NEUROLAB

DESCRIPTION OF COMPUTER MANIPULATOR THAT ALLOWS TO ESTIMATE FUNCTIONAL CAPABILITIES OF THE USER AND TO PERFORM PRENOSOLOGICAL DIAGNOSTICS

CONTENT

FOREWORD (1)

Existing preventive measures and treatment modes were developed as applied to specific types of diseases. Thus, at present time one falls under attention of the public health service system only when he or she has specific disease suspected or diagnosed.

Recently accumulated experience in space and polar medicine, in labor and sport's physiology regarding estimation of state of health of practically healthy people, living and/or working at inadequate environmental conditions allows to put a question of development of a new area of knowledge lying at the boundary between physiology and pathology — prenosological diagnostics. Under 'prenosological diagnostics' one should mean estimation of **functional** state of organism and its adaptive capabilities during the time when clear signs of illness

do not yet exist. Prenosological diagnostics deals with identification of boundary states between norm and pathology that may be called *'prenosological states'*.

…most accessible and convenient for mass screening are such methods of cardiological diagnostics as electrocardiography, ballistocardiography, seismography, measurement of blood pressure, **pulse metering**. Wide use of the mentioned methods and broad fact base acquired resulted in development of theoretically important thesis of cardio-vascular system being an indicator of adaptive reactions of organism.

The new aspect of estimation of people's state of health is a development of pertaining to the prophylaxy approach to preventive health care, adopted in this country, as well as papers of World Health Organization regarding mass screening of the population.

Process of adaptation precedes development and появление appearance of the disease. Disease arises as a result of the lack of adaptive mechanisms, their exhaustion and failure.

1. DESCRIPTION OF COMPUTER MANIPULATOR THAT ALLOWS TO ESTIMATE FUNCTIONAL CAPABILITIES OF THE USER OR PERFORM PRENOSOLOGICAL DIAGNOSTICS

1. INTRODUCTION

Given device belongs to computer peripherals and presents a computer mouse which combines capabilities of computer manipulator and of the device for individual monitoring of functional capabilities of the user. It is analogous to the device for determination of psychophysiological state of the man (patent #2214166 of Russian agency for patents and trade marks, registered in the State registry of inventions of Russian Federation on October 20, 2003) by its capabilities regarding registration and analysis of heart rhythm.

The used method of determination of functional state of the organism is based on mathematical analysis of heart rhythm parameters in compliance with recommendations of European Society for Cardiology and North American Electrophysiological Society. Development of this method was conducted under the direction of Talalaev Anatoly Anatolyevich, doctor of medicine, professor, academician of Russian Academy of Natural Sciences.

This product represents yet another step on the route to estimation of basic functional capabilities of the man. Proposed variant uses combined integrated criterion of estimation, based on mathematical analysis of heart rate parameters and expressed using 'traffic-light' representation system; it is supplemented with

tabular and graphical representation of check-up results. The system will be gradually improved and detailed comments will be added to tabular and graphical representation of results, that concretely define functional state.

The concerned manipulator is unique; it allows each user of the device to perform estimation of his/her functional state in convenient time or, in case of necessity, to reveal disturbances of his/her **functional** capabilities.

Disturbances of functional capabilities can be caused by either natural or "artificial" means.

2. HEART RHYTHM VARIABILITY AND OTHER CYCLIC PROCESSES

Physicians' interest to exploration of heart activity has appeared long ago. It was in the ancient times when high self-descriptiveness of heart rate-based diagnostic criteria was appreciated. For example, pulse-based diagnostics was mastered in Ancient China and in Ancient Greece. It is said in the book 'Secret Principles of Medical Treatises' (of Ming Dynasty): 'If you want to know the exact illness, you should study pulse, and only then you will make no mistakes'.

Parametric description of electrocardiographical signal (ECG), based on cyclic character of heart activity has been widely distributed. Active development of methods for quantitative analysis of electrical heart activity began from the second part of the 20-th century. This is how the foundation of cybernetic cardiology was laid.

So-called 'heart rhythm variability analysis' (HRV analysis) is widely known and highly popular direction of secondary quantitative analysis of ECG at present time. Popularity of HRV analysis is to a considerable degree stipulated by the ease of extraction of series of RR-intervals from the ECG signal (so-called 'rhythmogram'), that reflect the activity of sinus node (SN — heart rhythm's pacing lead) with acceptable precision. Thorough study of statistical characteristics of rhythm organization by SN was the first stage of its quantitative analysis. Gradual accumulation of results of experimental and clinical researches as well as development of mathematical methods resulted in standardization of methods of HRV analysis.

