

As manuscript

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**System mechanisms of regulation of human vertical  
posture stability and controllability**

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**The English version of the abstract has been presented in adapted form**



**The full text of the thesis and dissertation abstract in Russian language is available in FGBNU Research Institute of Normal Physiology named after Anokhin and on the official website [www.nphys.ru](http://www.nphys.ru)**

## SUMMARY

**Relevance of the research topic.** In the last decades of the XX century physiological concepts, tools [Nashner, 1985], methods [Horak, 1990] were suggested – that are widely used even now, including research technology of human vertical posture stability using stabilometry as a main method. The physiological basis, the explanation is to a large extent were the so-called "mechanical models" [Kruchinin, 2014]. The association of prevailing concepts and related tools for the development of areas generally relates the influence of research technique on the science [Glozman, 2010]. Such influence, "instrumentalism" is clearly seen in the results and conclusions of the array of Russian thematic dissertations that have come out for the last decade [Kubryak, Krivoshey, 2016] and that have been analyzed by us. The overwhelming majority (~ 97%) of considered dissertations were carried out with the help of Russian instrumentation and software for stabilometry offered by two producers - the two development teams based on their own interpretations of the earlier theoretical and technical solutions. In this regard, the narrowing of choice of methodical solutions available to the researcher, means of obtaining results and their interpretations affected the elaboration of recommendations, usually in the practice areas, which are more dependent on the toolkit. With the manifestation of "instrumentalism" are also related methodological and "technological" shortcomings - for example, lack of a reliable comparison of the absolute values of the indicators obtained at different times in different observations, including because of an exception of due metrological support [Grokhovsky, 2015] of using different ways of calculating the stabilometry indices. The set of problems indicated above hinders the development of adequate physiological standards for the use for stabilometry of Big Data approaches [Krittanawong, 2016], the implementation of responsible telemedicine, telemetry projects with the transfer of physiological parameters. In other words, the development and implementation of research approaches, tools that would ensure a broader and more flexible range of available methods, precedes the emergence of new scientific results in the field.

This subject is relevant for healthcare – in Russian state standards of care stabilometry was designated by primary source A05.23.007, and others, implying use of technology and equipment (Stabiloplatform) in the treatment and rehabilitation purposes, for example, A19.24.001.014 «Training with biological feedback regarding support reaction in diseases of the peripheral nervous system. "comfortable and verified assessment is also in demand associated with the use of stabilometry in other practical areas - for example, in the assessment of operators, sports, monitoring of non-physical development of children and others. In addition to studying the publications, we collected and took into account expert views, the analysis of which indicates to the relevance of relevant studies - the example of high performance sport in a survey of elite athletes-shooters [Ivanov, Kubryak, 2011].

So, we believe that the topic of this paper should be considered as relevant in a broad theoretical and practical context.

**The degree of scientific development of the problem.** The disadvantages of commonly used to describe the physiological mechanisms and the quality of management vertical posture, the so-called "reflex" and "mechanical" concepts should include an explanation of the real complexity of behavior, such as ignoring the "proactive orientation". The most profound systemic idea discussed in the field we believe is the concept of "internal body scheme", which allows the creation of afferentation, which can be interpreted by the brain ambiguously, allowing to investigate the function of "internal representation system" [Levick, 2006]. In studies with the stimulation or inhibition of receptors [Billot et al., 2013] of various disorders or sensitive analyzers changes [Ivanenko et al., 1999], in the posture regulation, offered explanations based on the concept of multisensory integration [Ferrè, Haggard, 2015]. Subject publications cover a wide range of practical fields of medicine – Clinical Pharmacology [Baston et al, 2016.] Neurology [Kalron et al, 2016]., Regenerative medicine [Hugues et al, 2016], Otorhinolaryngology [Alahmari et al, 2014. ] and other [Perinetti et al., 2012]. Among the common shortcomings, in our opinion, in the first place, it should be noted the methodological problems associated with the choice of theoretical justification, issues of physiological interpretations, and the standardization and quality of indices [Schubert, Kirchner, 2014]. Special thematic research of modern Russian theses points to common problems.

Working hypothesis has been formulated on the basis of provided analysis: Study of the properties of the system of regulation of vertical stability and controllability of human vertical posture can be carried out by assessment of emergent\* properties of the system and the result of purposeful behavior within a standardized problem while the inclusion of artificial feedback.

The possible *consequences* of the main hypotheses: (A) the system of regulation of human vertical posture can be evaluated by investigating the possibility to reconfigure the control parameters while actuating artificial information channel (biofeedback for support reaction) and related analysis; (B) the restoration or improvement of the quality of the vertical posture regulation system in humans in the absence of compelling violations may be provided to create an artificial feedback on the support reaction, facilitating the optimization process – realignment of control system parameters; (C) the same task management strategy with biofeedback for support reaction may be similar when the system in various structural elements - the use of different structural elements (for instance, feet from front position, legs from sitting position, by hand).

