Isometric-based Method for Hardware Automated Diagnostic of Functional Status of Central Nervous System

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Abstract—**The paper presents a new isometric method of determining the functional condition of the central nervous system. The method is based on the analysis of involuntary oscillatory movements of limbs of a human body secreted on the background of voluntary movements. A variant of the hardware implementation of the method is shown, the results of testing people with different health status are demonstrated.**

I. Introduction

According to [1], examination of the controlling function of a nervous system on the whole organism is one of the most complicated problems in the understanding of brain working.

One of the methods of central nervous system status evaluation is connected with the analysis of human limbs movements [2].

Two main kinds of limb movements could be selected – they are involuntary and voluntary movements. Voluntary movements are acts of locomotor behavior of a human being. Involuntary movements proceed as a simple reflex act and in most cases are involuntary rhythmical oscillatory movements of body parts – tremor [3].

Parameters of involuntary movements of movable parts of human limbs define central nervous system state of the person. The said oscillations emerge due to involuntary muscular contractions and are inherent to every person, being a physiological norm. Changes of amplitude, frequency and form of oscillations are signs of the disturbance of central and peripheral neuron mechanisms of movements' regulation, and they could be used to evaluate functions of different brain structures.

Based on the received data and the results of their statistical processing, we can carry out evaluation of psycho-emotional and functional states of a human being, and perform diagnostics of neurophysiological and cognitive disturbances on early stages.

The evaluation results are of interest in different fields. Tremor forms analysis is very important in neurological practice. Increase of the amplitude and change of frequency and form of oscillations with respect to norm (frequency and amplitude of physiological tremor) are indicators of the disorder of central and peripheral neuron mechanisms of movements' regulation.

In sports and fitness the suggested method can be effectively used for the following:

- medico-biological selection and determination of admittance to sports activity;
- monitoring functional readiness of athlete's organism that will facilitate correction of the admissible level of stress and prevent destabilization of psychophysical state, enhance social sportive status and help to preserve athlete's health;
- monitoring athlete's rehabilitation process after undergone injuries and diseases.

So, analysis of oscillation forms of the movable links of limbs as an indicator of the state of locomotive sections of the central nervous system is of great scientifical and practical importance [4].

The earliest method of tremor registration was mechanography. Modern devices of such a type assume usage of graphics digital tablet connected to a personal computer. But interpretation of the results of the method is difficult because of nonlinear dependence and great number of factors effecting the final result.

For a long time electromyography, recording bioelectrical muscular activity, was used for the tremor analysis. Method of spectral analysis of electromyography envelope was developed as an improvement, that allows to analyze tremor waveforms. But the said method registers electrical potentials of muscle bundles or muscles and allows only to judge indirectly about biomechanical characteristics of movements, and besides that does not reflect dynamics due to the treatment being carried out.

Now the used methods of tremor parameters registration are based on the conversion by different sensors of the displacement of movable links of an object to the output electrical signal, its preliminary processing, transformation to a form suitable for storage and successive mathematical analysis. There are

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tensometric sensors recording the applied stress, conductive sensors detecting magnetic field change during limb movement, accelerometric sensors based on the registration of movement acceleration. Movement signals generated by accelerometers are analyzed in order to detect the time of their initiation and their location in the predefined frequency range. Tremor is selected from the other movements by the said two criteria.

The method and device for the movement patterns evaluation is known. When this method is under way, movement of the markers fixed on the body of the examined person is recorded for the evaluation of the kinetic patterns of head, body and limbs' movements. Trajectory curves of every marker are defined in 3-dimensional space as a time function. Computer analysis evaluates the curves in terms of image recognition by comparing them with the corresponding standard patterns. It allows usage of the received data to evaluate central nervous system functions and to define clinical picture, especially due to psychic, psychosomatic and/or neurological disorders.

But analysis of body elements oscillations does not truly evaluate voluntary and involuntary controlling actions from the central neuron structures on a motor apparatus because of the fact that in such a case the character or parameters of the recorded oscillations of body parts are to a greater extent governed by the inertial features or the mass of the movable element.

All the listed methods of the analysis of tremor and movements turn out to be subjective because not controlling force influences on a motor apparatus are registered, but the result of their successive transformation, which is non-linear. Based on the movement data, it is impossible to make a conclusion about formation of controlling commands and to evaluate functional state of the central nervous system structures. Moreover, existing methods of movement registration do not allow evaluating of a hidden developing pathology that does not show itself externally. And there exist a hypothesis that external tremor manifestations, for example, Parkinson's disease tremor, appear 10-15 years after the disease begins.

