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REVIEWS

Psychophysiological Indicators of Postural Control. Contribution of the Russian Scientific School. Part I

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Abstract—This article aimed to systematically review the published results of studies of psychophysiological mechanisms of posture maintenance and identify the key factors that influence the effectiveness of postural control. The recommendations of "Preferred Reporting Elements for Systematic Reviews and Meta-Analyzes" (PRISMA) were followed for the review. The results were classified, taking into account the target psychophysiological mechanisms and factors affecting postural control. The article presents the theoretical and empirical results of the Russian scientific school of research on the role of support afferentation in the sensorimotor mechanisms of cognitive and postural functions. Due to the limited number of randomized studies found, it was impossible to make meta-analytic comparisons, so the literature analysis was carried out only qualitatively. Meanwhile, our systematic review provides promising information about possible relationships between stabilometric and psychological indicators of postural control, which have theoretical significance and application in the correction and training of posture control. However, more thorough research is needed to overcome the methodological shortcomings that we have encountered in our qualitative analysis.

Keywords: postural control, sensory afferentation, attention, memory, emotions, mood, dual tasks, fine motor skills of fingers, stabilometry, EEG, EMG

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The actual works of Russian researchers aroused interest in the psychophysiological mechanisms of postural control. N.A. Bernstein [1] and V.S. Gurfinkel [2] define postural control as one of the most common examples of sensorimotor integration performed by a feedback mechanism [3]. The very idea of the vital role of feedback in regulating physiological functions and psyche also arose at N.A. Bernstein's and P.K. Anokhin's Russian physiological school [4, 5]. Impairment of the feedback mechanism between afferentation, information processing, and operational units of sensorimotor integration underlies most mental disorders [6, 7]. As early as ancient times, the interrelationship between mental disorders and impaired postural control [7]. However, empirical data that would provide evidence for the interrelationship between postural and psychological characteristics of a person under normal conditions is insufficient, to say nothing of few works devoted to the psychophysiological mechanisms of postural control. In the meantime, the study of the relationship between the peculiarities of motor control and psychological parameters is also of practical relevance to the development of brain-computer interfaces and biocontrol technology, the efficiency of which largely depends on the personal parameters of motor and cognitive capacities.

The next surge of interest in the study of postural control also occurred in the Soviet physiological school in the 60s of the past century due to the development of research into the effects of zero gravity (the absence of gravitational stimuli) on a human body [8]. The works supervised by I.B. Kozlovskaya have shown for the first time that the long-term lack of feedback from foot support zones has dramatic consequences for all physiological processes [8, 9]. At the same time, a unique role is given to support afferentation (feeling underfoot support). The weakening of feedback from baroreceptors of the foot can cause numerous disorders, beginning from impaired biosynthesis of the structural proteins of muscle tissue [10] to the pathology of the entire musculoskeletal system [11, 12], the cardiovascular respiratory [9], endocrine [13] and other vegetative systems [14]. For example, the study of the organization of the sensorimotor system of postural control resulted in the appearance of new terms: "gravitational mechanisms" and "support afferentation" [8], as well as the development of the concepts of afferent control of locomotion [8, 12], biomechanical studies of the system of internal representation in locomotion control by Yu.A. Levik et al. [15], and the

theory of "redistribution of attention" (*reweighting*) between different types of afferentation in postural control by R. Peterka [16]. Later on, to overcome the consequences of deficit of support afferentation, the prospects of using stimulation of the support areas of the sole, either instrumentally (with the equipment designed at the Institute of Biomedical Problems, Moscow) [17] or by training the feeling of support in the anterior part of the foot by the targeted techniques of Aikido [18] or dances [19] have been shown, which is accompanied by improvement of not only postural but also cognitive and psychoemotional functions [18, 19].

Investigation of the support afferentation role in psychophysiological health has gained new relevance with modern information technologies presupposing the application of more and more electronic gadgets in everyday life, which leads to reduced physical activity and alteration of the pattern of cognitive activity [20]. In addition to the negative consequences of a sedentary lifestyle, prolonged sitting per se causes the impartment of physiological and cognitive [21] and afferent functions [20–23]. At the same time, it is also necessary to take into account the adverse effects of high-frequency electromagnetic waves emitted by electronic devices and gadgets [24], which are also associated with cognitive and psychoemotional disorders and even with the appearance of depressive symptoms already in childhood and adolescence [24]. Thus, the problem of postural control disorders as a result of weakened support afferentation of a sedentary lifestyle gains particular relevance.

The current relevance of studying the psychophysiological mechanisms of postural control is also determined by the necessity to predict the risk of falling and correct balance in older adults, the relative number of which has steadily increased over the past 20 years [25].

Finally, in the years of the COVID-19 pandemic, a new relevance of studying the interrelationship between postural control and cognitive/afferent functions has appeared due to, first, social isolation resulting in a sedentary lifestyle and, second, the rising prevalence of depression as a neurophysiological complication of the coronavirus disease [26].

Thus, the relevance of studying the psychophysiological mechanisms of postural control is dictated, firstly, by the task of identifying stabilometric indices of cognitive and psychoemotional functions and, secondly, by the search of instrumental approaches to prediction, diagnosis, and rehabilitation of mental disorders via the study of stabilometric measurements of postural control.

The first part of the review presents the stabilometric characteristics of postural control, the studies of the relationship between postural and psychological factors, where particular attention has been focused on the role of different inputs in the mechanisms for maintaining the equilibrium. The roles of dual postural–cognitive and postural–psychomotor tasks in balance maintenance and possible neurobiological mechanisms of postural stability under normal conditions have been assessed.

Since the works of Russian scientists have made a weighty contribution to the study of psychophysiological correlates of postural control, the present review will increase the international prestige of the Russian scientific school.

For reviewing the studies devoted to the psychophysiological mechanisms of postural control, literature data were searched by the following keywords: "postural control," "sensorimotor integration," sedentary lifestyle," "gravitation," "support," "vestibular," "proprioceptive" and "visual" "afferentation," in combination with the keywords such as "cognitive functions," "memory," "attention," "decision making," "imagination," "emotions," "fine motor skills," "dual tasks," "anxiety," "depression," "stabilometry," "Electroencephalography," and "Electromyography" (Table 1). Literature was searched in the *Web of Science*, *PubMed*, *Scopus*, and RSCI databases according to the recommendations of "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (*PRISMA*) and using the methods described in *RELISH* (*RElevant LIterature SearcH*) [27]. The present review includes the results published in the articles with a Digital Object Identifier (*DOI*), completely corresponding to the keywords (Table 1), except for those published only as abstracts.