**Goals and objectives.** The goal of this work is to explore the features of the regulation of the human vertical posture stability and controllability from the position of system concepts and to develop relevant methodology to study the function Stabiloplatfom, by including in artificial feedback in goal-directed behavior.

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\* Properties that can not be explained, expressed in terms of the properties of individual elements of the system - an explanation for this and other terms, see "Glossary" the full text of the thesis (in Russian), on page 152 (RUS). Available on the official website of the Research Institute of Normal Physiology PK Anohin: [www.nphys.ru](http://www.nphys.ru)

To achieve this goal were defined objectives relating to, *At first*, Measures for improving the reliability and validity of the physiological assessments stabilometric study; *Secondly*, Research of influence of changed peripheral afferentation (as commonly used methodological approach) on the performance of vertical posture stability; *third*, Studies of the stability of the parameters of stability and the vertical human posture controllability when the biofeedback for support reaction; *fourthly*, The study and use of biofeedback for support reaction for investigation and correction of functional characteristics system. Specific tasks of the present paper are the following:

1. to develop a method for studying the stability and regulation of the human vertical posture on the basis of the assessment of mechanical work pressure center in the support plane;
2. to examine the characteristics of impact of artificial short-term change of (dental) occlusion on the stability of the vertical posture in healthy volunteers;
3. To study the characteristics of the influence exerted by artificial modulation of the stop signal, the stability of the vertical posture;
4. explore the parameters of the vertical posture of volunteers in the demonstration of different images;
5. develop a way to study human vertical posture control system Stabiloplatfrom using artificial feedback to achieve due to the instruction of the result (in goal-directed behavior);
6. to study characteristics of influence exerted by the artificial modulation signals from the periphery (view) and incorporating artificial feedback on the stability of healthy person's vertical posture stability;
7. investigate the effect of short-term performance of daily tasks with biofeedback on the result of instruction in healthy volunteers;
8. study the characteristics of the study stabilometric vertical posture in the model of complex disorders of the nervous support (after ischemic cerebral stroke);
9. examine the features of performance of the same tasks with biofeedback for support reaction by using different methods of execution on Stabiloplatfrom - feet from a standing position, feet from a sitting position, with the hand.

**Scientific novelty:** For the first time there has been developed a way to study the stability and regulation of the human vertical posture associated with the assessment of the mechanical operation of the pressure center in the support plane - RU Patent 2456920.

The explanation of the differences previously described by various authors in the stability of the vertical posture with short-term change in the peripheral afferent related, for example, to manipulation of the occlusal plane or orthotic foot ("before" and "after") by methodological problems seems quite new: ambiguity, low reliability of commonly used indicators of stabilometry (eg, *S* - "Area of statokynesigram"), as well as the presence of reactions by type of Pavlovian reflex "What's that?". The new results may also include the fact that viewing a simple, smooth images with clear outlines, can contribute to greater stability of the vertical posture of man. Accounting

for these often overlooked circumstances will improve the reliability of the results of stabilometric study.

A new technique to study human vertical posture control system Stabiloplatfrom in the stipulated instructions purposeful behavior, using the biological feedback by support reaction -patent RU 2530767. Also RF patent has been obtained for the method involving the use of estimates related to the mechanical work of pressure centre in the support plane and biofeedback for the support reaction - RU 2476151. In the context of -Useful model: RU 152606 and RU 144682. There has been developed and registered a Russian computer program - RU 2013610968, that enables to carry out the tests and corrective procedures for the person in Stabiloplatfrom (including methods using artificial information channel), as well as to automate the work of a specialist, including offering automatic objective opinion on the measured parameters.

A new result can also be considered that the performance of the motor task in short procedure with biofeedback by reference reaction (for Stabiloplatfrom) may show a vertical posture changing control parameters, at least within a few minutes after this procedure. It should include a new discovery that performing the same task with biofeedback by using different performance methods on Stabiloplatfrom (standing, feet from a sitting position, using the arm) is a systemic similarities and differences are involved in the structural elements.

Optimization of the vertical posture control system is achieved faster with the addition of artificial feedback and formulation of the problem of using the new information channel in goal-directed behavior. RF obtained patents for inventions that offer practical application of this provision in medicine are RU 2573554 and RU 2489129.

One of the new options appraisal system regulating human vertical posture can be a study of the possibility of reconfiguring the control parameters, when including biofeedback for support reaction and analysis of the relevant changes. This approach has systemic character and is different from the reductionist notions of posture regulation. It has been practically implemented in the abovementioned software (RU 2013610968).

