Methodical recommendations

KARDiVAR.TV

USE KARDiVAR SYSTEM FOR DETERMINATION OF THE STRESS LEVEL AND ESTIMATION OF THE BODY ADAPTABILITY

Standards of measurements and physiological interpretation

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These methodical recommendations are made on the basis the materials presented in following publications:

Baevsky R.M., Berseneva A.P.   Estimation of adaptable opportunities of an organism and risk of diseases development M,, Medicine, 1997, 236 p..

Baevsky R.M., Ivanov G.G., Chirejkin L.V., etc.   Analysis of Heart Rate Variability with use various electrocardiographical systems (Methodical recommendations).. The Bulletin of arrhythmology, 2001,24, pp..65-85

Grigoriev A.I., Baevsky R.M. Problem of health evaluation and conception of norm in space medicine. M.,Firm"Slovo", 2006, 192 pp.

Content

Foreword

The presented methodical recommendations are intended especially for users without special medical education as physiologists, psychologists, teachers, sport and fitness trainers, and others who would like to use the KARDiVAR system with the purpose of health preservation, reduction of a stress level and dynamic control at body functional states.

The KARDiVAR system is not a medical device, as its function is not intended to diagnostic of diseases, though, it can (with success) to be applied to control the efficiency of medical treatment. However, the results received with the help of the KARDiVAR system are treated from the point of view of improve of a health state and of a stress reduction. Certainly, device can be used by practical med. doctors and other medical professionals, considering received data with medical conclusion. In this case the special medical scientific literature is recommended (with medical training) where the appropriate questions are considered at level of modern medical knowledge.

The KARDiVAR system provides recording the electrocardiosignals (E.C.G.) from body of the person, registration, processing, and analysis of this signal and formation of the conclusions about body functional state, about stress level, about health. Moreover, the system can give the information to healthcare and preventive recommendations, to monitor changes of the functional states in various conditions of influence to organism, to estimate efficiency of some special methods for health support. All these peculiarities and opportunities of the KARDiVAR system have not any comparable system in the marketplace make its use as suitable instrument for everyone who is interesting in problems of health and stress.

In methodical recommendations the scientific-theoretical principles of the heart rate variability analysis (as a main method used in the KARDiVAR system) are presented; practical recommendations for interpretation of obtained results are given and particular examples of the analysis and estimation of data are considered. Plenty of scientific publications of HRV analysis with various theoretical approaches are devoted so in these recommendations only the most important references of them are presented. At the same time, particular scientific-theoretical approach is stated which proceeds from modern knowledge about stress, body functional state and estimation of a level of health. Just this approach is used in the KARDiVAR system as a base of knowledge with automatic interpretation of received results. However, as actual results of the HRV analysis (the numerical data) completely correspond to the standards, they can be used by other approaches.

Material of these methodical recommendations is intended on experts without special medical knowledge but with common biological knowledge and with interest in problems of psychophysiology, ecology, management of health. It means that for correct interpretation of obtained results from the KARDiVAR system, it is insufficient formally to study these methodological recommendations, only.

Systematic constant work (on development of the new approach to estimation of a level of health and new understanding of a role of stress in reduction of reserve body capabilities and in development of diseases) is required. Only the creative attitude to work with the KARDiVAR system can bring effective results in the decisions (important for each analyzed person) to keep good health and decrease the stress level.

Introduction

In Ancient China some thousands years ago, so called "Pulse diagnostic" was applied to estimate health level, to diagnostic, prognostic. By this method, the doctor for a long time (half to one hour or more) is discovering the patient's pulse on both hands closely "pondering" received information and then concluding the body infringements (what organs), determining exact their localization (heart, liver, lungs, kidneys etc). "Pulse diagnostic" also helps to choice the treatment and to estimate its efficacy. Hence, already from old times the research of pulse of a person served to the purposes of an estimation of a total body state as a whole, permitted to diagnose various diseases and states. The knowledge and experience of "pulse diagnostic" were transferred from generation to generation and till now this method is widely used in Chinese and Tibetan medicine.

First attempts to realize a method of "pulse diagnostic" on the basis of modern mathematical methods and computer technologies concern to break of 60's of the last century. For the first time it was used in space medicine, when the first flights of the person in space have begun. Then it was important to receive the maximum information of body functional state, using minimum of data volume transmitted from space. As it is known, in time of Yuri Gagarin flight only electrocardiogram and breath were transferred to the Earth. Therefore was resolved to try to extract maximum of information from records of pulse and that was possible on the basis of study of fluctuations of RR-intervals in electrocardiogram. Now, it corresponds to HRV analysis.

In first space flights was established that under extreme stress influence (during start, before landing) variability of RR-intervals much decreases, while during flight (some hours after beginning the orbital flight or on 2-3rd day of flight) the variability of RR-intervals is appreciably increased in comparison with earthly norm. Then conclusions about influence of autonomic nervous system on fluctuations of duration RR-intervals were made. Arising (under influence of stress factors) amplification of activity of sympathetic part (displacement of autonomic balance to sympathetic part) conducts to reduction of HRV to increase its stability. In condition of weightlessness, when (as result of energy expenditure reduction, influence of the blood replacement to the head and decrease of intrapulmonary pressure) parasympathetic tone increases and expresses amplification of RR-intervals variability is observed.