After removing the repeating references, the lists of the studies were checked; the summaries of keyword search results are presented in Tables 2–4, respectively.

Stabilometric Measurements of Postural Control

The weighty contribution of the Russian scientific school was made at the very beginning of postural control studies for the objectification of the measurements of postural stability. According to the recommendations of the International Consensus on postural control measurements [27] established based on "Research Methods to Evaluate Standing Stability" developed in 1952 by Russian scientists [28], the efficiency of the balance maintenance system is assessed by measuring oscillations in the foot plantar center of pressure (COP) relative to the center of gravity (CG) [29]. These variations reflect the movements of body segments or joints, muscle activity, the movements associated with respiration [30], and the work of the cardiovascular system [31]. Thus, previous evaluation of postural stability by the results of clinical tests was supplemented by instrumental measurements of the amplitude and frequency of CG and COP oscillations in the anterior-postural (COP_AP) and medial-lateral directions (COP_ML) using stabilographic devices

Table 1. The search strategy for the psychophysiological correlates of stabilometric characteristics of postural control in the *MEDLINE* system

Position no.	Keywords	Number of data sources
1	*Posture AND control AND Stabilometry OR posturography*	2014
2	Combination #1 *AND vestibular*	31
3	Combination #2 *AND cognitive AND task AND performance*	1
4	Combination #2 *AND attention*	3
5	Combination #2 *AND memory*	2
6	Combination #2 *AND affective*	10
7	Combination #1 *AND visual*	102
8	Combination #7 *AND cognitive*	35
9	Combination #7 *AND attention*	5
10	Combination #7 *AND memory*	3
11	Combination #7 *AND affective*	2
12	Combination #1 *AND gravity*	92
13	Combination #12 *AND attention*	1
14	Combination #12 *AND memory*	0
15	Combination #12 *AND emotion*	0
16	Combination #12 *AND cognitive AND task AND performance*	1
17	Combination #1 *AND muscles*	256
18	Combination #17 *AND cognitive task*	15
19	Combination #17 *AND emotion*	5
20	Combination #17 *AND memory*	0
21	Combination #1 *AND proprioceptive*	0

[28, 30]. Later it was established that COP_AP is the most sensitive index of the fear of falling and situational anxiety [32].

The spectral analysis of postural fluctuations made it possible to establish at least two frequency systems of postural stability, which were named, in the figurative language of Russian scientists from Gurfinkel's laboratory, as "conservative" (below 2 Hz) [33] and "operative" (above 4 Hz) [15]. Later, Yu.S. Levik et al. [15] showed that the relatively high-frequency COP oscillations did not affect the value of CG variations [15, 29]. COP oscillations with the frequencies below and above 1 Hz demonstrate the opposite effect on the reflexes and EMG activity of m. soleus while standing [34]. The effects of experimental conditions on the maintenance of upright posture were assessed by analyzing the changes in the median frequency (*MF*) and the root-mean-square value of amplitude spectra (*RMS*) in the ranges of 0–0.5 Hz for the CG variable and 0–3.0 Hz for the COP–CG variable. Thus, the recent studies by G.V. Kozhina et al. have shown that COP with frequencies above 0.5 Hz has almost no effect on the values of CG fluctuations and does not depend on the anthropometric parameters of subjects [35].

The evidence of the coexistence of the two systems of balance maintenance was provided by the studies of zero gravity at the Russian School of Aerospace Medicine [29], in the differential diagnostics of vestibular disorders [36], as well as by using the theoretical model of B.W. Dijkstra et al. [37]. It has been shown that the ability to maintain balance persists during the short-term absence of gravity (zero gravity);. However, the conservative (tonic) system of balance maintenance is immediately impaired, the voluntary postural control takes effect [29]. This fact indicates two different types of postural control effective on different time scales, which is evidence of the weighty contribution of the cognitive component to postural control [38]. Later, statistical analysis revealed three types of COP oscillation dynamics correlating with psychophysiological indices [29, 38]. For example, the peak in the range of 3–5 Hz is a signal for the presence of Parkinson's tremor [39]. Inclusion of the center of mass in analyzing the balance maintenance system proposed first by Russian [27]. Then Japanese [40, 41] researchers make it possible to study the dependence of postural control on the factors such as age [37, 41] and respiration [41].

Since the system of postural control cannot be described as a linear system, in recent years, stabilographic information has been analyzed by the methods of nonlinear dynamics, in particular, calculations of correlation dimension, Lyapunov exponents of Shan-

Table 2. Interrelationship between stabilometric and psychophysiological parameters of postural control in visual afferentation

Ref.	*RCT*/*SGT*/*CCS*	Number of subjects (number of women), (age)	Stabilometric parameters, procedure (measuring instruments)	Measurements of psychophysiological functions	Conclusions
			Visual afferentation		
Smetanin et al., 2020 [56]	*RCT*	12 (6) healthy subjects, age (–)	Filtered sagittal components of *MF* and *RMS* oscillations (CG and COP-CG). Subjects used glasses with polarization filters oriented in parallel to the respective filters of projectors	Viewing a picture with two grounds of the same scene shifted relative to each other: the view of aqueduct from a window (42 sessions by 3 homonymous, 40 s each, in a randomized order)	It has been shown that under the conditions used: 1) postural control depends on the parameters of "binding" (obtaining feedback) of the foreground of visualized environment to subject's body shifts, in spite of the presence of immobile background; 2) initial destabilization of the body in case of feedback delay by 0.2 and 0.5 s, stabilization with a delay of 0.8 and 1.0 s
Smetanin et al., 2016 [58]	*SGT*	16 (8) healthy subjects (64.3 ± 7.6 years old)	Amplitude-frequency characteristics of COP in the *AP* and *ML* directions	Visual perception (only the virtual 3D image of the ball was seen)	Under test conditions, the shifts of the ball destabilized the upright posture. Destabilization increased along with the increase in the ball size
Kozhina et al., 2018 [65]	*SGT*	4 (–) healthy subjects, age (–)	Amplitude and frequency characteristics of CG and COP–CG variables	35 tests on visual perception with a duration of 40 s were performed	Process of standing under conditions of one-type destabilization of visible visual environment significantly changed by the end of the tests, approaching the conditions of immobile visual environment with respect to stability

Table 2. (Contd.)