Of special note is the first time a systematic analysis of an array of modern Russian dissertations, that proposed the use of stabilometry. Here the concept of "instrumentalism" is associated with an explanation of the current level of human vertical posture stability studies on Stabiloplatfrom and possible ways of development of the thematic areas, including ways to improve the objectivity of evidence and research.

**The key provisions of the thesis put forward for upholding are the following:**

1. A measure of the physiological assessment of human posture stability and manageability associated with the mechanical work performed by the person in the center of pressure of the support plane, which increases the reliability of stabilometric studies.

2. The systemic nature of the factors influencing the stability of the human vertical posture with targeted changes of peripheral afference has been revealed, the account of which contributes to the efficiency of research with the use of stabiloplatform.

3. The feasibility of expanding the research tools of stability and controllability of human vertical posture has been revealed by including artificial information channel (biofeedback for support reaction) in a standardized behavioral task by executing which assessments may be obtained differing from those in the methods of passive research vertical posture to the signal modulation from the periphery.

4. Practical research tools for studying the stability and manageability of human vertical posture, based on the concept of the system functions of the organization, including the assessment of the results of the external behavior of targeted and relevant parameters of the posture in the procedure with biofeedback for support reaction have been elaborated.

5. It was revealed that in a standardized behavioral task performed on Stabiloplatform, changing methods of execution (feet in standing and sitting positions, with leaning on the arm), a similar strategy can be used.

Synopsis and thesis in Russian structured according to GOST R 7.0.11-2011, bibliography – GOST R 7.0.5-2008. Thesis 6 applications – up to 215 pages. The text of the dissertation contains a list of abbreviations, a list of illustrations and a list of terms. It contains 28 illustrations and 19 tables. The annexes contain 16 more tables with the summary data, 8 figures and a list of publications of the work basic scientific results with Internet addresses of 46 publications of RSCI, FIPS, Scopus, ORCID, PubMed, DOI or other databases, or journal resource. References include 259 sources, including 152 Russian and 107 foreign.

## The main content of the work

**Chapter 1. Literature review.** Ideas of the systems in relation to physiology have been considered. Different views on physiological studies, theoretical models of control of the vertical posture of man have been provided. The application of the basic method of research of vertical posture stability – stabilometry has been described, ideas about the physiological sense, and analysis of indicators have been covered. Evolution of the paradigm – *conditionally as* a movement from the "reflex" vertical posture control models to a simple "mechanical", like "single-link inverted pendulum", then to the complex "multi-tier" model, and, further, to the concepts of "sensorimotor integration", further – to the "body schema", system ideas. The overview also illustrates the opinion submitted, for example by the Soviet philosopher G.N. Volkov that "historically technology is primary to science". Our analysis of the practice of stabilometry in Russia on dissertations from 2005 to 2015, indicates exposure to stability studies and human vertical posture regulation heavily influenced by the level of technological development, research tools, and ready-made techniques.

**Chapter 2. Material and methods of the study:** The author personally, or in collaboration with his colleagues, if determined by the specifics of the study (indicated by the specific names in the relevant sections), made observations in healthy volunteers and patients (in collaboration with doctors), which was associated with the study of actual physiological indicators for the different states of a person (model). When the observations modern ethical principles, according to the local ethics committee, and, in accordance with the Declaration of Helsinki of the World Medical Association and the GOST R 56509-2015 "Services to the population. Good Practices of Humanitarian Studies " were respected. As part of this work was carried out: 3531 hardware not invasive measurements of human conditions involving 181 volunteers and 108 patients. The analysis of literature and collection of opinions in the study of the relevance of the theoretical research, development, analysis of experimental data, generalizations were proposed. In order to achieve the objectives and achieve the objectives of the thesis the following key methods and procedures were used: a study support reactions (on Stabiloplatfom); biofeedback for the support reaction (on Stabiloplatfom); Mathematical analysis. Stabilometric system "Electronic device STABILOTRENAZHER (STABILITY SIMULATOR) ST-150 by TU 9441-005-49290937-2009", Russia; RF Registration number of the medical device FSR 2010/07900; RF Certificate of type approval of measuring RU.C.39.004.AN 41201. The analysis of stabilometric studies and tests with biofeedback for support reaction was carried out in a regular program STPL (RU 2013610968). We used the following key indicators: **A** – Assessment of the mechanical work done by the center of pressure in the support plane ( "the index of energy consumption"), calculated according to the algorithm described [Kubryak, Grokhovsky, 2012], in joules, and derivatives thereof; **S** – Evaluation of the scattering of pressure centre positions on two axes, the "area of statokineziogram", in square millimeters; **L** – Assessment of the size of the trajectory of the center of pressure – "statokineziogram length", in millimeters [Skvortsov, 2010]; **Tp** – Estimate