With knowledge of space medicine, the physiological and clinical research on study of RR-intervals variability have shown its dependence not only on autonomic balance, but also on condition of various levels of cardiovascular regulation and whole body physiological functions. At present time findings about extremely complex character of changes of RR-intervals fluctuation, about influence to them by different parts of hormonal regulation, energetic and metabolic gears, daily periodicity of functions, psycho-emotional factors etc. was generated. There was the necessity of development of the scientific concept, determining a role and a place of

HRV analysis in applied physiology, in clinical practice and in prophylactic medicine. Such concept was created within the framework of modern doctrine about health, developed, esp. in space medicine.

Peculiarity of the offered scientific concept is the fact, that it, not excepting other modern approaches of HRV analysis on first place, puts the principles of multiplanimetric, multilevel heart rhythm regulation. The HRV analysis is a method of an estimation of the states of gears of physiological body functions, particularly the common activity of regulatory gears, neuro-hormonal regulation of heart, and ratio between sympathetic and parasympathetic parts of autonomic nervous system. The method is based on recognition and measurement of temporary RR-intervals of the electrocardiogram, construction of dynamic range of cardio intervals and subsequent analysis of obtained numerical lines by various mathematical methods. The HRV analysis includes three stages:

1) measurement and presentation of dynamic lines of cardio intervals;

2) analyses of dynamic lines of cardio intervals;

3) estimation of results of the HRV analysis.

In the KARDiVAR system the first stage will be realized by means of the "KARDiVAR", second stage by means of the base "VARICARD-KARDi" software and third stage - by use of the programs " OUT DOC ", and "Dynacont".

One of the important features of the KARDiVAR system consists that at the first investigation phase registration simultaneously three standard and three unipolar leads of an electrocardiogram (I, II, III, aVR, aVL, aVF) is carried out. It is essential advantage of the KARDiVAR system in comparison with other systems as allows already at the first investigation phase visually to choose the most suitable for HRV analysis lead of electrocardiogram, and also operatively to determine presence of clinically significant changes of the electrocardiogram.

KARDiVAR system. Methodical recommendations.

1. Technique of heart rate variability (HRV) measurement

By use of the KARDiVAR system, it is expediently to distinguish two kinds of research:

1) Measurement in conditions of relative rest

2) Functional testing measurement

Each of these kinds of measurements is characterized by certain peculiarities of a technique.

1.1 Measurement in conditions of relative rest

ECG-signal of one leads is registered and its sharpest R-waves are recognized. The "KARDiVAR" permits to see the ECG-signal in any of six leads.

To obtain the standard results, it is necessary that the duration of record should last not less than 5 minutes. Then the appropriate option regulation time of automatic record (within current 5 minutes) is established. Occasionally, the record can be longer, if arrhythmia is present and/or if it is necessary to receive the information about slow waves of 3rd and higher orders (with periods of more than 1 minute).

HRV analysis measurement begins not earlier than 1.5-2 hours after meal. The measurement should be carried out in quiet room with constant temperature of 20-22 degrees of Celsius. The cancellation of physiotherapeutic procedures and drug therapy is recommended before measurement (if possible, according to measured person health condition), or these factors should be taken into mind in the estimation of results of measurement. Before measurement start, a period of adaptation to environmental conditions in duration of 5-10 minutes is necessary.

The ECG record can be carried out in sitting or supine position with quiet breathing. In any case the conditions during measurement should be quiet. The measurement of women is desirable to provide out of menstrual period, as the hormonal changes in body are reflected in cardiointervalogram. It is necessary to remove all negative influences resulting in emotional excitation, not to talk with analyzed person and (importantly) to exclude calls of other persons to medical staff and occurrence of other persons. During HRV measurement the patient should breathe quietly without deep inspirations, not to cough, not to swallow saliva.

1.2 Functional testing measurement

The functional testing is an important part of HRV analysis. The purposes of functional testing can be various; however, its result is an estimation of reaction of autonomic regulation gears and estimation of other standard influences. Dependence of various functional exercises on various parts of a control system can be tested or

investigated, and the body adaptation reaction as a whole. Sensitivity and reactivity of autonomous nervous system, its sympathetic and parasympathetic part and influence of this system to other testing factors can serve as a diagnostic and prognostic data. So, for example, by diabetic neuropathy the reaction of a parasympathetic link of regulation on test with fixed rate of breath (6 respirations in minute) is one of major diagnostic attributes. The list of functional tests of the most frequently used at research is below submitted:

Table 1

	The name of functional test	Maintenance of test and characteristic HRV changes	Purpose of testing	Average time (minutes)
1	Active orthostatic test	Transition from position supine to position upright is accompanied by vascular center activation with heart rate increase , growth of arterial pressure and increase of HRV low-frequency power spectrum	Research of sensitivity and activity of the centers of regulation of a vascular tone.	12
2	Test with the fixed rate of breath rhythm	At rate of breath of 6 resp/min is observed increase of low-frequency fluctuations power spectrum	Research of the regulation of vascular tone centers (and their functional reserve)	3
3	Valsalva test	At a delay of breath on an expiration with tension	Estimation of stability of vegetative balance	2

KARDiVAR system. Methodical recommendations.