Ref.	*RCT*/*SGT*/*CCS*	Number of subjects (number of women), (age)	Stabilometric parameters, procedure (measuring instruments)	Measurements of psychophysiological functions	Conclusions
Redfern et al., 2007 [66]	*RCT*	59 (48) with anxiety disorders; 22 (19) healthy; 21 with panic disorders and agoraphobia	*RMS* of oCOP on a stable platform and a platform with sinusoidal movement of the visual environment in the *AP* direction	Anxiety; fear of height	Patients swayed much more in response to a moving visual scene than the control subjects, without differences between the *NPA* and *PAG* groups. In patients with severe agoraphobia, COP is much higher than in patients from the control group and in anxiety patients with low phobia
Gudkov and Demin, 2011 [67]	*RCT*	80 men (age of 69.0 ± 6.6 years), two groups: normal vision and poor vision	Rate of oCOP, the mean radius of COP deviation (*R*av, mm) in the *AP* and *ML* directions to "Stabilotest" ST-01	Complains about vision	Impaired vision is accompanied by an increased rate of COP, *R*av, and COP in the *AP* direction
Lions, 2016 [68]	*RCT*	12(–) subjects (from 17.3 to 34.1 years old)	Rate of oCOP using a *Multitest* platform; eye movements were recorded with *Mobile T2* (*e*(*ye*)*BRAIN1*)	The amplitude of saccades; duration of retention of visual attention	The rate of COP under conditions of a visual task of search is much less than under the dynamic needs of free watching
García-Liñeira, et al., 2021 [120]	*RCT*	316 (158) subjects (6–12 years old)	Characteristics of acceleration by three axes *X*, *Y*, and *Z*. *RMS* while standing on one foot with EO and EC (*Actigraph LLC*)	Response to closing eyes	Acceleration of body fluctuations is higher with EC. The value of the increase in *RMS* decreased with age more slowly in boys than in girls

RCT, randomized controlled test; *SGT*, single group test; *CCS*, case-control study; COP, the center of pressure of the feet; oCOP, oscillations of the center of pressure of the feet; CG, the center of gravity; *RMS*, root mean square value of the range of COP-CG oscillations; EC, eyes closed; EO, eyes open.

Table 3. Interrelationship between stabilometric and psychophysiological parameters of postural control during vestibular, proprioceptive, and support differentiations

Ref.	*RCT*/*SGT*/*CCS*	Number of subjects (number of women), age	Stabilometric parameters, procedure (measuring instruments)	Measurements of psychophysiological functions	Conclusions
			Vestibular afferentation		
Grabherr et al., 2007 [72]	*SGT*	Eight astronauts	Microgravity	Time of solving a mental task requiring mental transformation of one's own body or parts of the body; error frequency	The time of task solution increases under conditions of microgravity
McKay et al., 2013 [75]	*SGT*	31 healthy subjects	Vestibular stimulation by cold water sequentially into both ears	Self-evaluation of the future risk of illness	Vestibular stimulation reduced nonrealistic optimism
Chen et al., 2018 [101]	*SGT*	23 (–) patients with Parkinson's disease (PD), 23 (–) healthy subjects	oCOP (*RMS*); OCOP derivative (*JERK*)	*Mini-Mental State Examination* (*MMSE*); *Montreal Cognitive Assessment* (*MoCA*); *Geriatric Depression Scale* (*GDS*); *Dual cognitive-postural task*	During dual-task performance, *RMS* and *JERK* increased in PD patients more than healthy subjects
Indovina et al., 2019 [53]	*RCT*	52 (–) subclinical agoraphobia; 52 (–) control group	Persistent postural perceptual dizziness	19 demographic, psychological, and psychiatric variables	In agoraphobia, the functional connectivity between visual and vestibular networks is reduced, the values of connection in the two cerebral networks are lower; one of them is for the processing of input visual information about movement in space, threat assessment, and initiation/suppression of behavioral responses (visual-spatial-emotional network) and the other one is for the control and monitoring of movements (vestibular-navigation network)

Table 3. (Contd.)

Ref.	*RCT/SGT/CCS*	Number of subjects (number of women), age	Stabilometric parameters, procedure (measuring instruments)	Measurements of psychophysiological functions	Conclusions
Ribeyre et al., 2016 [128]	*SGT*	26 (15) vestibular schwannoma (25–76 years old)	*Sensory Organization Test* (*SOT*) Balance maintenance test	Quality of life, anxiety, depression, and the reaction of coping with stress	The more significant are the posturographic impairments; the worse is the quality of life. The higher are the anxiety and depression affects. The more serious are the everyday consequences and the adverse reaction of coping with stress
Kerr, 1985 [129]	*SGT*	24 (12) healthy subjects	Tandem Romberg test for 12 s (*Kistler force platform*) in COP-CG in the anterior-posterior and medial-lateral directions	Spatial memory task; associative memory task	In the standing position, the estimates of spatial task memorization are decreased. Memorization in the sitting position is better than that in the upright position for spatial but not for simple memory
Doumas et al., 2012 [102]	*RCT*	15 (8) with major depressive disorder (MDD), 24 (11) healthy subjects (18–35 years old)	Standing and sitting on a stable and moving platform at rest and during cognitive task performance	Working memory task	In MDD, working memory accuracy is lower than in control. Dual-task performance resulted in lower accuracy. In management, accuracy did not differ between the two dual-task conditions. In MDD, it was considerably different, but stability did not decrease
Dutta et al., 2014 [130]	*SGT*	104 (50) (71 ± three years old), 24 (–) before and after biocontrol SGT; “falling”; “nonfalling”	Berg Balance Scale (*BBS*). oCOP (*Wii Balance Board*)	Hindi Mental State Exam (*HMSE*); Geriatric Depression Scale (*GDS*); 14-channel EEG	oCOP in women > than in men, inverse correlation with *HMSE*. oCOP, the θ/α ratio of EEG power in “more depressive” is higher than in less depressive subjects

Table 3. (Contd.)