Besides that, in the known devices and methods of movements' registration, conditions of receiving corresponding electrical signals from sensors are not taken into account. Possibility of further application of some or other analysis and interpretation methods to such data depends on the conditions of their acquisition, especially when movements are recorded with the aid of different sensors fixed on the examined person, for the results could differ depending on physical parameters (mass, dimensions) of the sensors, their orientation and location on the movable parts of a human body.

As the natural method of controlling actions' registration is the direct measurement of the force developed by muscles, isometric method (without visible movement) of force measurement is widely known and applied in medical practice for the examination of biomechanics of human movement and evaluation of the central nervous system functional state [5], [6], [7].

Of all kinds of methods used for the examination of motor system activity, isometric force can give fuller data about the activity of its structures, because activity in central sections of the motor system is proportional to the value of voluntary effort.

But in the known devices based on this method human body weight is measured and body oscillations (center of gravity projection) are registered when a person retains stand-up vertical position, and that in its turn also does not allow to evaluate true values of voluntary and involuntary controlling actions from central nervous system on the human motor apparatus, i.e. on movable links of a body.

Most of the mentioned methods are not widely applied due to the described disadvantages.

Advantages of the suggested method of the evaluation of central nervous system functional states based on the isometric method are as follows:

- high reliability on account of the exclusion of influence of limbs movable parts' inertial mass on the form and amplitude of oscillations;
- possibility of testing procedure standardization due to the only one parameter registration;
- possibility to reveal wide class of functional specialties and dysfunctions of a central nervous system;
- full detection of controlling brain structures' activation features compared with the movements' analysis;
- maximal easy testing procedure with the minimal influence on a human being;
- minimal time of examination.

The purpose of the work was the development of a new original isometric method of the evaluation of central nervous system functional state and the development of hardware and software for its implementation .

The result of the work is a new innovative product – the instrument allowing to reveal with high degree of reliability functional specialties and pathological states of the central nervous system based on the isometric method.

II. Isometric Method of the Evaluation of Human Motor System Integral Activity

The researchers from the Institute of the Human Brain of the Russian Academy of Sciences, named after N.P.Behtereva, offered a principally new method of the analysis of human motor activity. The method allows to register voluntary effort and divide from it oscillations being an involuntary component. Parameters of isometrically regulated stress give the most correct characteristic of central controlling processes [8], [9].

The currently available results of the studies of principles of transformation of pulse flows in neuronic structures show that the segmental level of the peripheral section of the systems of movement control is unable to compensate for some disturbing influence.

Researches on electronic models showed that proprioceptive muscular apparatus forming at the segmental level lines of motoneuron activity control is really a mechanism of multiparameter homeostatic regulation of muscular contraction. Cortex of great hemispheres and subcortical structures of the brain are also involved in the same homeostatic regulation.

The suggested method based on the results of the said research puts into correspondence involuntary micro-stress and the state of the central nervous system of a person. The method implementation consists in the following procedure [10]. A person sits in front of the screen monitor at the table on which two tensometric dynamometers are placed. The examined people touch corresponding support surfaces by fingers of the stretched ahead hands and follow the stress value looking at the shift of marks on the screen. The marks shift along the vertical axis of the screen proportionally to the applied stress.

The task of the examined person is to keep marks on the screen at the same level when they are shifted proportionally to the stress applied by the right or left hand. Involuntary oscillations and voluntary force change in the isometric stress are selected to correct marks location on the screen.

The stress of every hand is registered, conversed to the analog voltage, which, via analog-to-digital convertor, is entered into a personal computer for the real-time visualization on a screen and for the subsequent processing. Duration of the registration is selected so that enough measurement points will be received for the statistically confident evaluation of time sequences' parameters. Testing protocol is approved by the ethics committee of the Institute of the Human Brain of the Russian Academy of Sciences, named after N.P. Behtereva. Informed consent for the participation in the examination is received from all the examined.

For the registration and examination of involuntary movements of mobile body parts isometric method of stress registration is used, wherein the stress is registered without visible shift of a mobile link in the point of contact with the hard measuring element. Parameters of such a mode, in correspondence with the principles of ring-type regulation and hierarchic organization of the movements control system, most fully reflect the structure of motor commands descending to motoneurons of the segmental level.

Such registration method allows to exclude influence of the movement of mobile limbs' links' inertial masses and most deeply and fully reveal diversity of complicated processes of hierarchic interaction of subcortical structures between each other and with the other systems taking part in the movement organization, the registration being objective and so making analysis of voluntary and involuntary nervous system activity objective too.

Registration of only one parameter – confining force – allows to standardize testing procedure and to objectively evaluate not only frequency but amplitude characteristics of stress oscillations as well, comparing different researchers' results. Such comparison is unobtainable if the tremor recorded by movement sensors is analyzed because the tremor parameters depend on the sensors' type, their location on a patient's or a tested person's body and on the constitution of the examined person, and in most cases are subjective.