	The name of functional test	Maintenance of test and characteristic HRV changes	Purpose of testing	Average time (minutes)
4	Isometric loading test	At deduction of handgrip during 1 minute at a level of 30 % from a maximum increase of heart rate and HRV reduction	Activation of sympathetic nervous system	2
5	Physical loading test	Various degree of increase and stabilization of heart rhythm on intensity of physical loading	Activation of sympathetic nervous system and the centers energetic-metabolic exchange regulation	3 -5
6	Pharmacologic-al tests	Are used for testing reaction of the regulatory mechanism various parts	Activation or braking of various parts	10 -60
7	Ashner test	At press on the eyeball is marked the heart rate decrease	Activation of a nervus vagus nuclei	1

The "VARICARD-KARDi" software allows automatic realization of functional tests. For this purpose, there is a special option - "scenario" – which makes possible to choose necessary tests as well as to create the script of new test. So, the optional script allows create new measurements actions, commands, indications, and duration of test. The actually running tests are possible to watch on the PC display screen. Specified parameters of HRV analysis could then to expand possibilities of measurement with goal to increase further quality of statement of the tests.

It is necessary to note the following peculiarities of the HRV analysis at functional tests:

- Background record will be carried out in conditions of rest (see above) during not less than 5 minutes. For comparison background record records in similar duration, received at different stages of functional test, should be used.

- The transients of functional tests should be analyzed by special methods (here these methods are not mentioned). Thus, it should be allocated from record visually or automatically with use of appropriate algorithms, taking into account nonstationarity and nonlinearity of the process. The analysis of transients can have independent diagnostic and prognostic importance.

- Estimation of changes of HRV parameters in functional tests follows to carry out the data received by other methods of research.

2. Scientific and theoretical basis of the HRV analysis

2.1 General principles

The regulatory systems of organism - it is the constantly working apparatus of tracking the conditions of all systems and bodies, their interactions and observance with goal to reach balance between body and environment. The regulatory systems activity depends on conditions in which the body is and on its functional state. The science about management in living organisms (biology cybernetics) considers a complex of regulatory gears as uniform, interconnected multiplanimetric, multilevel, hierarchically constructed system. In this system there is the strict distribution of "duties" between its separate levels, each of which carries out specific problem. For decisions to solve any of certain specific problem-particular system of interactions between various regulatory gears is organized, which provides the optimal mode of organism operations in concrete conditions. Thus, as reply to changes of external or internal conditions in body, there is the specific functional system, including certain regulatory gears and certain executive bodies. The theory of processes of management in living systems was first developed by Russian researcher P.K. Anokhin in his theory of functional systems (1962).

It is suitable to take into account the research of V.V. Parin and R.M. Baevsky (1966) with their development of knowledge of the processes of management in living organisms on principles of hierarchical interaction of levels of regulatory systems management. Two from these hierarchically interconnected regulatory systems cooperate between themselves in such a manner that activity of higher level of management depends on functional condition and functional reserves of lower level of management. It is possible to distinguish three degrees of activity of regulatory systems:

1) performance of functions of the CONTROL,

2) realization of REGULATORY FUNCTIONS,

3) fulfillment of functions of MANAGEMENT.

In usual conditions, when the adjustable (controlling) system of a lower level works in normal mode, without additional loads, the higher level of the regulatory gear executes only control functions, i.e. perceives the information on condition of adjustable system and does not interfere with its work. If additional load arises, if the adjustable system needs to increase the charge of energy (functional reserves) to provide the necessary functions, the regulatory gear is passed on other mode of operations - higher levels periodically "interfere" with process of management and correct it: helping the adjustable system to carry out functions. It is possible to speak about transition of the regulatory gear to realization of the regulation functions. In this case (through appropriate nervous and humoral channels) the adjustable system is signaling to the system of management, ensuring mobilization of necessary additional functional reserves. If the own reserves of adjustable system appear insufficient for

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achievement of necessary effect, regulatory gears pass to control mode. Here its activity much grows, as for process of management it is necessary to connect other, higher regulatory levels providing mobilization of functional reserves. Accordingly the tension of regulatory gears (their activity) grows. Thus, by the degree of a tension of regulatory gears, it is possible to judge functional reserves of cardiovascular system and body adaptability possibilities.

Degree of regulatory systems tension - this integrated body answer to whole complex of the factors influencing on, irrespective what they are connected with. By conditions of influence of a complex of the factors of extreme character, then the general adaptive syndrome arises (H. Selye, 1960), which represents the universal body answer on stress impact of any nature and is displayed as the same syndrome of the same type in kind of mobilization of body functional reserves. Healthy organism, (having sufficient stock of functional opportunities), answers on stress influence with usual, normal, (so-called working) tension of regulatory systems. So, for example, if to us is to step up the stairs, naturally, energetic mobilization of additional resources grow and are necessary. However, for somebody such mobilization is not accompanied by a significant tension of regulatory systems and the pulse arise (for example on 5-th floor) totally with 3-5 more pulses, the cardiovascular homeostasis does not practically change. For other people this load represents the expressed tension of regulatory systems with arise of more than 15-20 pulses: what indicated presence of infringement homeostasis.