Ref.	*RCT*/*SGT*/*CCS*	Number of subjects (number of women), age	Stabilometric parameters, procedure (measuring instruments)	Measurements of psychophysiological functions	Conclusions
Leandri et al., 2009 [62]	*RCT*	15(8) amnesia (*aMCI*); 15(8) moderate Alzheimer disease (AD); 15(8) control	oCOP *AP*; COP of *ML*; SGT area; Romberg test	*Unified Parkinson's Disease*; *Rating Scale* (*UPDRS*); *Geriatric Depression Scale*; *Basic Activities of Daily Living* (*BADL*)	COP of *AP* correlated with the motor scale of *UPDRS* in AD patients and specifically differed from *aMCI* of healthy control
Kapoula et al., 2011 [76]	*RCT*	23 (–) patients with deafness; 2 (–) on the left, eight on the right, and three bilateral; 18 control	Stabilometry with *Technoconcept*, 40 Hz	Attention to sound is enhanced, attention to posture is reduced	An increase in mediolateral movement is more significant in persons with deafness when attention is distracted
			Proprioceptive input		
Ivanenko et al., 2000 [78]	*SGT*	6(–) healthy subjects (20–49 years old)	COP oscillations with EC using: hard floor; mobile support for translational rotations motion in the frontal direction; support turned at 90 degrees for rotational motion in the sagittal direction; mobile support for the translational-rotary movement in any direction	Moderate vibration (60 Hz, 0.8 mm) to the tendons of the anterior tibialis muscle (*TA*) (3–5 cm above the ankle joint) or the tendons of Achilles of the triceps surae (*TS*) using two identical vibrators (300 mm), 9 cm in length and 4 cm in diameter; EMG activity of the muscles of the ankle joint; EMG activity of the soleus and anterior tibial muscles; subjective assessment of difficulty	Effects of vibration of shin muscles dramatically decreased on mobile support; the effect depended on direction—muscle vibration varied configuration of the body only on the stable supports in the sagittal plane. Subjective difficulties with maintaining balance did not explain the differential effect. Reactions were present on a front swing, even though subjective is more challenging to maintain balance, and support vibration, in this case, was more significant than while standing on a sagittal swing

Table 3. (Contd.)

Ref.	*RCT/SGT/CCS*	Number of subjects (number of women), age	Stabilometric parameters, procedure (measuring instruments)	Measurements of psychophysiological functions	Conclusions
Gusarov et al., 2020 [77]	*RCT*	14(–) athletes (16–20 years old), 7(–) experimental group and 7 (7) control	Amplitude, rate, and area of COPD stabilometric at the moment of fixation of a static exercise (MBN platform)	Stimulation of the biceps femoris and the lateral head of the gastrocnemius muscle on the left leg. Current strength—5 A, frequency—20 Hz, time—1 min, alternating exposure (2 a) and pause (2 s)	Static exercise "right side bend," with its fixation for 1 min, causes a statistically significant shift of projection of the total center of mass of the body to the right in the frontal plane in the short term. During electromyostimulation (EMS) on the left muscle at the moment of posture maintenance, there is a statistically significant shift of the COP projection to the right. The changes in the rate and area of COP are statistically insignificant in the short term with and without EMS
Roma et al., 2021 [82]	*RCT*	31 young, 30 elderly subjects (EO and EC)	Length, area, and rate of COPD; *RMS*	Spatial memory test; counting backward; mental arithmetics; EMG of the *Tibialis anterior* (*TA*), *Lateral Gastrocnemius* (*GL*), *Peroneus Longus* (*PL*), *Erector Spinae* (*ES*) muscles	Solution of cognitive tasks did not cause tension in all muscles except for *PL* and *ES* and a decrease for all posturographic characteristics irrespective of age. Performance of cognitive task aloud causes an increase in activation of the *ES*- and *TA*-muscles and impairment of static posture control

Table 3. (Contd.)

Ref.	*RCT*/*SGT*/*CCS*	Number of subjects (number of women), age	Stabilometric parameters, procedure (measuring instruments)	Measurements of psychophysiological functions	Conclusions
			Support afferentation		
Stawicki, 2021 [19]	*SGT*	23 women— dancers (21.3 ± 1.7 years old); 24—not dancers (22.3 ± 1.0 years old)	Rate of COPD; different positions of feet	Experience of leg movements	Significant differences in stability with EC ($p = 0.04$)
Abou Khalil et al., 2020 [21]	*RCT*	18 (9) healthy subjects (23.11 ± 1.68 years old)	Sitting and standing positions, walking	The task for memorization of words presented visually; arithmetic tasks	Memorization of words is most efficient while walking. In eth sitting position, the response time is shorter than the standing position and walking
Roerdink et al., 2011 [42]	*SGT*	15 (0) (22 ± 1 years old)	COP of *AP* and *ML* for 32 s when sitting and standing; COP regularity	Time of response to the stimulus; attention to the visual stimulus	COPs are more regular in the standing position than in the sitting position. Awareness of postural control is greater while standing than while sitting. The response time to the stimulus is shorter while standing than while sitting
Zehr, 2014 [86]	*SGT*	14 healthy subjects (8) (30.3± ten years old)	Walking on a treadmill; EMG of the shoulder and the ipsilateral leg	Stimulation of five points on the sole	Statistically significant increase in the amplitudes of reflexes, kinematics, and sole foot pressure depends on the place and phase. The feedback from the skin of foot soles plays a vital role in controlling gait and standing balance

Table 3. (Contd.)

Ref.	*RCT/SGT/CCS*	Number of subjects (number of women), age	Stabilometric parameters, procedure (measuring instruments)	Measurements of psychophysiological functions	Conclusions
Mochizuki et al., 2008 [107]	*RCT*	8 (4) healthy subjects (26.1 ± 7.8 years old)	COPD in the sitting and standing position and at the beginning of movement while standing on a platform (*AccuSwayPLUS*)	EMG of the trunk and neck; EEG in C_z	Anticipation of imbalance causes the same changes in the cortical activity as real imbalance, irrespective of sitting or standing
Bourdin et al., 1998 [104]	*SGT*	9 (3) elderly subjects (71.1 years old); (3) young subjects (24.6 years old)	COPD on a platform (*AMTI model OR*6-5-1) sitting *vs.* standing	Time of response to sound stimuli	Sitting and standing with EC—the task for maintaining balance became more difficult for older adults and required more attention (increased time of response)
Azevedo, 2005 [126]	*SGT*	48 men (24.2 ± 4.7 years old)	COPD amplitude	*R*–*R* interval; assessment of emotion intensity	The oCOP amplitude decreased during the presentation of mutilation images compared to the images of sports competitions and objects. *RR* modulation continued after production of the stimuli. The increase in *MF* during the block of mutilations compared to sports in the medial-lateral direction

For designations, see Table 2.