of the time of one registered effective action in the task with biofeedback, in seconds. Statistical data and graphics analysis – in SPSS 13.0 [Gerber, Finn, 2006]. The adopted level of significance ( $\alpha$ ): 0.05, or 0.01. For the characteristics of the sample – indicators related to the actual distribution: median, quartiles [Orlov, 2004]. Selection of non-parametric methods of analysis - according to recommendations [Lemeshko, 1997], options analysis of biomedical data [Glantz, 1999]. Accordingly, the comparison of related data two-sample Wilcoxon test was used, for multiple samples, nonparametric analogue-way ANOVA, Friedman test was applied. If necessary, statistical modeling by the Monte Carlo method. Correlation analysis was performed according to Spearman method. Testing hypotheses about the stochastic independence of the sample elements (the presence or absence of trends) are a series of criteria, based on the sample median. For the assessment of the type of distribution for factor analysis one-sample criterion of Kolmogorov-Smirnov test was applied. The measure of sampling adequacy was assessed according to Kaiser-Meyer-Olkin. For the analysis of factors the method of principal component analysis with varimax rotation was used. For checking the null hypothesis of no correlation between the parameters Bartlett test of sphericity was used. Procedures such as clustering and multidimensional scaling, visual analysis, the construction of graph were performed according to «ForceAtlas» algorithm in Gephi 0.9.1 program [Bastian, Heymann, Jacomy, 2009]. Tables, graphs, linear and polynomial trend calculation reliability of approximation, arithmetic were prepared in MS Excel 2010 software. Aggregated data for the calculations presented in the main sections and annexes of the thesis.

**Chapter 3. Results.** 3.1. Features vertical posture assessment parameters related to the calculation of the mechanical work of the center of pressure in the support plane. By using techniques such as multidimensional scaling and clustering, the properties of the sample values of all known indicators **L**, **S** and new **A** observing for phase were visualized and examined - the graph built by the algorithm «ForceAtlas», based on 200 measurements performed sequentially in two dimensions in 10 volunteers for 10 days. Obtained 6 clusters corresponding to the studied parameters pairwise **L**, **S**, and **A** received with open and closed eyes of the tested volunteers. The most clear differences clusters to index **A** interpreted as his most unambiguous as the state changes and sustainability – that is, more reliable transmission of features and smaller exposure to random troubles. The lowest resistance to random noise figure **S** appears as a more pronounced "feathering" of the corresponding cluster. Based on the calculation of the mechanical work done by the center of pressure in the support plane index **A**, shows the greatest resistance to interference and most unique displays is replaced by the test conditions.

In the second stage 120 measurements carried out made jointly with SS Grokhovsky, a series of 60-second single-phase test of the "target" biological feedback reactions involving 6 smoking volunteers for 10 days by two measurement per day – immediately before and after the usual smoking. In all volunteers after smoking statistically significant increase in the **A** was observed at  $\alpha = 0.01$ , while the index for **S** in only two subjects had a statistically significant change, at less severe

conditions –  $\alpha = 0.05$ . Thus, a particularly important indicator **A** associated with the calculation of the mechanical work of the center of pressure in the support plane, as well as possible derivatives (eg, power), are its most unambiguous and reliability in assessing the posture parameters.

3.2. Features vertical posture stability at short-term changes in the artificial occlusion. 96 measurements in two individual runs on 4 phases each were performed, each in 12 healthy right-handed volunteers sequentially "open eyes" – "eyes closed" – "open eyes, altered occlusion" – "eyes closed, altered occlusion." Monitoring was carried out in conjunction with the candidate of medical sciences, dentist I.V. Pogabalo. The high probability of random variation index **S**, that can point to fallacy of frequent conclusions of researchers on changed conditions of the test subjects (or the patient in dentistry, with manipulation in the occlusal plane), if the conclusion is made only based on this indicator in single measurements. Meanwhile, the analysis of indicator associated with the assessment of the mechanical operation of the pressure center in the support plane (**A**), points to the possibility of non-random changes in the test the vertical posture stability at short-term artificial change of occlusion. Vertical posture stability characteristics at short-term changes in the artificial occlusion may be associated with novelty, and, if necessary, estimates of the impact of the selective occlusion of changes in the regulation of posture using stabiloplatfrom, appropriate techniques and reliable indicators should be used.