Even in conditions of rest the tension of regulatory systems can be high, if the person has not sufficient functional reserves. It is expressed, particularly, by high stability of heart rhythm, characteristic for raised sympathetic tone. This part of the regulatory gear, responsible for emergency mobilization of energetic and metabolic resources by any kinds of stress, is activated through nervous and humoral channels. It is a component of hypothalamic-pituitary-adrenal system, realizing the body answers on the stress influence. The important role belongs to central nervous system, which coordinates and directs all processes in body.

Heart is the rather sensitive indicator of all events occurring in organism. Rhythm (but also the value of its reduction adjustable through sympathetic and parasympathetic parts of autonomic nervous system) very sensitively reacts on any stressful influence. To judge degree of regulatory systems tension is possible with help of many methods: by study of the adrenalin or noradrenalin hormone contents in blood, on changes of a diameter of a pupil, on sweat volume etc. But the most simple and accessible method, and continuous dynamic control enabling information - is HRV analysis. Changes of heart rhythm - it is universal operative reaction of whole body as reply to any influence of the factors of internal information and external environment. However average frequency of heart rate as traditional measuring method reflects only final effect of numerous regulatory influences to cardiovascular apparatus, characterizes peculiarities (usually) of the homeostatic gear. One of important problems of this gear is to supply balance between sympathetic and parasympathetic parts of autonomous nervous system (autonomic homeostasis). To

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the same frequency of heart rate can correspond with various combinations of activity of the parts of system managing autonomic homeostasis. Besides, the heart rhythm reflects influence of higher levels of regulation, too. It gives the basis to consider sinus node as the sensitive indicator of adaptive body reactions during its adaptation to conditions of an environment.

Each moment of life, the organism tests the continuous influence of the factors rejecting imbalance in one or other side. Simultaneously preventing or compensating already arising shifts, then come into effect the regulatory gears. The work of regulatory gears is directed by the fact: to support balance between systems inside organism and between organism and environment. The doctrine about balance inside organism (the doctrine about homeostasis) was developed by well known French scientist Claude Bernard (1896) and was developed further by American scientist Walter Cannon (1932). Alongside, the theory of adaptation doctrine about homeostasis was worked out by Gorizontov (1976) as one of basic parts of the modern doctrine about health. Knowledge about health as the adaptive process, directed to optimization of interaction organism with an environment and on maintenance of homeostasis of main systems inside organism was for the first time considered in work by known Russian pathophysiologist I.V. Davydovsky (1965). At the present stage, the development of a scientific presentation have received further development in space medicine (A.I. Grigoriev, R.M. Baevsky, 2006) and are realized in kind of specific automated systems for estimation of a level of health, in which conducting role plays methods of HRV analysis.

2.2 The gears of heart rhythm regulation

The main information of regulatory system state (heart rhythm analysis) is made by "functions of disorder" of cardio intervals duration. On fig.1 the ECG record with cardiointervalogram, formed by results of automatic measurement of RR-intervals duration, is submitted. Sinus arrhythmia reflects complex processes of interaction of various contours of heart rate regulation.
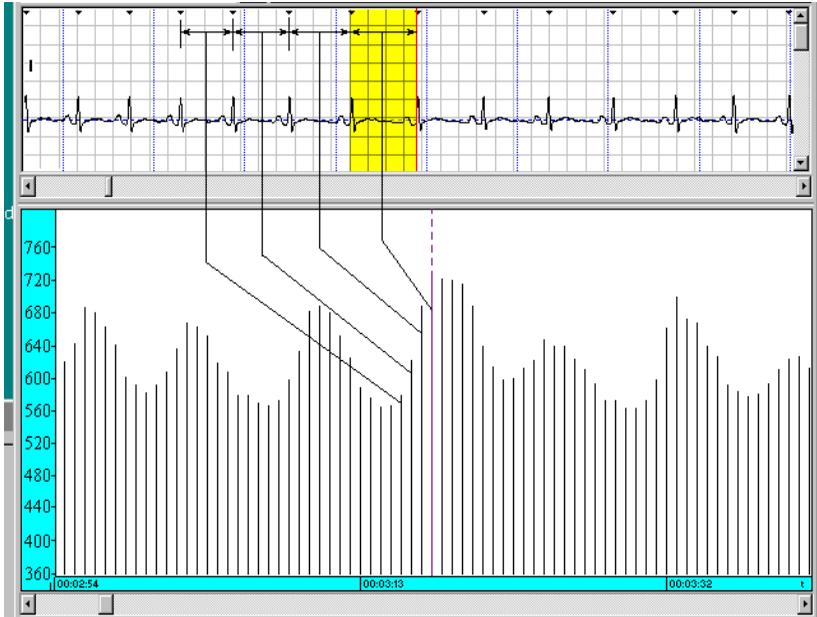
Fig. 1. Construction of cardiointervalogram according to change the durations of RR-intervals of the electrocardiogram