Table 4. The interrelationship between stabilometric and psychophysiological parameters of postural control during the dual-task performance and sensory modulation

Ref.	*RCT*/*SGT*/*CCS*	Number of subjects (number of women), age	Stabilometric parameters, procedure (equipment for measurement)	Measurements of psychophysiological functions	Conclusions
Aftanas et al., 2018 [83]	*RCT*	25(11) healthy subjects; 25(11) major depressive disorder (MDD)	*E* of oCOP in EC and EO, Δ*E* during the motor and ideomotor tasks performance	Depression scale (*BDI*-II); level of rumination (*RRS*); test for oppositional finger adduction; counting the number of movements; counting the number of imagined movements	Finger fluency in MDD patients is less than in healthy subjects. *E* during motor and ideomotor tasks increased in healthy subjects and decreased in patients. Δ*E* positively correlated with the level of rumination
Modulation of afferent inputs					
Vuillerme, 2003 [84]	*SGT*	9(4) healthy subjects (23.8 ± 2.6 years old)	COP with EC, 4 states: quiescence/absence of touches, quiescence/touches, fatigability/absence of touches and fatigability/touch	Subjects' standing on their toes caused fatigue of calf muscles to the point of exhaustion	Slight touch with fingers resulted in a decrease in postural swaying under fatigue absence and case of fatigue. Interestingly, this stabilizing effect was more marked in the state of exhaustion
Kozhina et al., 2017 [85]	*SGT*	Healthy volunteers – 8 men (47.6 ± 5.3 years old); 6 women (43.0 ± 5.2 years old)	Quiescence; in the presence of a weakly felt (0.1–0.8 *N*) tactile contact between the outer surface of the forearm of the left relaxed arm and the plane of the free end of a resilient steel plate (passive touch); root mean square value of the spectra of fluctuations (*RMS*) of CG and COP; oCOP in *PA* and *ML*: *MF* (variable COP–CG) (Stabiloplatform-2)	The contemplation of two images of the same scene shifted relative to each other: the view from the window at the aqueduct	*RMS* (COP–CG) and *RMS* (COP) in an immobile visual environment and with an antiphase coupling of the anterior plant with fluctuations of the body at rest in the absence of tactile contact, like during passive tactile contact between the spectra of fluctuations of both variables, were the minimum and the maximum in case of synphase connection and standing with EC. Under passive contact conditions, the body's fluctuations decreased in both directions, and the *RMS* of the spectra of both variables (CG and COP–CG) decreased under all visual conditions. Under conditions of tactile contact, a statistically reliable increase in the *MF* spectra of the COP–CG variable was found only for fluctuations of the body in the sagittal plane
Deschamps, 2016 [73]	*SGT*	5(3) healthy volunteers (50.41 ± 6.93 years old); 9(5) MDD (51.88 ± 10.01 years old)	oCOP rate with EC and EO, eth regimen of walking three times per week within two months	*BDI*—depression scale	The level of depression did not change

E is the energy for balance maintenance; for other designations, see Table 2.

non–Kolmogorov–Klimontovich entropy, and regularity of COP movement [39, 42, 43]. Such analysis makes it possible to assess the role of the cognitive component of postural control [42, 43]. One of such integral indices, the energy expenditure for COP oscillations developed by French [44] and Russian [45] researchers, is calculated as a sum of the increments of kinetic energy (in Joules) (E) determined by the change in the rate of displacement of the center of pressure at each discrete section of statokinesiogram (SKG) during the test. This index quantifies the functional activity required to maintain postural stability [44, 45]. At present, computer technologies have been developed to measure postural stability by stabilometric [46] analysis, which can be performed even with smartphones [47]. Here, it has been shown that the measurement of the velocity of COP oscillations is preferable compared to accelerometric parameters [48].

Psychophysiological Correlates of Postural Control

Upright posture control is one of the essential evolutionally significant human functions presupposing the involvement of the higher nervous system [49]; the latter's functions are based on the laws of self-regulation with the participation of feedback [1, 5]. Throughout the past 100 years, numerous reviews and empirical research have been devoted to studying human postural control's kinetic and biophysical mechanisms [50–52]. However, how postural stabilometric characteristics are associated with the psychophysiological correlates of cognitive and psycho-emotional activity efficiency has not been sufficiently investigated. The available works are more often devoted to discussing neurological consequences of impaired postural characteristics; the data on the involvement of higher nervous activity in the biophysical mechanisms of balance maintenance is presented to a lesser extent [53, 54]. In the meantime, successful relationships between humans and the environment are associated not only with the efficient perception of signals from the visual, vestibular, proprioceptive, and baroreceptor systems, which determines automatic stabilization of the body at rest and in motion [55] but also with the accuracy of the internal representation of the body position in space, cognitive assessment of the structure, sizes and movements of objects of the external world [35]. Suppose one or several of these systems are impaired due to aging or neurological disease. In that case, the postural control system must correct the relative weight coefficients of input data to maintain balance [16, 36].

The relationship between psychophysiological and stabilometric indices of balance maintenance is given in Table 2 by sections according to the modality of sensory afferentation. Separately, Table 2 presents the results of studying the paradigms of dual cognitive- or motor-postural tasks.

The role of visual afferentation in psychophysiological mechanisms of postural control. The visual system involved in the solution of the task of posture stabilization, participating in assessing the value, rate, and direction of COP oscillations [29, 57] (Table 2). It means that the role of visual afferentation increases in case of violation of the stationarity of the visible environment [29, 57], which, in turn, explains that visual inputs are more significant for postural control than postural control vestibular or proprioceptive ones [57, 58]. O.V. Kazennikova et al. [59] show that the balance maintenance system can ignore the signals bearing inadequate or ambiguous information. In the case of the multiple repeated measures with perturbation of an equilibrium state, the stability parameters approached the values of regular standing with eyes open [60]. Therefore, the authors supposed that improving the quality of standing in case of consecutive repeated measures of the same type results from training in the more effective use of visual feedback.

The assessment of visual activation in the Romberg test, which has been used for 150 years, shows abnormalities associated with postural control deficits of neurological [61] and cognitive [62] genesis. On the one hand, the presence of central vision allows one to combat fatigue more rapidly [63]; on the other hand, V. Nougier et al. have shown that it makes no difference for balance maintenance whether the central or peripheral vision is used [64]. This contradiction is compromised by the studies of B.N. Smetanin et al. have shown that central vision exerts a greater effect on the control of frontal plane motion under the conditions when somatosensory information is insufficient; peripheral vision under the same conditions exerts a greater impact on the power of oscillations in the sagittal plane [56].

