareness of a correctly performed activity, similar to motor training on the basis of sensory corrections [87]. Mental training with the involvement of feedback is aimed to activation of the brain integrative functions. As it has been mentioned previously, psychoemotional disorders have the sensorimotor disintegration origin, and postural disbalance is a particular case of sensorimotor disintegration. Therefore, the stabilometric biofeedback task must include the training of sensorimotor integration.

There is an interesting example of training the maintenance of the upright posture with biofeedback, using a head tilt sensor attached on the lower part of the neck. The sensor generates a feedback signal based on the changing tilt and curvature of the spine as vibration in case of hunching and tilting the head

Table 2. The results of literature analysis by the keywords: “depression,” “stabilometry,” and “biofeedback”

No.	Keywords	Number of sources
1	<i>Biofeedback AND Posturography AND Posture control</i>	815
2	<i>Biofeedback AND Posturography AND Balance control</i>	317
3	<i>Major depressive disorder OR MDD</i>	562
4	<i>Combine #1 AND #3</i>	0
5	<i>Combine #2 AND #3</i>	0

downward [88]. The authors have noted the efficiency of such training with respect to the quality of life, stress reduction and mood improvement in the group of healthy volunteers using this gadget. An important practical aspect of its application can be the convenience and simplicity of using it in the sitting position, which is especially relevant for people who actively use computers, pads, smartphones, etc.

Meantime, the literature search using simultaneously the keywords “depression,” “stabilometry,” and “biofeedback” did not yield any results (Table 2).

In Russian studies, the stabilometry method is actively used not only for diagnosing the balance function but also for its correction in the framework of neurological rehabilitation [28, 89–92], as well as for increasing efficiency in high performance sport [93, 94]. It should be noted that Russian authors very rarely take into account the psychoemotional state and peculiarities of cognitive functions of patients exposed to postural stability training. Quite often, the detailed descriptions of stabilometric parameters and training devices used, the presence of a control group of healthy subjects, the peculiarities of psychological examination are either not presented at all or described as secondary (e.g., a kind of neuropsychological examination without indicating the tests and assessing the dynamics of their changes as in [89], or assessment of the higher psychological functions in [90]). Therefore, researchers indicate the need for the common and strict methodological standards to overcome the deficiency of well-controlled studies and heterogeneity of electrophysiological and stabilometric data [21].

For example, high quality design and detailed description of techniques and results are presented by I.V. Krivoshey et al. [28] in the work with two control groups (healthy volunteers and patients with neuroses receiving no treatment), as well as three experimental groups of patients with neuroses undergoing rehabilitation with three different combinations of measures: the course of stabilometric biofeedback, the “Balance” course of specifically designed therapeutic exercises, and the course of stabilometric training with

BFB and the “Balance” course of therapeutic exercises simultaneously. This study confirms the efficiency of the used correction techniques, which not only lead to functional motor changes but also have a psychotherapeutic effect, reduce anxiety and depression and are a guide to recovery. The results of clinical testing of patients from the BFB subgroup by the CoPD coordinates demonstrate the higher efficiency of biofeedback compared to the conventional training of postural control by physical exercise for improving mental health [28].

CONCLUSIONS

Thus, the analysis of Russian and foreign studies of the impaired postural control rehabilitation suggests that the improvement of qualitative and quantitative indices of the maintaining posture function with the use of stabilometric biofeedback and/or physical exercises aimed at postural control training is also accompanied by improvement of the psychoemotional state (reduced anxiety, depression, fatigue, apathy, and decrease in pain score) and, in general, the quality of life improvement. However, in these studies authors mostly did not take into account or did not present the data on the factors influencing the efficiency of biofeedback [21]: the initial individual neuroendophenotype, using dual tasks for redistribution of attention, the threshold level for feedback presentation, the time of feedback presentation delay, the available information on the progress and monitoring. Consequently, the efficiency of stabilometric biofeedback is determined by several psychophysiological mechanisms and situational circumstances that should be controlled and modified by researchers and experts.

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COMPLIANCE WITH ETHICAL STANDARDS

This work does not contain any studies involving animals or human subjects performed by any of the authors.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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