Simultaneous registration of the effort of every hand allows not only to select voluntary, controlled, and involuntary components of the descending commands formed in the nervous system and related to tremor parameters, but to reveal asymmetry in inter-hemispheres interactions, using the results of correlation analysis.

The suggested new method of the effort involuntary component selection during voluntary controlling of isometric muscular tension is an objective and sensitive tool for the subtle analysis of the amplitude, form and frequency spectrum of involuntary oscillations, in parameters of which features of functional organization, activation levels and temporal interrelations between structural formations of the motor system are reflected.

III. HADWARE REALIZATION OF ISOMETRIC METHOD OF THE EVALUATION OF HUMAN MOTOR SYSTEM INTEGRAL ACTIVITY

The proposed method is implemented in the device named tensometric analyzer [11]. It consists of a hardware module and a personal computer with the appropriate software. The structural implementation of the analyzer is based on a program-oriented approach which assumes the maximum use of the personal computer possibilities. The hardware module is implemented as a peripheral device and the main of its functions is registration of the examined person hand effort. The hardware module includes registering and control devices Fig 1.

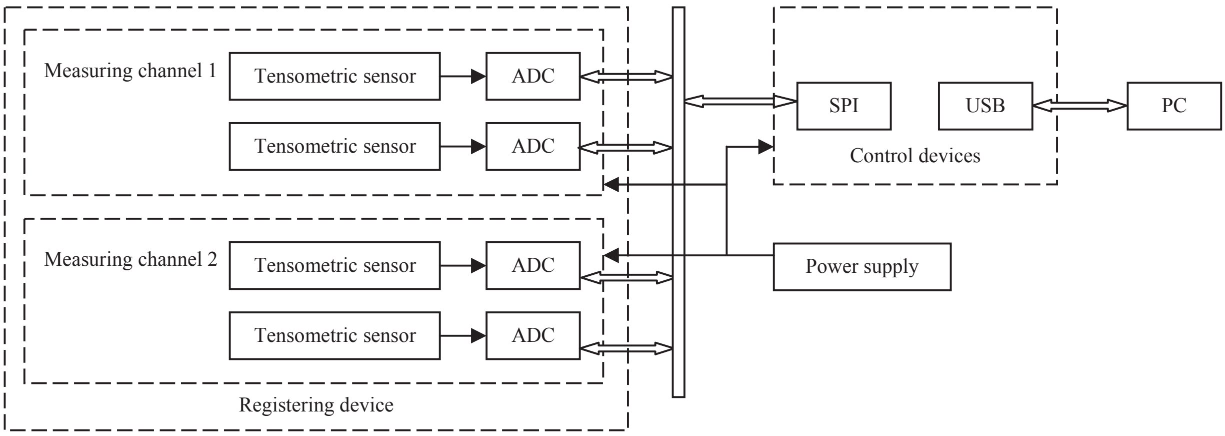

Fig. 1. Block diagram of the tensometric analyzer

The registering device provides data acquisition from sensors when patient's hands act upon them, and records the following parameters:

- maximum voluntary effort which is sufficient to perform tests for different groups of patients, the maximum value of the effort reaching 10 kg;
- amplitude of oscillations which normally does not exceed 2% of the voluntary effort;
- effort created by involuntary oscillations of arms, usually having periodic nature, with significant fluctuations in the range of 0 ± 16 Hz.

The registering device performs the measurement of oscillations of body moving parts, primary filtering and primary transformation of the measurement data. Due to the need for recording parameters of two limbs, there are two measuring channels in the registering device. After the primary filtering, sensors' information is divided into four independent flows of measurement data. The registering device includes two converters of mechanical movements' parameters to electrical signals, units of signals' normalization and four analog-to-digital converters.

The converters of mechanical movement parameters into analog electrical signal are based on tensometric sensors. The S-shaped sensors are used as sensitive elements. The sensor signals are divided into voluntary and involuntary components by means of operational amplifiers' stages. For signal conversion to a digital form 24-bit ΣΔ analog-to-digital converters are used. Conversion of measurement data is performed using the original structural-functional approach [12] to provide fault-tolerant tracking of pulse flows and their functional processing.

The control device is implemented on system-on-chip microprocessor and performs three functions:

- control of the measuring module using a synchronous serial interface SPI;
- preprocessing of the data (restructuring data arrays of measured values for later transmission to a personal computer);
- data exchange with a personal computer using USB interface.

The software for the personal computer is based on the M-V-VM pattern [13]. It provides separation between application logic and the graphical user interface and makes an application easier to test, maintain and improvement.