It is evident that visual effects, including nonspecific ones, are implemented mainly via the regulation of musculo-articular stiffness (first of all, in joints of the lower limbs) [65] and are mediated by changes either in the tonic contraction of the respective postural muscles or in the role of vestibular and (or) proprioceptive subsystems of posture regulation, the impairment of which is also associated with depressive disorders [66]. However, the results presented in these works only indirectly confirm the above assumption. At the same time, R. Peterka [16] has shown that human response to body oscillations is based on a relatively simple feedback mechanism with the linear combination of weighted sensor scales. Here, the quantitative estimates of sensor scales vary depending on the availability of sensory information from the visual or proprioceptive system and the amplitude of perturbations caused by the visual environment or platform inclinations. The works of B.N. Smetanin has shown that visual afferentation is not obligatory for balance maintenance and plays only the modulating role of the quality of stability, which is of interest in this context [58]. The explanation of the above lies in

the feedback mechanism and in the proactive control determining the capability of a person to assess the pattern of future changes and to be promptly rearranged [5, 67], which demonstrates an essential contribution of the cognitive component to the dependence of postural control on visual afferentation. Here we should add the evidence obtained by C. Lions et al. and by B.N. Smetanin: the amplitude of COP oscillations under the conditions of visual cognitive task is much less than under conditions of free viewing of a picture [68] or does not depend [58] on the complexity of visual feedback in young, healthy subjects. At the same time, other studies have established that the presence of visual feedback about oscillations of the body had a positive effect on maintaining posture in the tests with both young and elderly subjects [69]. To explain the differences between the findings, we should interpret the process of integration of several sensory inputs from proprioceptors and baroreceptors (first of all, from the lower limbs and feet) and vestibular organs, on the one hand, and from eye receptors and extraocular muscles, on the other hand. In the opinion of B.N. Smetanin, the key difficulty of such study is as follows: the proprioceptive signal flux and support afferentation carry information adequate to the real spatial position of the body, while the visual flux, as a result of the considerable contribution of cognitive modulation, has distorted information [58].

The role of vestibular afferentation in psychophysiological mechanisms of balance maintenance. Most reviewed studies demonstrate the involvement of the vestibular system in cognitive and emotional functions, which are seemingly far from the functions such as spatial orientation or postural control [70] (Table 3). The answer to the question of how the modulation of vestibular signals changes the efficiency of solution of cognitive tasks such as mental spatial imagery or number processing [71], or affective functions, is provided by the results of studies related to the change in orientation of the body (rotation of the body), clinical observations of patients with vestibular disorders [53], as well as the studies performed under conditions of microgravity [72]. The effect of descending cognitive and psychoemotional processes on the perception of vestibular stimulation, i.e., postural control disorders, is also investigated [73]. The results of these studies demonstrate that the changes in vestibular afferentation are accompanied by the shift in the mental representation of parts of the body [74], mood [75], tactile and pain perception [70].

Z. Kapoula et al. [76] supposed that external sound stimulation in the case of tinnitus affects COP oscillations due to the activation of the attention switch. Another possibility is the weak integration of sensorimotor signals and/or poor interhemispheric communication.

Thus, the role of cognitive processes in balance regulation due to the changes in the vestibular input can be considered proven.

The role of proprioceptive afferentation in psychophysiological characteristics of postural control. Various experimental approaches have demonstrated the effects of proprioceptive inputs on psychological functions in literature (Table 2). For example, in the case of voluntary changes in muscle tone caused by a static posture (e.g., "right side bend"), COP oscillation is corrected in the frontal and sagittal planes [29, 77]. Yu.P. Ivanenko et al. varied the direction of support movement. They applied the vibration of lower leg muscles to subjects standing on a shaking platform mobile in the sagittal, frontal, or both directions. Postural responses were present only on the supports that were stable in the sagittal direction. Thus, it can be assumed that the direction of postural instability influences the reaction of proprioceptors of talocrural muscles only in the sagittal direction [78]. However, it is unclear whether this disturbance of stability is specific or nonspecific, targeted at weakening proprioceptive effects of the ankle joint muscles.

Hypodynamia, the work with a computer under nonergonomic conditions, psychoemotional overloads come first among the causes of functional disorganization of muscle tone, as it occurs in case of weakened leg support [79] and, accordingly, impaired postural control [17]. The role of support afferentation in the weakening of muscle tone has also been proven by the studies of dry immersion and experiments with animals [80].

Despite the well-known interaction between sensory and motor systems in balance maintenance and the possibility of training postural muscles [81], the process of triggering muscle reactions opposing natural postural instability has not been completely elucidated. Moreover, it is unclear why the performance of a cognitive or psychomotor task does not decrease but even increases postural stability in some groups of healthy subjects [82] and patients with depression [83].

The role of tactile sensations in psychophysiological characteristics of balance maintenance. It is known that the visual and vestibular inputs demonstrate the ability to play a dominant role in postural control; however, the role of tactile signals has recently also raised interest. Some works [84, 85] showed the postural control mechanism, where COP oscillation parameters changed without the modulating effect of proprioceptive, visual, or vestibular receptors. Therefore, an additional receptor system has been proposed, which seems to depend on tactile sensations and to be associated with disorders of the musculoskeletal system [84, 85]. It has been established that a light (i.e., "unsupported") touch of a finger or forearm skin reduces postural fluctuations, even even though the forces of contact were much lower than those necessary for provid-

ing mechanical support [84–86]. It presupposes that the tactile signals from finger or forearm skin can be combined with other sensory information in the CNS, providing different spatial orientations in posture stabilization [85].

The role of support afferentation in the psychophysiological mechanisms of postural control. It is known that upright body position results from human evolution in phylogenesis [87]. Maintaining an upright position presupposes overcoming the force of gravity and, consequently, postural activity is an unconscious operational background for any locomotive and cognitive acts. It is supposed that walking upright during evolution resulted first in the transformation of the lower limbs and caused the formation of a highly specialized human foot [87], which had lost the grasp function and turned into one powerful lever. In the upright posture, the main load falls on the big toe [88], which, though it had lost its mobility typical of other primates, began to play the crucial role in support afferentation together with the frontal part (pad) of the foot. Second, the walking on two limbs made it possible to free the upper limbs and transform them into an organ of labor—arms with hands that became capable of precision grasping and complex work activity. Third, as a consequence of the participation of humans in work activity, it became necessary to solve problems and to plan tasks, which caused the development of the cerebral cortex, the number of nerve cells increased, their arrangement changed, and the number of network architectures also increased [89].

Thus, walking upright became the cause of the formation of a highly developed brain capable of performing, together with the inclusion of evolutionally new support afferentation into the arrangement of balance maintenance system, cognitive functions such as abstract thinking and planning [90]. Based on the above, it can be supposed that support afferentation is involved in the balance maintenance system and has an effect on cognitive functions.