All the mathematical estimations of HRV analysis can be divided into two groups. The first group is built up of statistical parameters of variation series of rhythmogram: mean value, standard deviation, mode, mode amplitude, range of deviation. The second group is built up of secondary parameters of HRV analysis: index of vegetative balance (IVBE), vegetative index of rhythm (VIR), tension index (TI), index of adequacy of regulation processes (IARP). Important role in the development of these methods belongs to R.M. Bayevsky, who developed method for estimation of degree of tension of regulatory mechanisms of various levels in

the process of adaptation of cardio-vascular system to accidentally or constantly affecting factors of the environment

Scientific and technological advance in the field of optoelectronic technologies gave means to conduct pulse metering and — to some degree — oxygen saturation of blood by measurement of transparency of human body's tissue. It is achieved by illumination of certain parts of boy (usually fingertip lobe) by the infra-red source and measurement of the part of the light that has passed through the tissue that is reach in blood vessels and capillary. At each heart beat pressure in blood vessels is changing cyclically, that leads to change of the tissue's transparency. Graphical registration of pulse wave, based on optical characteristics of the body tissues in the spectral range of $\lambda = 680$ nm is referred to as photoplethysmogram (PPG).

PPG signal, containing not only information on heart rhythm, but also other information peculiar to pulse wave, can also be used for HRV analysis. In order to obtain this information a hardware and software complex was developed, consisting of:

- optoelectrical sensor, containing IR-radiator and photoreceiver, installed inside a computer mouse;
- primary processing unit, installed inside a computer mouse, where selective amplification and analog-digital conversion is being performed;
- software, that operates on a PC and controlling pulse registration unit, allowing to not only conduct standard mathematical HRV-analysis, but to also analyze frequency and shape of the pulse wave;

Besides standard HRV analysis, use of PPG signal for pulse registration allows to estimate state of cardio-vascular system and regulation systems by the shape of pulse wave. Mathematical processing of high-quality PPG signal also allows studying other cyclic processes, as well as reactions to external factors.

3. HEART RATE VARIABILITY (HRV) FROM THE HEALTH SCIENCE'S POINT OF VIEW

HRV (or heart rate variability) is a method based on analysis of heart rhythm parameters that reflects general adaptive capabilities of the human organism at the given moment and at the given conditions.

It is the method for express estimation of the state of adaptive mechanisms of cardio-vascular system through the characteristics of the heart rhythm. Level of functional capabilities of cardio-vascular system and degree of tension of vegetative nervous system is being determined.

The native feature of HRV analysis is its high sensitivity to various internal and external influences. This method is based on measurement of time intervals between successive heart beats, making up series of cardio-intervals and following analysis of the numeric series using various mathematical methods. Thus, the ease of information acquisition is combined with the possibility to extract extensive and multifarious information on physiological functions' regulation and adaptive reactions of the whole organism from the data obtained.

At present, the most significant methods are:

- Statistical methods;
- Geometrical methods;
- Spectral methods of HRV analysis;

3.1. ESTIMATION OF RESULTS OF HEART RHYTHM VARIABILITY ANALYSIS

Complex estimation of heart rhythm variability provides diagnostic of functional state (but not diseases). Changes in organism state's balance in the form of activation of the corresponding branch of regulatory mechanism is being considered as a component of adaptive reaction in response to various stressive effects. One of the methods for estimation of such reactions is determination of state of functional capabilities (SFC). It is determined using special algorithm taking into account statistical parameters, histogram parameters and spectral parameters of series of cardio-intervals. SFC allows for differentiation of various degrees of tension of regulatory systems and for estimation of organism's adaptive capabilities.

During estimation of SFC three classes of functional states are conventionally introduced, which are represented in the form of 'traffic light' for clearness: green — meaning that it is all right and no special measures for prophylaxy and treatment are needed; yellow —meaning that sanitary and preventive measures are required; and finally red — meaning that diagnostics and then treatment of possible diseases is required.

Introduction of green, yellow and red 'health zones' allows to describe the man's functional state in respect to the risk of disease development. For each step of 'state ladder' corresponding 'diagnosis of functional state' is provided regarding degree of evidence of tension in regulatory systems. Besides, it is possible to assign one of the four classes to the inspected person according to the classification adopted in the prenosological diagnostics:

- Normal state, or state of satisfactory adaptation;
- Functional strain
- Overstrain, or state of unsatisfactory adaptation;
- Exhaustion of regulatory systems and adaptation failure

One should note that estimation of regulatory systems' state using SFC as a result of HRV analysis has no analogues. Results of complex HRV analysis are presented along with the HRV results and the results of spectral analysis with classification of inspected person's state according to SFC values. The conclusion construction algorithm also provides for formation of formalized prophylactic recommendations on the basis of prenosological diagnostics.