On fig. 2 cardiointervalogram samples (diagram of cardio intervals duration changes), appropriate to (described above) three degrees of activity of regulatory systems are submitted. On this curve, there are three types of fluctuations: the shortest – respiratory, longer – slow waves of 1st order and the longest – slow waves of 2nd order.
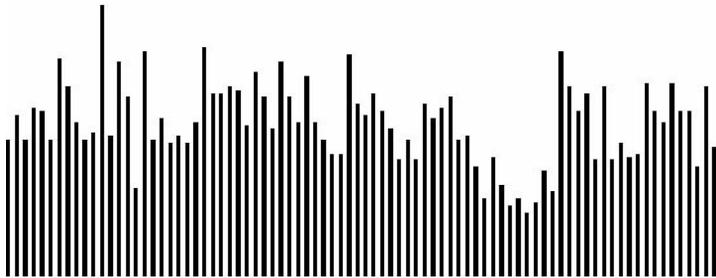
Fig. 2. A sample of cardiointervalogram with various types of oscillatory processes (respiratory waves, slow waves, very slow fluctuations)

At realization of functions of the control, when regulatory gears work independently and completely manage the problems, then (in cardiointervalogram) the respiratory fluctuation prevails (sinus respiratory arrhythmia). These waves reflect normal active answer of sinus node on reflectoric reactions connected to changes of blood filling and intrapulmonary pressure by respiration. If (for maintenance homeostasis) the additional activation of cardiovascular sub cortical nervous center is necessary, it is possible to see (on cardiointervalogram) alongside with respiratory waves, also, slower waves of 1st and 2nd order. In case the reserve capabilities of regulatory gears are highly reduced then the respiratory and slow fluctuations of heart rhythm are suppressed even more by slow wave activity of the highest autonomic centers. Thus, even the simple visual analysis of cardiointervalogram, can say much about regulatory systems activities, and, as a minimum, permits to judge degree of activity of regulatory systems, that has important value for determination of a stress level and estimation of health.

The deeper scientific analysis considered above cardiointervalogram can be made on basis of two-planimetric model heart rate regulation (Baevsky, 1968). It is based on cybernetic approach, at which the control system of sinus node is represented in kind of two interconnected contours: central and independent, managing and controlled with direct and feedback channels. If to present a control system of heart rhythm in sense of two contours, as shown in fig. 3, on the basis of data of presence of respiration and non-respiratory fluctuations of heart rhythm - the following situations can be considered: sinus node, nerve vagus and their nuclei in the brain are providing bodies of lowest, independent control contour of regulation. The indicator of activity of this contour is respiratory sinus arrhythmia.
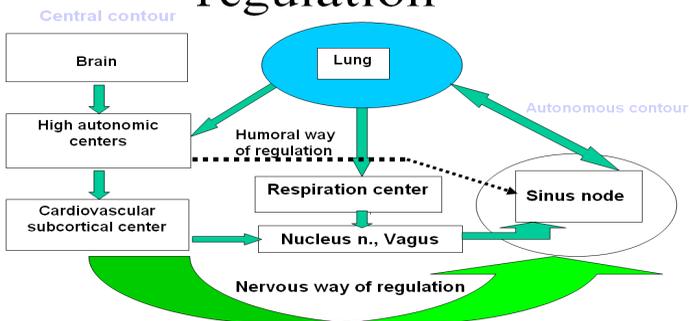

Fig. 3. Two-planimetric model of management of herat rhythmt (see the text)

Thus, the respiration system can be considered as an element of a feedback in independent contour of heart rate regulation. Managing (high, central) regulating contour is characterized by various slow oscillations of heart rhythm. Its indicator is non-respiratory sinus arrhythmia. The direct connection between managing and controlled contours is carried out through nervous (basically sympathetic) and humoral channels. A feedback also has a nervous and humoral way, but the most important role plays afferent impulses from baroreceptors of heart and vessels, with chemoreceptors and with extensive receptor zones of other organs and tissues.

Independent (controlling) contour - in conditions of rest - works in independent mode, which is characterized by expressed respiratory arrhythmia. The respiratory waves amplify during time of sleep or at narcosis, when central influence to independent contour of regulation is decreased. Various loads on body require process of management of the central contour of regulation conduct to reduce the respiratory component (sinus arrhythmia) and to amplification of non-respiratory component. The general principle consists of: the higher levels of management are braking the activities of lower levels. The amplitude of respiration waves of heart rhythm is reduced accordingly to activity of the central (managing) contour involved in regulatory process. As an independent contour - this in essence the contour of parasympathetic regulation- the centralization of management means displacement of autonomous homeostasis to the side of prevalence of sympathetic nervous regulation. Therefore easing of respiratory arrhythmia is connected usually with amplification of the sympathetic tone.

The manager, or the central contour of heart rhythm management, represents all "floors" of management by physiological functions from sub cortical centers of a brain up to hypothalamic-pituitary-suprarenal level of autonomous regulation and level of central nervous system influence on autonomic function. The central contour can (schematically) be presented as consisting from three levels. To these levels - they correspond not so much with anatomical or morphological structures of a brain: how many certain functional systems or levels of management are formed during management of physiological functions of body:

- **Level C** - a level of maintenance the intrasystemic homeostasis: particularly the cardio respiratory system. Here main role play sub cortical nervous centers, esp. vasomotoric center as a part of sub cortical cardiovascular center: rendering stimulating and inhibitory action on heart through fibers of sympathetic nerves;

- **Level B** - a level executing balance of various body systems among themselves and maintenance intersystemic homeostasis Main participation of function of this level of management provide higher autonomic centers (including hypothalamic-pituitary-suprarenal system), ensuring hormonal and autonomic homeostasis;

- **Level A** - a level of organization of interaction of body with external environment (the adaptive activity of organism). This level concerns central nervous

system, switching on brain gears of regulation, coordinating functional activity of all systems of organism according to influences of the factors of external environment.