The software for the personal computer provides biological feedback and also executes collection, structuring and processing of the received data. The software for PC performs the following functions: realization of biological feedback; organization of database of the tested persons; pairing with the control device; processing of the measuring data. The PC software of tensometric analyzer consists of the following modules: the module of interaction with the device, the module of graphic interface, the supervisor module, as shown on Fig. 2.

The interaction module provides the link between peripheral hardware of the tensometric analyzer and an interface to the other software modules. For the correct implementation of biofeedback USB interface is used in the interrupt mode. Data streams characterizing the involuntary movements of the limbs are used to display feedback on the screen. Data streams corresponding voluntary motion are applied for obtaining information about the functional state of the central nervous system.

The supervisor performs the basic connecting function between other modules and implements the following functions: converting of data arrays (packets), entering the data, mathematical processing, preparing data for graphical display, working with the file system. Also the supervisor module contains model classes of the main data and basic user-interface elements.

The module of graphic interface implements on-screen display of graphic information, including visual stimuli for a person under test and interface settings for the operator.

Biological feedback implements combination of psychophysiological test procedures. During these procedures the examined person obtains information about the status and the change of some or other of his own physiological processes by means of external feedback circuit. In tensometric analyzer visual stimuli-signals are used. Biological feedback is implemented by displaying, on the monitor placed opposite the examined person, visual indicators changing position in accordance with the voluntary effort of each hand [14].

To show actions of an examined person on formation of voluntary effort the smoothed measurement data are used. Based on these data, user actions are displayed on the screen by moving graphic elements (markers). A line segment and a pair of line segments were selected as markers (Fig. 3 a), the markers should have contrasting colors. Alignment of graphic elements is the position when the first segment is inside the other pair as shown in Fig. 3 b.

The elements are shown in the patient's window and duplicated in the operator's one. The operator can specify the following parameters: color of reference elements; size of reference elements; grid step; background color.

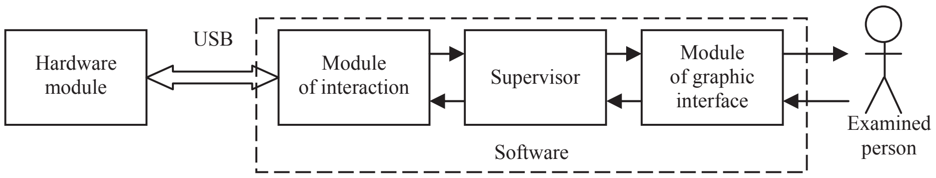

Fig. 2. Block diagram of interconnection of the software modules

Additionally, the operator sets the duration of the testing process and test conditions such as holding of markers at a predetermined level, the formation of a maximum or minimum effort by person under test. During the testing process the operator obtains the intermediate results of measurement involuntary effort characteristics.

For analyzing the results of isometric effort records, the software should have the following possibilities:

- processing of data arrays to get analytical and diagnostic results;
- processing of results by methods of mathematical analysis;
- presentation of test results in the form suitable for visual analysis.

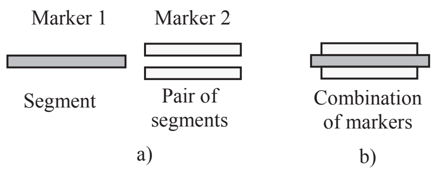

Fig. 3. Block diagram of interconnection of the software modules

Test results are represented by time series of voluntary and involuntary components of the hands' motion, as well as by their spectral characteristics received after the Fourier transformation [15, 16].

The need for spectral analysis exists due to the cyclical activity appearing when a person retains isometric effort. It depends on the structural organization and functional state of the system of motion control and is reflected in output parameters.

IV. The Results of the Evaluation of the Motor System Integral Activity

Developed hardware-software system was used for examineted the patients with movements disorder of various causation: in the chronic period after stroke, at multiple sclerosis, Parkinson's disease and parkinsonian syndrome, infantile cerebral paralysis and brain injury.

The results of the evaluation of the motor system integrated activity obtained with the developed system are shown in Fig. 4. In this study a healthy person and patients with different pathologies took part. On the waveforms it can be seen that the evaluation process in time allows detecting different manifestations of tremor:

- for a healthy person (Fig. 4 a, b) cyclical activity has a tendency to calm down with time;
- for a patient with the diagnosis of symptomatic tremor (Fig. 4 c, d) decrease in the amplitude of high-frequency tremor and reduction of the asymmetry of the oscillations of right and left hands is inherent;
- for a patient with the diagnosis of Parkinson's syndrome (Fig. 2 e, f) the tremor does not qualitatively change over time.