One more thing that is worth noting is the study of organism's state and its functional capabilities and the possibility of changing them using 'artificial' means.

Description of the method for detection of influence presented hereafter was developed based on the experimental measures, obtained using BioMouse device. Concrete examples of data analysis obtained using mentioned methods of HRV analysis are quoted in the following description.

3.2. ENERGY-INFORMATIVE INTRUSION (IMPACT)

Negative energy impact (including extrasensory) could be detected using the following criteria.

Criteria, obtained using PPG signal analysis:

3.2.1. The look of PPG signal can itself serve as the main indicator of the presence of impact. Numerous peaks and gaps could appear during inspection, the signal could contain bounces. As a rule, heart rate may slow down, but may also increase rapidly. Fragments of normal signal are intermitted with fragments of irregular shape, with enlarged amplitude, with prolonged cardio intervals (range of deviation could be enlarged up to two times with reference to normal one (less than 200 ms), fading sinus waves and jerky leaps can be observed in hear rhythm, i.e. there occurs failure of heart rhythm and of the cardiovascular system as a whole; blood pressure might be undetectable (being very low). One should avoid heart stress and should stay at rest. After energy impact to heart rhythm is discontinued adaptive mechanisms should restore rhythm to its normal state.

3.2.2. The spectrum of PPG signal differs significantly from the normal one.

Spectral analysis of normal PPG signal determines presence of the most part of the power in the range of the first harmonics that corresponds to heart rate frequency. Power of higher harmonics, up to the 7th, is usually evident, too. Harmonic's power is falling with rise of the frequency. When the person is inspected being in a good physical conditions and in favorable conditions, then there is a band in the spectrum heaving frequency of around five times less than base frequency of hear rate and of power commensurable with the 3rd harmonic of the heart rhythm.

Otherwise (when energy-informative impact is present), PPG signal's spectrum contains "noise" (that is, peaks non-coherent to the heart rhythm). Total power of PPG signal is reduced, with normal values being 0,8..2,8 relative units

heavy decrease of spectral power (to 0,0016-0,0018) can be observed (HRV_428.pds) with feebly marked structure (cardiac insufficiency). In case harmonic's power is rising with the rise of frequency, one mighe say that frequency band of external influence is identified. In the base of accompanying samples (HRV_2957.pds, HRV_2958.pds, HRV_2898.pds, HRV_475.pds) a peak can be observed of around 8 Hz, whose power is commensurable with one of the high-order harmonics of the PPG signal spectrum.

Following are the criteria obtained from results of the standard HRV analysis.

3.2.3. High frequencies prevail in the cardio-intervals spectrum, having power of 3000 to 10000 ms^2/Hz and higher with pronounced chaotic peak- (saw-) -like representation, often heaving symmetrical crown-like shape. Ultra low frequencies of the cardio-intervals series spectrum might reach zero. This spectral range of the cardio-intervals series spectrum is normally (for healthy person) commensurable with other spectrum ranges, or is higher. Physiological nature of this spectral range of the cardio-intervals series spectrum is not recognized by the modern medical science.

3.2.4. Histogram of cardio-intervals distribution has deviations from normal distribution: asymmetrical and multi-mode shape (i.e. has more than one peak).

3.2.5. The scattergram, depending on power of external influence, might look like "clowd" with increasing depression.

3.2.6. State tends to move towards low-right cell of the state matrix.

3.2.7. Statistics

- dispersion (with normal values being between 600 and 900 ms^2) exceeds 2 and 3 thousand, sometimes reaching 10 thousand;
- variation (with normal values being 3..5%) can grow by an order;
- tension index (with normal values less than 200..250) can reach 10 times;
- index of functional state can grow from 1 to decades and higher;
- price of psycho-physiological adaptation is reduced a few times and tends from thousands to hundreds;

4. CONCLUSION

Investigation and analysis of HRV is modern method for studying regulatory mechanisms of human's physiological functions. Heart being an indicator of

adaptive reactions of the whole organism ‘responds’ to various internal and external influences. In spite of non-specific nature of observed changes of HRV, they give important information of the state of vegetative nervous system and of other levels of neurohumoral regulation.

Indisputable advantage of short records of cardio activity is wider range of use of the method, simplicity of hardware and software required for investigation, possibility of quick receipt of the results. All this defines prospectivity of the most widest distribution of HRV analysis in applied physiology, prophylactic medicine and clinical practice.

REFERENCES

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