At optimal regulation state - the management occurs with minimal participation of highest levels of management, with minimal centralization of management. At no optimal management - activation of higher and higher levels of management is necessary. It is displayed in kind of reducing respiratory arrhythmia and amplification of the non-respiratory arrhythmia and so the occurrence of slow waves of the higher and higher orders. As higher levels of management are activated, so longer the periods of appropriate slow waves of heart rhythm are present (Baevsky, 1978).

Sinus respiratory arrhythmia was discovered last century (Ludwig, 1847). The uniform opinion on origin of respiratory arrhythmia is not fully explained, though the majority of the researchers consider the respiratory arrhythmia as the conclusive fact of influence of respiration on heart rhythm and active participation (in this process) of vagal nerves nuclei, braking the excitation transferred to sinus node through appropriate nervous terminations, causing shortings of the cardio intervals duration on inspiration and lengthening on expiration. In opinion of Sayers (1973), the breath influence on cardio intervals duration is intermediated through intrapleural pressure and activity of baroreceptors.

Non-respiratory sinus arrhythmia represents fluctuations of heart rhythm with periods lasting 7-8 seconds (frequency below 0, 15 Hz.). Slow (non-respiratory) fluctuations of heart rhythm correlate with similar waves of blood pressure and plethysmogram. Distinguish slow waves 1st, 2nd, and higher orders. An existing level of knowledge does not permit rather precisely to specify a source of an origin of each of kinds of slow waves. M. Sayers (1973) considers that the slow waves of heart rhythm of the 1st order (with period from 7 to 20 seconds) are connected to activity of system of blood pressure regulation, and waves of the 2nd order (with period from 20 to 70 seconds) - with system of thermoregulation. It is supposed, that fluctuations with periods lasting longer than 20 seconds are determined by the mechanical characteristics of vessels smooth muscles, nonlinearity of this mechanical system and opportune interference of slow fluctuations with respiration is emphasized, especially at deep depth of breath, particularly, by intellectual and physical loads.

It is shown, that by sportsmen with low level of serviceability as well as by untrained persons (in rest) the slow waves oscillations are very often observed (Vorobiev, 1978). V.Kapejinas and D.Zemajtite (1983) have noted cardio intervals changes of heart rhythm - transition from large amplitude waves to prevalence of slow waves - by long lasting physical load and by low trained sportsmen.

Short records (duration up to 5 minutes) permit to reveal only waves with periods not longer than 1,5 -2 minutes. However (with more extended registration), the heart rhythm fluctuations with periods in minutes and tens of minutes are observed: what speaks about presence of interrelation between heart rhythm and various structures of a control system: which are responsible for generation of

appropriate fluctuations. So, for example, A. Navakatikjan with co-authors (1979) has revealed connection of slow waves of heart rhythm with fluctuations of the blood contents of catecholamines and corticosteroids. Connection between slow waves of heart rhythm and activity of system pituitary-suprarenal glands is noted (Karpenko, 1977; Navakatikjan, Kryjanovskaja, 1979).

The structure of heart rhythm includes not only oscillatory components in kind of respiratory and non-respiratory waves but also acyclic processes (so-called fractal components). An origin of these components of heart rhythm is connected to multilevel and nonlinear character of regulation processes of heart rhythm with presence of transients. Recently to study of nonlinear dynamics in fluctuations of heart rhythm is devoted to large numbers of the publications.

One of conducting experts in this area is the American scientist A. Goldberger (1990, 1998). To his name the development with reference to HRV analysis of the theory of chaos and representations about fractals, repeating structures reflecting formation in various scales is connected. Fractal structure – that is one of the laws of nonlinear chaos. However, now these approaches to HRV analysis have only research (experimental) character and have not, actually, practical value.

Thus, heart rhythm, strictly speaking, is not the stationary casual process with ergodic properties: that means repeatability of its statistical characteristics on any arbitrary parts. HRV reflects a complex picture of diverse managing influences on cardiovascular system with interference of periodic components of different frequency and amplitude and with nonlinear character of interrelations of different levels of management. Follows to mean that by use of short records (up to 5 minutes) we are artificially limiting number of investigated regulatory gears, decrease a range of researched managing influence on heart rhythm. Though, it simplifies the analysis of data but does not simplify interpretation of results, as the changes of heart rhythm reflect the whole spectrum of interaction of regulatory systems at different stages of body adaptation to conditions of an environment. Therefore by estimation of results of the analysis of "short" records it is expedient to learn the stated knowledge of two-planimetric model. In spite of the fact that this knowledge is based on simplified model of heart rhythm regulation, it is suitable to take into account multilevel hierarchical character of management in living systems what permits to judge degree of activation of various levels of a control system.

2.3 Main methods of the HRV analysis

The methods of study HRV can conditionally be divided into three groups (Baevsky, Kirillov, Kletskin, 1984):

1) methods of a statistical estimation of a numerical line of cardio intervals;

2) methods of an estimation of connection between cardio intervals;

3) methods of revealing the latent periodicity of a dynamic line of cardio intervals.