The features of the evaluation method of the motor system integrated activity are shown on the waveforms Fig. 4 representing in the same scale involuntary component curves of a certain retained effort. Schematically the waveform is divided into 5 ranges with different efforts:

(j = 1) – very weak [0.0; 0.5] kg;

(j = 2) – weak [0.6; 1.6] kg;

(j = 3) – medium [1.7; 3.2] kg;

(j = 4) – strong [3.3; 5.0] kg;

(j = 5) – very strong [5.1; 7.5] kg.

For the healthy person (Fig. 4 a, b) and every patient (Fig. 4 c – f) two curves for each are represented. Every curve consists of five fragments (6 second duration each) of oscillograms of the measurements of an involuntary component corresponding to the retained efforts: the upper curve – for the left hand and the lower curve – for the right. In each couple the left extreme curves are received in case of the minimum effort and increase to the right. The right extreme curves are obtained in case of the effort close to maximum. The special methods of analysis enable to obtain characteristic signs from the curves of isometric effort.

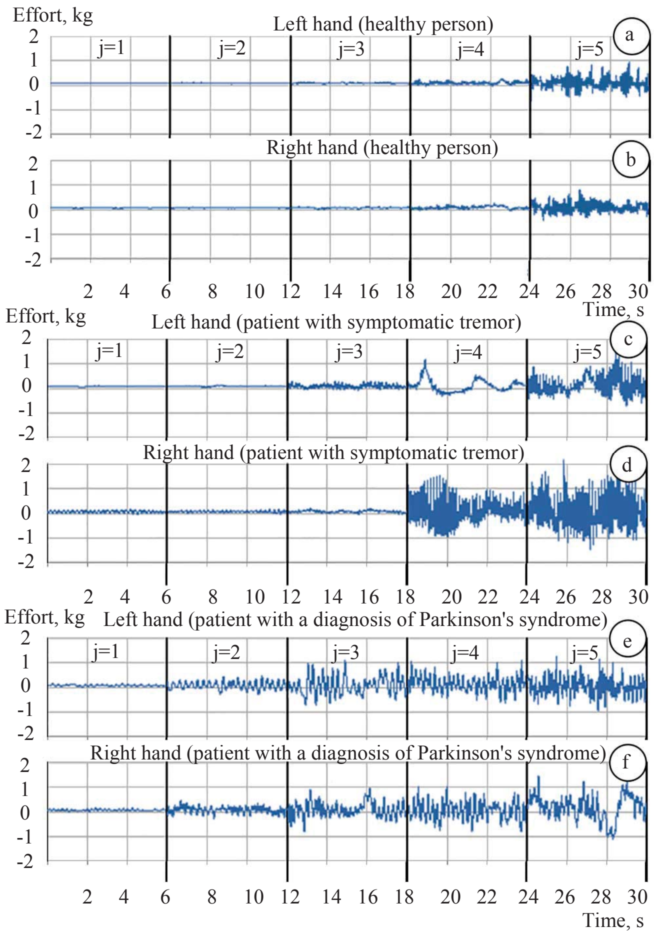

Fig. 4. Result oscillograms

Figs. 5, 6 present the examples of preliminary express assessment of the functional status of the central nervous system of the healthy person for five tests (T1 ÷ T5) on five ranges of efforts. Figs. 7, 8 show the examples of preliminary express assessment for the patient with the diagnosis of symptomatic tremor.

The statistical analysis characterizes average values of the retained efforts during the test (Figs. 5 a; 7 a) and the average values of the involuntary components (Figs. 5 b; 7 b). The standard deviations characterize their dispersions (Figs. 5 b; 7 b). These parameters change at modification of feedback conditions and characterize the state of sensor channels of the person under test.

At the same time the difference between average values of the retained efforts of any gradation isn't considerable when the gradation changes (Figs. 5 d; 7 d). The difference between neighboring average values of the appropriate involuntary component for the healthy person increases a little at the beginning of a gradation, and decreases at the end (Fig. 5 e). For the patient with the diagnosis of symptomatic tremor the said difference has a pronounced nonlinear increase at the approach to the maximum gradation (Fig. 7 e).

The spectral analysis of the effort retained according to the gradation (Figs. 6 a, b; 8 a, b) characterizes the person's ability to correct his movements.

The spectrum's power (Figs. 6 b; 8 b) in the range of 0 – 1 Hz shows the extent of conscious controlled execution of the test. In this range the power of spectral components of the healthy person (Fig. 6 b) is proportional to the effort. The patient with the diagnosis of symptomatic tremor (Fig. 8 b) has nonlinear increase of this power.

Activity in the range of frequencies over 1 – 2 Hz is involuntary and characterizes the functional status of neural structures of the brain. The significant growth of amplitude of spectral components in this range is the indicator of pathological states. Distributions of spectral density, normalized to the maximum value, are presented on Figs. 6 a, b, c, e and Figs. 8 a, b, c, e. It allows to compare them under different tests with different efforts.