3.3. Features of vertical posture stability at short-term change in the tactile properties of the support surface. 304 measurements in the individual series of 8 consecutive phases ("barefoot" – "hard" – "medium" – "soft"), respectively, with open and closed eyes) were performed in 38 volunteers, together with the doctor traumatologist orthopaedist VI Nechaev. For studying the effect of different types of surfaces in contact with the bottom (pads) on stabilometric parameters, factor analysis was performed. The main factor is associated with a different individual sensitivity of the foot receptors of the skin properties (its thickness, dryness, etc.), and other individual characteristics. It is possible that the sensitivity and other characteristics of foot is predominantly associated with the sex of the subjects, or the volume measures of care for the skin of the foot. The second important factor – the change in the tactile properties of the support. Established "masking" influence of the reflection of posture parameters of signals that are different due to the change of support surfaces. There were no statistically significant pairwise differences for indicator **A** In the "hard", "medium" and "soft" modes relative to "barefoot". Short-term changes of the tactile properties of the bearing surface in the sample, small changes in vertical posture parameters, weakly associated with the type of surface and indicate to the reasons such as the novelty effect.

3.4. Influence of the type under consideration images on the stability of the vertical posture. 180 consecutive measurements were performed in conjunction with S.S. Grokhovsky. In this case, we looked at the dynamics of change of indicators separately for each of the 9 right-handed subjects in 4 sessions (on different days, with a control series) with the presentation of 5-statical images – 3 of them differed by type

and arrangement of geometric shapes, woods image and illusory helix. It was found that the presence of more than one (in comparison with the image of the forest) visual markers helped stabilize posture. In other words, viewing more clear, simple, comfortable oriented images with clear boundaries can contribute to greater stability of the vertical posture.

3.5. Features of achieving the result of purposeful behavior in a problem with the artificial feedback support reaction. In the first phase 128 measurements in 21 volunteers were carried out in a simplified single-phase (phase-controlled only) test model. The first phase was held in conjunction with the candidate of medical sciences, AL Guseva and candidate of medical sciences, SD Chistov during 5 weeks – from 2 to 9 tests. In healthy volunteers in this sample, the test of the "target", without training - fast, already in the first test, the achievement of individual-level results. In carrying out this type of test, in order to evaluate the result of the statement execution, should take into account possible training and learning rate, which is estimated to be high, even without special training. The simplicity of the procedure facilitates rapid learning and applicability of the test.

In a second step 388 measurements were performed on two series of phases: 1-n – without biofeedback, 2-n – feedback from switching. 9 volunteers had an opportunity to pass a large (arbitrary) number of tests from April to August of the calendar year, but not more than once a day. Significant differences of index **A** while targeted at the management of the posture of the regime without such feedback. Check for differences in index **S** indicates its applicability to small analysis for this case. Correlational analysis for **A**, **S** and an external indicator result indicates a low probability of direct links between stabilometric parameters and achieved result. That is, without any change in control of the vertical posture, for example, results in increased "effort" are required to "guarantee" the improvement of the result. In other words in a two-phase test, the result of goal-seeking behaviour and price of the result were expressed in the change of stabilometric parameters.

3.6. Effect of different modes and the inclusion of biofeedback for support reaction (visual channel) on the parameters of the vertical posture in goal-directed behavior. 1032 measurements in 43 volunteers were expressed in three individual runs at 8 phases 30 sec. each during one session (on different days). Phase sequence: "open eyes" – "eyes closed" – "examining the target with two eyes" – "biofeedback, two eyes" – "examining the target with left eye" – "biofeedback, left eye" – "examining the target with right eye" – "biofeedback, by right eye". The procedure was carried out together with the candidate of medical sciences, AL Guseva and candidate of medical sciences AM Polivoda. The evaluation of the vision influence on the stability of posture is often carried out on the area ratio (**S**). Statokineziograms for open and closed eyes, as "Romberg coefficient" [Skvortsov, 2010]. In connection with the detected drawbacks of indicator **S**, analysis was carried out and improved method was offered. The result of the sample Romberg for volunteers was like a "different" in three different sessions:  $p = 0.01$ . For the modified coefficient is calculated similarly, but on the basis of one-valued index **A**. We observed no significant differences:  $p = 1.84$ . The

analysis of the results of reliability (Cronbach's alpha) of the sample according to the modified Romberg coefficient and standard "ratio Romberg": 0.3 and 0.05, respectively. While certain conditionality of the application of Cronbach's alpha method in this study, evaluation by simulation of internal consistency, based on the average correlation between items presents visual differences of stability of coefficient calculation options. Thus, the calculation based on Romberg coefficient index **A** It is more reliable and straightforward to assess the degree of influence on the balance of the body in comparison with a conventional method. The analysis in this sample indicates a similar state with the contribution of volunteers in the position sensor providing vertical posture in three different sessions during the experiment, which increases the accuracy of the results.