Agrees to the recently published standards of European Cardiological Society and North American Society of Electrophysiology (Heart rate variability, 1996), two groups of methods are mentioned: temporary (Time Domain Methods) and frequency (Frequency Domain Methods). Temporary methods concern the statistical analysis and geometrical methods, the frequent method- spectral analysis. The broadest applications in Russia (USSR) within last 30 years have received following five methods of the HRV analysis:

1) Statistical analysis,

2) Variational pulsometry, which - corresponds to geometrical methods,

3) Autocorrelation analysis,

4) Correlation rhythmography;

5) Spectral analysis.

These methods are the mostly widespread and large experience of their application in various areas of clinical medicine and applied physiology is now saved.
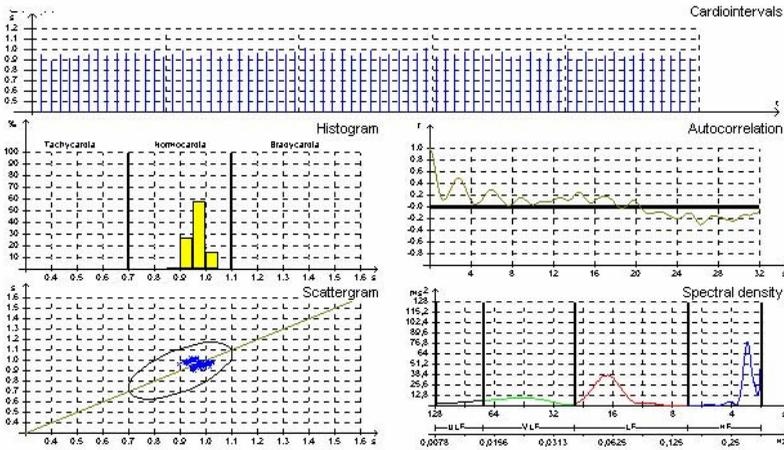

Fig. 4. Samples of the diagrams formed by "VARICARD-KARDi" software by results of the analysis of cardiointervaligram (a). b - the histogram (variationalpulsogram),c - autocorrelation function, d - scattergram (correlation rhythmogram), e - spectral function.

The KARDiVAR system will realize all above named methods of the analysis. On fig.4 a sample of listing of the diagrams, formed by the program on cardiointervalogram in duration 5 minutes measurement is submitted. All above-stated methods of the analysis are here submitted (except statistical, which are realized in table form). On each of diagrams a number of informative parameters (see below) are defined. Moreover, the "VARICARD-KARDi" software provides the complexity of HRV analysis, not having any analogues in world practice. There are the special programs. So, by means of the program "OUT DOC" the certain set of parameters is formed as parameter of activity of regulatory systems – IARS (Index of Activity of Regulatory Systems), with formulated conclusions about degree of regulatory systems tension. On the basis of this conclusion, the preventive recommendations could be given to the measured person (see further).

Statistical characteristics

The statistical characteristics of a dynamic number of cardio intervals include: Heart Rate (HR), Average Square Deviation (Standard Deviation Normal to Normal-SDNN), Coefficient of Variation (CV). Except these "classical" statistical parameters there are calculated another four different parameters: SDSD, RMSSD, NN50, pNN50. A new dynamic line of numerical values of differences between each previous and subsequent cardio intervals is for this purpose formed. Receiving line of values differences, it is possible to distinguish constant making of a dynamic line and all slow fluctuations. There is only the fast component of variability (only respiratory fluctuations of cardio intervals). Therefore, all different parameters in this or that measuring reflect activity of parasympathetic part of autonomous nervous system, i.e. concern to independent contour of management .SDSD - the average square-law deviation of dynamic line of different values, RMSSD - the square root of sum of squares of different values (Root Mean of Sum Successive Deviations); NN50 - the number of different value above 50 milliseconds, pNN50 - the same parameter, but in % from common number of analyzed intervals.

Variational pulsometry

The essence of variational pulsometry consists of study of the law of distribution of cardio intervals as of casual sizes. A curve of distribution - histogram is for this purpose is constructed. The method "variational pulsometry" corresponds to geometrical methods of European-American standards. On fig. 4b a typical curve of distribution with main mathematical parameters designated on is submitted: Mo (Mode), AMo (Amplitude of a Mode), MxDMn (variation scope = Difference between Maximal and Minimal value). Medical and physiological interpretation of the specified parameters is below given in brief.

Mode - the most value frequently observed in the dynamic line of cardio intervals. In physiological sense - this is the most probable level of cardiovascular functioning. By normal distribution and high stationarity of researched process, Mo poorly differs from M (mathematical expectation), i.e. from average value. The

distinction between Mo and M means worsened stationarity (of researched process) and shows (most probably) presence of transients (more significantly).

The amplitude of a mode (AMo) is number of cardio intervals appropriate to Mo value, in %. This parameter characterizes similarity of values of cardio intervals and reflects stabilizing effect of heart rhythm management, which is caused, basically, by degree of sympathetic system activation.