Spectral density in the range of 1 – 3 Hz characterizes features of program automatic maintenance of an effort (pose of body) by movement control system with involving in control process the cerebral cortex and subcortical structures.

The increased amplitude of spectral components in the range of 3 – 7 Hz in comparison with adjacent areas is connected with structural changes in the nervous system, for example, parkinsonism or chorea. On Figs. D, E for the patientwith the diagnosis of symptomatic tremor this growth of amplitude is distinctly shown in the big side. Also, comparing spectral components in this range for different gradations of effort shows

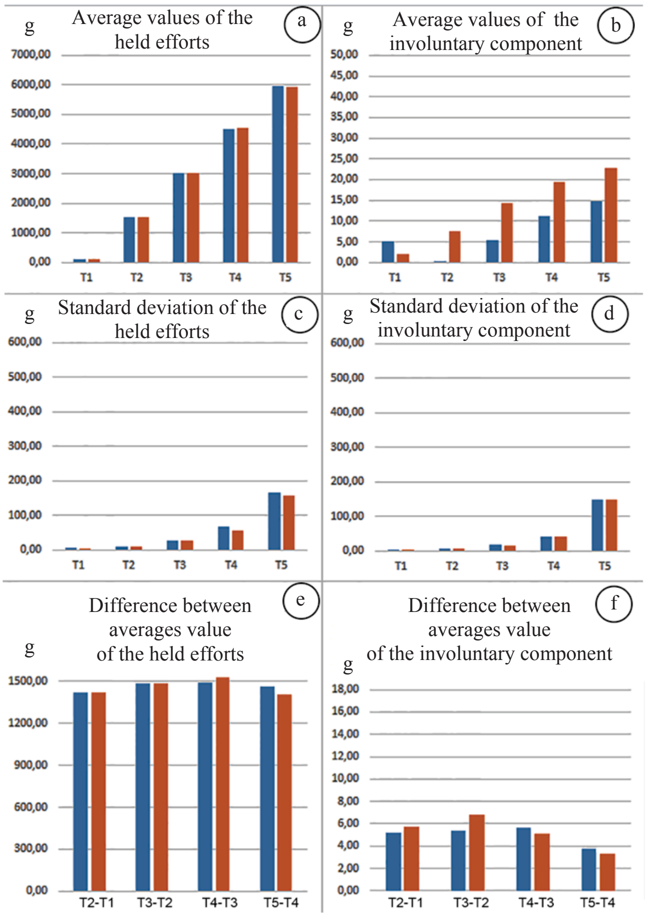

Fig. 5. Results of assessment of the functional status of the healthy person

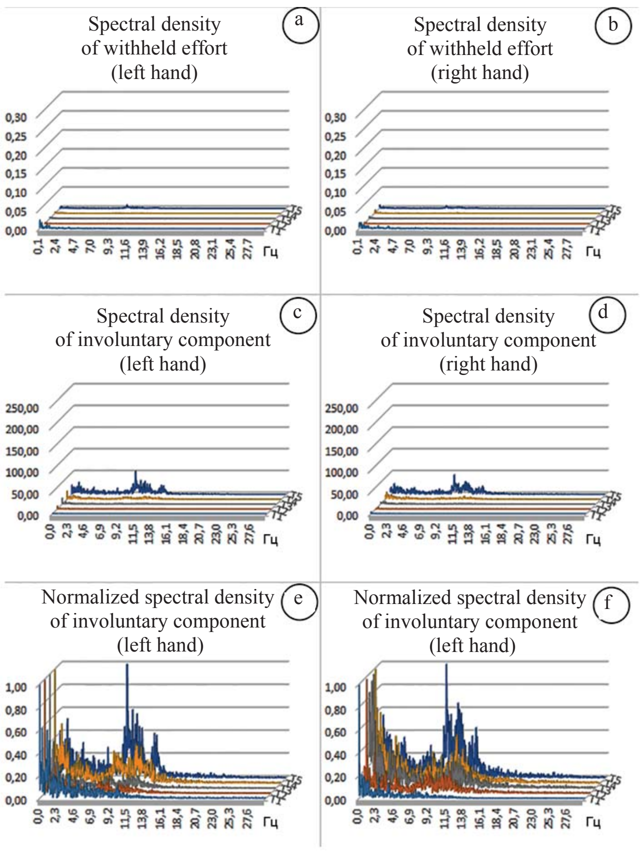

Fig. 6. Spectral density of results of assessment of the functional status of the patient with the diagnosis a symptomatic tremor

change of amplitude according to gradation. The growth functions for the left hand (Fig. 8 b) and for the bad right hand (Fig. 8 g) differ.