Comparison of **A** index values in different modes of the entire sample, with inclusion and without the inclusion of biofeedback support reaction sequentially in three different sessions indicates that statistically significant for the whole sample ( $\alpha = 0.01$ ) differences were observed between the indicator **A** versus modes of *non-biological feedback* with two eyes and any one eye, in all 3 sessions. For modes *biofeedback* indicator for phase two eyes and any one was not statistically distinguishable. Similar results were obtained in the case of dividing the sample into those with a leading right or left eye. Thus, the restriction of (closing one eye) did not affect significantly the figure **A**. The inclusion of feedback artificial channel in the system reduced the role of restrictions procedure. In this context, intelligence of the factors was performed. It was found that when the biofeedback for support reaction, achieving a concrete result of purposeful behaviour has determined pose systemic change management.

3.7. Characteristics of effective volunteer action in a series of monthly recurring posture control problems in the biological feedback mode support reaction. 560 measurements in 20 pre-trained volunteers consistently for 27 days were performed. Monitoring was carried out in conjunction with the candidate of biological sciences EA Biryukova and IS Myronyuk The time of pointing the center of pressure to one target appearing on the periphery of the screen and return time of the mark to the designated central screen area was estimated for the emergence of the new "target" was one efficient action performed in vertical posture on the Stabiloplatfrom. Criterion series, based on the median of the sample shows no trend in each individual case. That is, the results of the volunteers of the sample were not associated with a potential increase "skill" or, conversely, decrease while performance of tests involving biological feedback support reaction in a task different from maintaining maximum static posture, on a daily basis, not reduced relevance of the tests. Individual results of the volunteers in these conditions tend to conform to a certain range, which characterizes the capability of a volunteer (check via runs test). The range of efforts required to achieve the appropriate level of individual capacity was usually limited. At the same time significant correlation between individual values of efficiency and stability indicators posture were observed. Thus, the productive actions of volunteers in a monthly series of short repetitive posture control problems in the biological

feedback mode support reaction related to their individual characteristics, and do not show any trends (eg, growth or deterioration), and, we believe, are associated with individual parameters of the system posture control regulation and reflect the current state.

3.8. Features stabilometric study vertical posture in the model of complex disorders of the nervous support/ assurance (after ischemic cerebral stroke).The observations carried out with the part of our employees – candidate of medical sciences MV Romanova, doctor of medical sciences EV Isakova and doctor of medical sciences SV Kotov, performed 432 measurements on stabiloplatforms, in 108 patients before and after a course of rehabilitation in acute, early and late periods. The patients were divided into two similar in severity of symptoms and characteristics of other subgroups, one of which received the modified physical treatments (biological feedback on Stabiloplatform), and the other - the traditional; under operating standards. In all subgroups of rehabilitation periods were estimated by standard neurological scales, a statistically significant improvement in the stability and controllability of the vertical posture. Quality (ability) of the central regulation of vertical posture, taking into account the actual state of the patients increased from an acute to a later period of rehabilitation. The patients underwent the variant of often used (according to the literature) double-phase stabilometric test – 30 seconds of quiet standing with eyes open and 30 sec. of standing with closed eyes, the beginning (after verticalization for the acute period) and at the end of the treatment course. The results of the pairwise comparison of selected indicators suggest that the stabilometric indicators obtained in closed eyes, have a higher discernibility of changes while using such type. Herewith the distinction the starting and finishing performance of the least is discernible in the later period of rehabilitation, deteriorating quality of comparisons. Quite often used in practical medicine index **S** It was the least reliable. Index **L** it was more reliable as a new indicator **A**. If **A** significant difference between the state of the subgroups of patients at the beginning and after the rehabilitation, all of these indicators index correctly the direction of changes, but the most unambiguous indicators show differences related to the assessment of mechanical work in a support plane. The difference between the relative values of the medians among the subgroups for index **A** after treatment is approximately 40%. Changes corresponding to those obtained by the scales to expert assessments, are most contrast for index **A**. In the case of the use of indicators "statokenizeogram area" type (**S**) Or related, in the later period of rehabilitation, indexing direction indicators may not be unequivocal, while the differences may be not discernible. In similar comparisons rehabilitation outcomes in subgroups at different periods of rehabilitation, it is necessary to underline the best results in patients for whom trainings with biofeedback for the

support reaction were used, according to the original method (RU 2573554), which, we believe, demonstrates the effectiveness of such training in the this case. No direct correlation between the indicators of neurological scales and stabilometric indicators were found, inter alia, because of the small scale variability of estimates of standing *Bohannon*; functional mobility of the scale when walking *Perry*; *Stolyarova* scale, which limits the number of statistical methods. Comparability of different diagnostic tools are, in our opinion, also limited and their features, including several different directions scale changes (eg, *Berg Balance Scale* above), general assessment "of man by man." Furthermore, application of the meaning stabilometric indicators is also associated with the procedures. Therefore, the features of stabilometric study vertical posture in the model of complex disorders of the nervous assurance (after ischemic cerebral stroke) should include the need for the selection of techniques, as well as application for the analysis the most definitive and sensitive indicators, in particular, the indicator associated with the assessment of the mechanical operation of the pressure center in the support plane .