In recent classical works, B.S. Shenkman and I.B. Kozlovskaya [79, 91] have generalized the data to assess the relevance of support afferentation studies using a "dry" immersion model. These studies have contributed considerably to the study of support afferentation in physiology, from cellular responses of postural muscle to psychological characteristics of human behavior. It has been established that removing leg support inactivates the pool of slow motor units, which leads to selective inactivation and subsequent atony [11] and the atrophy of muscle fibers expressing the slow isoform myosin heavy chain (which comprises most of the soleus muscle fibers). The fibers that have lost a significant portion of cytoskeleton molecules are incapable of effective actomyosin motor mobilization, which leads to low calcium sensitivity [92] and a narrow range of maximum tension [93]. The absence of support also leads to a decrease in the efficiency of protective mechanisms (nitrogen oxide synthetase) and a reduction in the activity of AMP-activated protein kinase, which triggers regeneration processes [94]. It is essential that the stimulation of support zones mitigates the effects of weakened support afferentation by repairing neural progenitor cells in the hippocampus and maintaining the activity of the central extracellular signaling pathway, which regulates proliferation, differentiation, apoptosis, stress response, and, ultimately, survivability [95, 96].

The analysis of stabilometric measurements of COP oscillations has shown that, even though the COP oscillation amplitude is more significant in the standing position of the body compared to the sitting position, COP oscillation trajectories are more regular (the lower entropy) in the sitting position compared to the upright position [84]. Based on the above, it can be supposed that regularity measures can be used to estimate the contribution of the cognitive component (attention) to postural control [90]. The greater attention to postural control in the standing position than the sitting position suggests an answer to the interesting question of why musicians' quality of musical performance is higher in the upright position than in the sitting position [97, 98]. It seems to be associated with the Bernstein principle of achieving automatism with the fine motor skills of fingers, which releases the maximum number of degrees of freedom necessary for musical performance. Suppose the attention resource is used to maintain balance in the standing position. In that case, this part of the attention is withdrawn from the control of finger motion, and it becomes more automatic. Another answer to the question of why finger movements of musicians are more "free" in the standing position than in the sitting place is the theoretical concept of reciprocal relationships between the tonic tension of muscles in the upper and lower halves of the body [51, 99]: the increased muscle tone of legs is accompanied by the decreased tone of arm muscles and, accordingly, by the lower energy expenditure for balance maintenance in the standing position [97]. Both of these hypotheses suggest that the interactions between fine motor tasks and postural-motor response can be effectively used for rehabilitation of motor and affective disorders [100] as an essential tool for "distraction of attention from pathological dominants" in clinical studies [44]. Thus, it can be supposed that the study of the role of attention distribution in postural control will allow the development of new approaches to the prevention and rehabilitation of psychogenic disorders.

The Role of Dual (Cognitive- or Motor-Postural) Tasks in the Study of Psychophysiological Mechanisms of Balance Maintenance

The role of cognitive factors, including distribution of attention in the balance maintenance system, is assessed using the paradigm of dual cognitive-postural

tasks [83, 101, 102]. Healthy young people can easily execute the tasks for maintaining balance in combination with other types of activity such as conversation or reading. At the same time, upon addition of the cognitive component, the strategy of postural control can "contract," i.e., the spread of COP oscillations can decrease [103]; in other cases of dual tasks, the efficiency of postural task performance can "extend," i.e., become less automatic than anticipated [66]. An example of such tasks is rock-climbing, when postural control is predominant over the accuracy of hand movements [104]. L. Jakobson and M. Goodale, after performing the kinematic analysis of highly accurate movements of hands with maintaining balance, have come to a conclusion that decentralization between the limitations of velocity (posed by the posture) and the limitations of accuracy (posed by finger movements) presupposes the existence of hierarchically organized movement control center [105]. Some authors used cognitive tasks to distract attention from balance control, create an external focus of attention [83], and/or investigate the direct relationship between the regularity of COP oscillations and the amount of attention invested in postural control [42, 43]. Other authors have shown that the training of balance stability, on the contrary, can influence the speed of finger movements and the efficiency of cognitive task performance [106].

It can be altogether concluded that dual (postural-cognitive and/or postural-motor) task performance testing is a suitable model for the study of mutual influence between cognitive abilities and the ability to maintain balance [83, 102] (Table 4).

Psychophysiological Mechanisms and Factors Determining the Interrelationship between Postural and Psychological Functions

Recently, B. Dijkstra has presented a literature review devoted to the functional neurovisualization measuring posture-related activity of the nervous system in healthy subjects [70]. It is known that the critical structural nodes of human posture control are the brainstem, the cerebellum, the basal ganglia, the thalamus, and several cortical areas. The meta-analysis of probability assessment of postural activation has shown that the anterior lobe of the cerebellum is continuously activated, modulating the activity of nuclei of the brainstem [37]. Not only arbitrarily induced imbalance per se but also the anticipation of body perturbation activates the cortex [107]. These data demonstrate a relationship between postural control and cortical activity [107]. The analysis of the brain's electrical activity (EEG) gives an idea of the functional organization of human postural control. In his pioneer works, R. Cole showed that verticalization is accompanied by not only enhanced heart rate and arterial blood pressure, which has been known previously, but also by the increased index of high-frequency (β) and α-2 power of electroencephalogram (EEG) and the lower θ-amplitude compared to the sitting position [108]. Analogous results were obtained later by some researchers [109–112]. During spaceflight under microgravity conditions, EEG was recorded for the first time by G. Cheron et al. [111], who showed an increase in the α-rhythm power at a frequency of 10 Hz and a slight shift of α-peak frequency from 9.9 to 10.4 Hz with eyes closed (EC). The increased EEG frequency and power in the α-rhythm band is a reliable indicator of voluntary inhibition [112–114], which can also be evidence of the cognitive component of postural control. Later, D. Lipnicki supposed that cortical inhibition could be accounted for by redistribution of blood volume towards the upper part of the body and stimulation of arterial baroreceptors under microgravity conditions, contributing to the inhibition of the cerebral cortex [115]. However, G. Cheron et al. noted a considerable increase in neural activation: the so-called Berger effect (the suppression of α-power while opening eyes) under microgravity conditions compared to the same characteristics on the Earth. At the same time, it was noted that the power of the frequency "range of anticipation," or μ-rhythm, had decreased before the physical opening of eyes, immediately after receiving the instruction "to open eyes" [111]. G. Cheron et al. assume that the sensorimotor and parietal-occipital cortices have a shared network affected by gravity. They have concluded that the enhanced reactivity of α-rhythms under microgravity is because, along with the decrease or even elimination of all sensory inputs of postural control, the response to the only visual information is unchanged in the absence of gravity is enhanced. Further studies of the effect of support afferentation on neural processes showed that the changes in EEG activity under microgravity were not explained by hemodynamic changes but rather reflected emotional responses associated with the sensation of zero gravity [116]. In addition, V. Brümmer et al. found a considerable decrease in β-power under microgravity, which they attributed to the weakening of excitation [116]. By analogy, the work of Russian authors showed a reduction in the amplitude of presaccadic EEG potentials in the absence of support afferentation [117] and hypodynamic style [118]. The authors believe that there must be other generators of electrical activity under altered gravity, in addition to the neural one [117]. It can be assumed that the phenomenon of a decrease in EEG amplitude in the so-called β-band can be explained by the technological peculiarities of EEG analysis, which does not allow estimation of the contribution of electrical oscillations from EMG generated by the tonic muscles of the scalp, which increases in case of emotional stress [118], as is reported by V. Brümmer et al. [116]. In addition, I.G. Nenakhov and A.V. Shvetshov indicate the effect of muscle tone on postural control [118].