In normal state the range of 4 – 7 Hz is characterized by the low amplitude of spectral components in comparison with the adjacent areas (Fig. 6 b). This is especially well visible on Fig. 7 d, e.

The range of 8 – 12 Hz characterizes the state of spinal segmental mechanisms of the movement control system. Activity in this range increases as the efforts approaches to the maximum muscular strains. Moreover, for the patient with the diagnosis of symptomatic tremor during analysis of the left hand (Fig. 8 b) and of the bad right hand (Fig. 8 g) it already begins to appear at medium muscular strains of the bad hand. Analysis of the involuntary component (Figs. 6 b, d, e; 8 b, d, e) allows to carry out more exact evaluation of the control process, in particular with the use of cross-correlative methods.

V. Conclusion

In this paper the authors presented the first results of the studies of the method to determine the functional state of the central nervous system based on the assessment of the involuntary component that is allocated on the background of arbitrary efforts generated by the tested person.

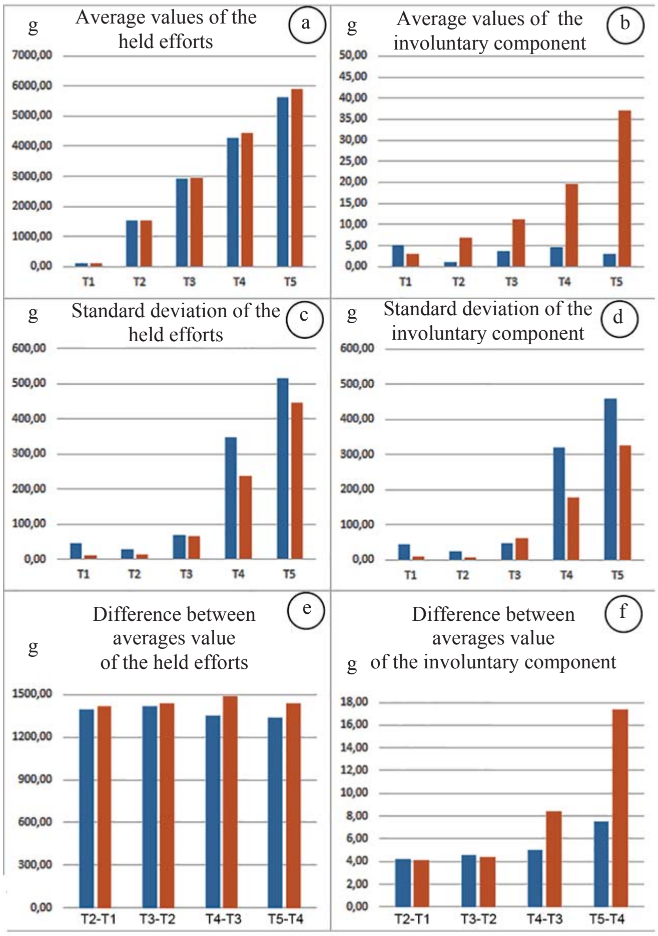

Fig. 7. Results of assessment of the functional status of the patient with the diagnosis a symptomatic tremor

The obtained early modeling results were fully confirmed during the analysis carried out for healthy people as well as for the people with abnormalities of the central nervous system with the use of the designed tensometric analyzer.

Created and tested tensometric hardware confirmed the feasibility of the method. Due to the usage of the original technical solutions the effective hardware for the automatic diagnosis was designed.

We plan to develop this method and hardware by using other statistical methods, the results of which will allow to get more information about the psychophysiological state of a person.

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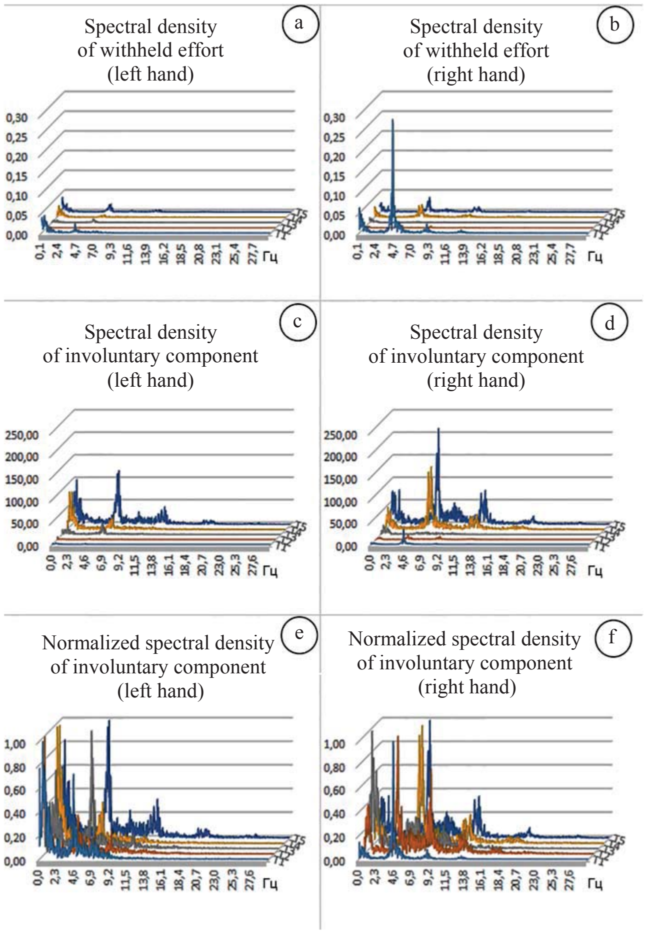