3.9. Features of achieving a result in a problem with a biological feedback reference reaction by changing the method of execution. Conducted 91 measurement in 13 right-handed preliminarily trained volunteers. It was performed together with the candidate of biological sciences AV Kovaleva, candidate of biological sciences EA Biryukova, candidate of biological sciences AK Gorbacheva and EN Panova. Scheme "standing, eyes open, calm" – "standing up, eyes closed, quietly" – "biofeedback standing" – "biofeedback feet from a sitting position" – "biofeedback, hand (power joystick on Stabiloplatfom)", plus repetition of the first 2-phase. Biofeedback task similar to that described above in paragraph 3.7. It was found that the performance of the tasks with biofeedback for support reaction manifested in the increasing stability of the posture (standing). Physically more difficult conditions for the implementation of "dynamic test" is the position of "standing", less complicated – the position of "sitting, legs rest on the Stabiloplatfom" the easiest – "sitting, hand control". If the results of the hand control instructions are in a relatively narrow range, then the management or standing feet from a seated position, the spread has increased dramatically, indicating individual differences in the regulation of motor control systems. There was quite a strong link between "energy consumption" acts and external results. Increasing the index associated with the mechanical pressure in the center of the work platform plane (**Am**) for all types of control, correlated with effectiveness (**Tp**) when performing manual tasks. The correlation coefficient of ~ 0.7 indicates a sufficiently close direct relationship patterns of the task standing on foot and with the feet remaining seated. Feedback index **Am** to performance, optimal indexing strategy here - precise movements with a small share of swings and

deviations, combined with the quick response and the absence of errors. The analysis points to similar strategies while performing the same task by different "instruments".

**Chapter 4. Discussion.** The results are discussed in the context of the system of physiological concepts, and assumptions. We believe that the "system mechanisms" of human upright posture regulation stability and controllability here is a way to regulate physiological functions, described, for example, on the humoral or neural level, the level of individual anatomical or morphological elements, but at the level of the system, building on its emergent properties, manifested in terms of accompanying the results of purposeful behavior. In this regard, basing on the above discussion of the results of confirming the position of the proposed hypothesis, it appears more evident in the schematic image on the background of classical physiological schemes.

To this end, in Figure 1, based on the scheme of functional system by PK Anokhin, supplement its conventional mapping artificial feedback caused by manual problem and identify possible principles of the system modified in such a way.