At present, it is difficult to draw any clear conclusions from the comparison of EEG parameters obtained during space and parabolic flights and/or under conditions of microgravity: firstly, EEG and EMG studies were insufficient; secondly, most studies were performed without taking into account the age, gender, and hormonal factors; thirdly, EEG analysis, due to merely methodological reasons, was performed without taking into account the individual EEG endophenotype [113, 114] that determines the strategy of achieving sensorimotor integration.

Age. Many studies have convincingly demonstrated the effect of the "age" factor on the relationship between psychophysiological and stabilometric characteristics of postural control [25, 66, 67, 119]. It has been shown that the variability of COP oscillations decreases with the maturation of children up to 10–12 years [120] and increases with aging after 40 years [119]. Numerous studies have demonstrated that postural control parameters in older adults are reduced and, accordingly, the risk of falling considerably increases [25, 30, 66, 67, 119]. Postural control impairment in older adults can be caused by the age-related weakening of almost all body sensory and operating systems. At the same time, it is supposed that the risk of falling in women is higher than in men [121] due to the weakened function of ovaries. However, the studies by T. Naessen et al. have convincingly demonstrated that estrogen replacement therapy does not improve postural control in older women if it is not accompanied by physical activity training [122]. When comparing the psychophysiological characteristics in women of postmenopausal age, we established that long-term physical activity (fitness, dances, or Aikido training for no less than eight years) is accompanied by the decline of psychological symptoms postmenopause. Still, the best stabilometric indicators of postural control (the lowest energy demands for maintaining balance and the lowest EEG and EMP reactivity during the dual cognitive-postural and motor-postural tasks performance) are noted only in the group of women training the sensation of support on the anterior part of the foot [18, 19]. The findings conclude that the most efficient method to overcome the risk of falling in older adults is a physical activity associated with the targeted postural control training.

Gender factor. Although there are several studies of the effect of gender on the ability to maintain a posture, no detailed results have yet been obtained [122, 123]. Inconsistency of the results obtained is due to a failure to consider the obvious fact that women in different phases of the hormonal cycle demonstrate significantly different psychophysiological characteristics [124], particularly postural stability [125]. The matter is that the periodic effect of 17-β-estradiol in women increases the plasticity of ligaments of the foot [24] and knee [125] and, accordingly, postural activation is changed. Estrogen relaxes the collagen cross-links in ligaments and alters the activity of actomyosin ATPase in skeletal muscles. In addition, estrogens significantly affect neuromuscular interactions involved in the motor control of ligaments and joints such as the knee [125]. However, no consensus on the impact of hormonal background on postural control has been achieved until now [123], and, hence, further studies are required.

Psychoemotional state. Because the same areas and networks of the brain are involved in the regulation of afferent functions, emotions, and mood and in the system of maintaining balance, more and more attention is focused on the study of interrelationships between these systems [7, 23, 25, 73, 83]. In particular, T.M. Azevedo et al. had recorded much lesser swaying of the body, as well as an increase in the median power frequency (*MPF*) of COP oscillations (indexing muscle stiffness), when healthy volunteers stood on a stabilometric platform while watching unpleasant (mutilations) vs. pleasant (sports actions) or neutral (objects) images [126]. As expected, pulse also slowed down while perceiving unpleasant stimuli. This pattern resembles "freezing" and "fear bradycardia" observed in many biological species as protective responses to threatening stimuli, which is mediated by the psychophysiological mechanisms contributing to survival [126]. Contrariwise, it has been shown that the presence or absence of support afferentation influences the valence of emotional response [127]. In particular, students in the sitting position with support on the feet perceive images more positively than sitting without permission on the feet [127]. In contrast, older women who have trained support stimulation demonstrate a lower level of anxiety and depression compared to women of the same age doing fitness only [18].

CONCLUSIONS

The analysis of modern literature devoted to the research into the relationship between postural and psychological characteristics of the ability to maintain balance has shown that beginning from Bernstein's works, sensorimotor integration and feedback underlying the relationship between postural and psychological functions is the critical psychophysiological mechanism of postural control. This statement is of fundamental and theoretical significance for understanding the evolutionally significant role of postural control and is confirmed in each reviewed study. Particular interest in studying interrelations between human postural and psychological characteristics is associated with revealing the role of gravity and support afferentation in the formation and development of psychophysiological functions at the Russian scientific school of aerospace medicine. The beginning of these studies is associated with recognizing the significance of support on the legs and stabilometric measurements in psychophysiological diagnostics, prevention, and correction of motor and psychological

functions. At present, there is sufficient indirect evidence that affective and cognitive processes are associated with the stabilometric parameters of balance maintenance. In literature, the following characteristics are distinguished as psychophysiological parameters of postural control: attention, spatial memory, mood, emotional tone, rate of decision making, and fine motor skills of fingers. It means that learning, training, and correction of these psychological functions can be performed by training postural control. At the same time, the most informative predictive stabilometric correlates of these psychological functions are the integral speed indices of COP oscillations in high-frequency ranges. At present, it is impossible to draw any unambiguous conclusions regarding the psychophysiological mechanisms of postural control due to relatively small sizes of populations under study and methodological heterogeneity (e.g., different instrumental methods for assessing the balance and gait and various methodological approaches to the analysis of cognitive and affective functions). Hence, it was impossible to provide a significant quantitative assessment of the psychological and affective correlates of postural control through meta-analysis.

However, despite the neurophysiological mechanisms underlying the described relationships, the age- and gender-related differences are still based only on indirect evidence. It can be supposed that the progress of modern high-precision measurement and information technologies in the nearest future will provide new knowledge in this field due to its fundamental significance for the development of the theory of the evolutionally most ancient function of maintaining an upright posture and relevance to the applied aspect of using nonpharmacological noninvasive stabilometric approach to training and/or correction of cognitive and affective processes.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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