Fig. 8. Spectral density of results of assessment of the functional status of the patient with the diagnosis a symptomatic tremor

REFERENCES

[1] S.P. Romanov, “Correlates of voluntary effort parameters with the functional state of the motor system”, *Russian Physiological Journal named after I.M. Sechenov*, 2005, pp. 488-501.

[2] M.P. Young and J.W. Scannell, “Brain structure-function relationships: advances from neuroinformatics”, *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* 2000. Vol. 355. N 1393. P. 3-6.

[3] G. Grimaldi and M. Manto, “Tremor: From Pathogenesis to Treatment”, *Morgan & Claypool Publishers*, 2008, p. 212.

[4] I.A. Ivanova-Smolenskaya, “Modern instrumental methods of tremor registration”, *New technology*, 2011, pp. 17-23.

[5] D.E. Vaillancourt and K.M. Newell, “Aging and the time and frequency structure of force output variability”, *J. Appl. Physiol.* 2003, Vol. 94. N 3. P. 903-912.

[6] H. Olafsdottir, W. Zhang, V.M. Zatsiorsky and M.L. Latash, “Age-related changes in multifinger synergies in accurate moment of force production tasks”, *J. Appl. Physiol*. 2007. Vol. 102. N 4. P. 1490-1501.

[7] Z.A. Aleksanyan and S.P. Romanov, “Feature of activity of nervous system at a movement control”, *Information and Control Systems*, 2012, No. 5, pp. 57-68.

[8] Z.A. Aleksanyan and S.P. Romanov, “Metrological aspects of tensotremorography in the evaluation of integrated activity of human motor system”, Web: http://chizhevski.ru/vestnik/7-tehnologia/93.

[9] Z.A. Aleksanyan and S.P. Romanov, “Biophysical bases of noninvasive monitoring of activity of motor system of the human”, *in Proc. VII international symposium*, Kiev, 17- 20 May, 2012, pp. 6-7.

[10] Z.A. Aleksanyan, O.B.Kostrova, H.H. Razin and S.P. Romanov, “Tremor-graphic system for change of a form and amplitude of fluctuations of mobile links of the human limbs”, *in Proc. V international scientific congress Neurobiotelecom-2012*, Saint-Petersburg, December, 2012, SPb: Polytechnic, 2012, pp. 197-200.

[11] P.N. Bondarenko, O.I. Bureneva and N.M. Safiannikov, “Analyzer of updating of a condition of the human”, *in Proc Regional meeting Actual problems of psychological safety*, Saint-Petersburg, June, 2012, SPb: Its Publishing, 2012, pp. 101-104.

[12] I.V. Gerasimov, S.A. Kuzmin and N.M. Safiannikov, “The Space-Time Formalism in Description of Quantum Information Object Characteristic Properties in the Context of Problem-Solving of Observable Quantities Soft Measurements for CARD-Systems VI-Environments”, *in Proc XVIII International Conference on Soft Computing and Measurements*, 2015, v. 2. pp. 140-144.

[13] Microsoft official website, "The MVVM Pattern", Web: https://msdn.microsoft.com/en-us/library/hh848246.aspx

[14] N.M. Safiannikov, Certificate of state registration of computer program № 2015614013 ”Program of visual influence on a person for the revealing of hidden states”; № 2015610884, applied 17.02/2015; registered 01.04.2015.

[15] H.I. Nussbaumer, “Fast Fourier Transforms and Convolution Algorithms”, *Springer*, 1990.

[16] Z.A. Aleksanyan, O.I. Bureneva, H.H. Razin and S.P. Romanov, “Method of assessment of a functional condition of the central nervous system of the person”, Patent of Russian Federation No. 2540534. 2014.