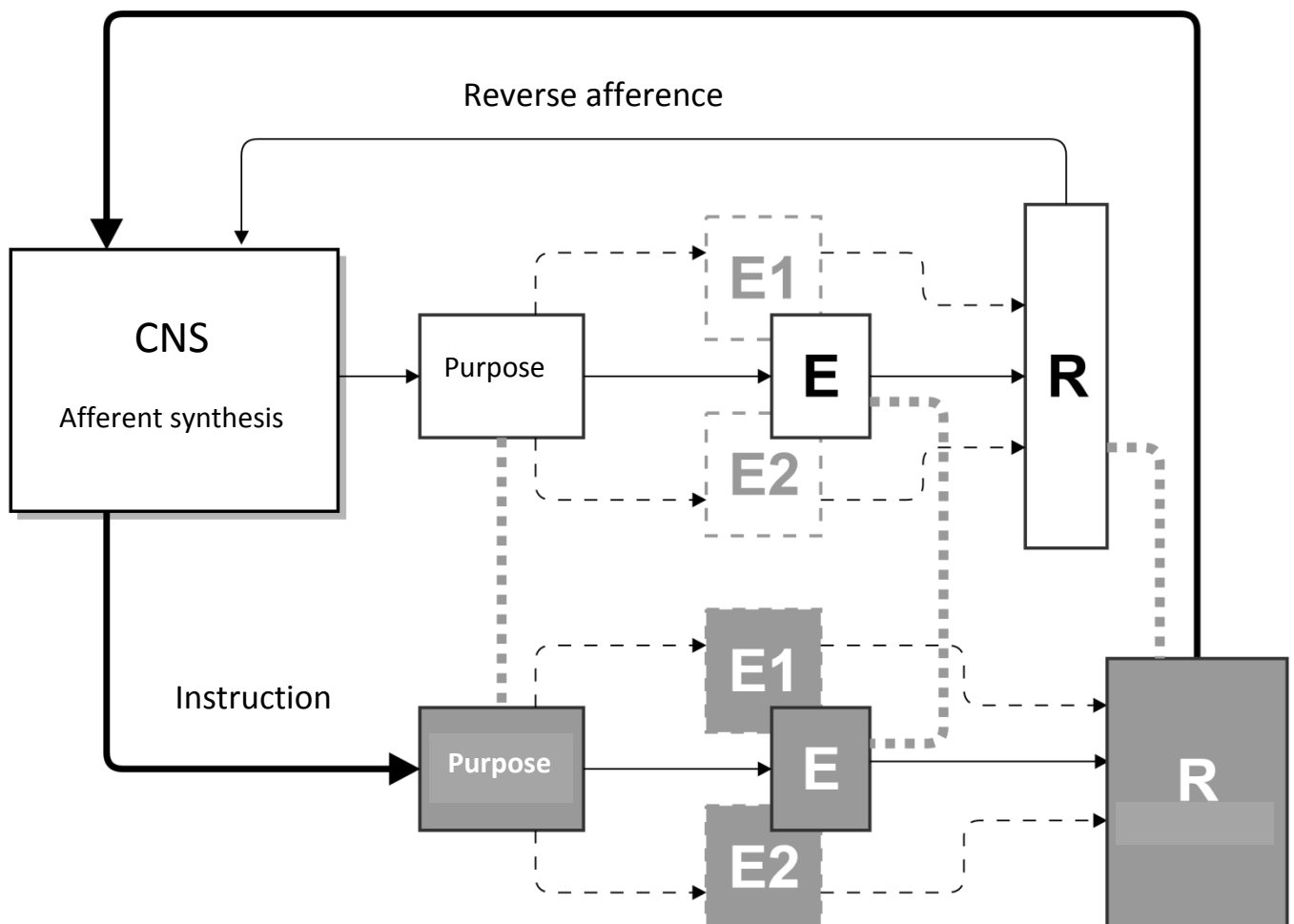


Figure 1. The classical scheme of functional system by PK Anokhin (light-colored figures) and the option to include an artificial feedback instruction in the conditioned behavior (in dark-coloured figures). Explanations in the text

In Figure 1, the following symbols are used: E – the final useful effect of the functional system; E1 and E2 – the deviation of the final efficiency of the system under the influence of various effects; R – receptor functional system, precisely adapted to the useful effect properties.

With explicit presentation of the instructions the aim of the regulation of vertical posture stability and controllability approaches the purpose of fulfilling the instructions, as the result of instruction and drawing closer to the ultimate beneficial effect of functional systems (targeted regulation of posture), and the system is supplemented by artificial "receptor", as if (constructively) adapted the properties of the useful effect – meeting the instructions.

The principles of "responsible stabilometric research" are described in the discussion. A variant of the classification procedures with biofeedback for support reaction (on Stabiloplatfom) has been offered. Overcoming the established methodological instrumental restrictions is indispensable condition for the development of areas available and widely used in the theme of stability and controllability of human posture stabilometry method.

## Conclusion

1. We have developed a new indicator for the study of the stability and the regulation of human vertical posture, based on an assessment of the mechanical work of the center of pressure in the support plane, so enhancing the uniqueness of interpretation of the results and their reliability in stabilometric study, compared with other indicators.
2. The effect of short-term changes of occlusion on the stability of the vertical posture, is ascribed to the novelty that shows limits for targeted research mutual influences of occlusion and posture outside systemic approaches.
3. It was found that deprivation of vision allows objectifying the effect of short-term modifications to the tactile properties of the bearing surface on the stability of the vertical posture, with slight changes in the indices are weakly bound to the type of surface and point to systemic causes.
4. It has been found that the viewing of simple, smooth, clearly focused images with clear contours, enhance the stability of the human vertical posture.
5. Two-phase test was developed in the system with artificial feedback support reaction, in which the external behaviour and achieved in the set purposeful behaviour and the value of the result expressed in the changes of stabilometric parameters.
6. It is established that while artificial limitation of view in the mode with biofeedback the system parameters (settings) are more important for the vertical posture stability, other than changes in the properties of the peripheral elements of the system.
7. It was revealed that a daily month course of short exercises with biofeedback for the support reaction in previously trained healthy volunteers did not cause targeted changes of the instruction performance result.



8. It was found that when stabilometric vertical posture study in a model of complex disorders of the nervous support (after ischemic cerebral stroke) vision "masks" change indicators posture regulation in standard tests such as "Romberg test" and inclusion in rehabilitation exercises with biofeedback improves the effectiveness of treatment, controlled by a new indicator of stabilometric research and standard neurological scales.

9. System similarity of strategies of perform the same task with biofeedback for support reaction when you turn in different structural elements - at different performance modes (feet from a standing position, feet from sitting position, by the hand).

### **List of major works published author on the topic of the thesis (by GOST, RF)**

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