The variation scope (MxDMn) reflects a degree of variability of cardio intervals values in researched dynamic line. It is calculated as difference of maximum and minimum values of cardio intervals and consequently at arrhythmias or artifact errors, what can be allowed, if the dynamic line of cardio intervals was not subject to preliminary editing. At calculation of MxDMn, usually, the extreme values of cardio intervals are rejected, if they make less than 3 percents from full amount of analyzed sample. Physiological sense of MxDMn is usually connected to activity of parasympathetic system. However, in number of cases, the significant amplitude of slow waves making value MxDMn (by long lasting records) can reflect a condition of activity of sub cortical nervous centers.

On data of variational pulsometry the number of derivative parameters is calculated, among which index of regulatory systems tension (Stress Index - SI) is the most common, which reflects a degree of centralization of heart rhythm management and characterizes, basically, activity of the sympathetic part of autonomic nervous system. It is calculated by following formula:

$$SI = AMo / 2Mo * MxDMn$$

This parameter has received wide application in sport medicine, physiology of labor, space research, and in clinical practice, too. The value of SI is normally in limits from 50 up to 150 conditional units (c.u.). At emotional load and physical work by healthy people, SI value is increased up to 300 -500 c.u., and by people of the senior age (with reduced reserves) such values are observed even in rest. At presence of coronary heart disease, the SI reaches 600-700 c.u., and in pre-infarction state even 900-1100 c.u.

Correlation rhythmography (CRG)

This method of graphic representation of a dynamic line of cardio intervals in kind of "cloud" (scatter gram) by construction of a number of points in rectangular system of coordinates. Thus, on axis of ordinates is postponed - each current R-R an interval, and on axis abscissa - each subsequent R-R an interval. On fig. 4c a typical sample CRG is submitted. Important advantage of this method is the fact that it permits effectively to distinguish and to analyze the cardiac arrhythmias. Numerical parameters CRG are in axes of ellipsis ("a" and "b"), formed by a cloud of points and their relation a/b. The physiological sense of the relation a/b is close to SI - it characterizes a degree of centralization of heart rhythm management, activity of sympathetic part of autonomous nervous system.

Autocorrelation analysis

Calculation and the construction of autocorrelation function of a dynamic line of cardio intervals (see fig 4b) is directed on study of internal structure of this line as a causal process. The autocorrelation function represents the diagram of dynamics of coefficient of correlation, received at consecutive displacement of an analyzed dynamic line on one number in relation to own line. After first shift of one value, when coefficient of correlation is less than one, than the respiratory waves are more expressed. When in researched sample dominate slow waves components, the coefficient of correlation after first shift will be only a little bit shorter than one. The subsequent shifts conduct to gradual reduction of coefficient of correlation down to occurrence of negative coefficient of correlation. The physiological sense of use of the autocorrelation analysis consists of estimation of a degree of influence of the central contour of management on independent contour. If this influence is increased, then closer to one the value of coefficient of correlation and first shift is close to one. Autocorrelogram permits to judge latent periodicity of heart rhythm. However, such analysis has only qualitative character.

Spectral analysis

For exact quantitative estimation of periodic processes in heart rhythm serves spectral analysis. The physiological sense of the spectral analysis is in possibility to estimate activities of different (separate) levels of regulatory systems. On fig.4d a sample of a typical HRV spectrum for sample of volume in 5 minutes is submitted. Here on axis abscissa values of periods of fluctuations in seconds are postponed, on axis ordinates capacities of appropriate spectral making in square milliseconds (ms2) are postponed. At spectral analysis of so-called short dynamic lines of cardio intervals (duration up to 5 minutes) it is possible to measure only capacities of respiratory waves and slow waves of 1st and 2nd order. As to slow waves of 2nd order, under European-American standards their range is determined in limits from 0,04 up to 0,003 Hz (or from 25 up to 300 s). However, the numerous literary data testify that in specified range fluctuations of a various nature are observed: connection with processes of thermoregulation (Sayers, 1973, 1981), by oxy-recovery processes, with metabolic processes, in particular with glycolysis (Boiteux et al, 1977). Thus, in range up to 300 s, it is possible to allocate waves not only 2nd, but also 3rd – 4th of the orders. Therefore, in the KARDiVAR system slow waves of 2nd order are calculated in interval from 25 to 66 seconds (0,04-0,015 Hz). As a rule, these waves are associated with activity of suprasegmental part of a brain (Haspekova, 1994), with activity of sympathetic sub cortical centers. As to slow waves 3rd – 4th of the orders, their main capacity is reflected, as a rule, in the 1st harmonic of spectrum. The names of spectral components, according to European-American standards are accepted. Their names reflect frequent structure: high-frequency fluctuations (High Frequency -HF), low-frequency fluctuations (Low Frequency -LF), very low-frequency fluctuations - (Very Low Frequency -VLF), and ultra-low-frequency fluctuations (Ultra Low Frequency - ULF). The frequent ranges of the specified components are submitted in table:

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Components of a spectrum	Frequency range in Hz	Period in seconds
HF	0,4 – 0,15	2,5 – 7
LF	0,15 – 0,04	7 – 25
VLF	0,04 – 0,015	25 – 66
ULF	Less than 0,015	More than 66

At spectral analysis it is usual for each of components calculate absolute total power in own range, average power in every range, value of a maximum harmonic and relative value in percentage of total power in all ranges (Total Power-TP). It is necessary to note distinctions in an estimation of spectral HRV components between the Russian and European-American recommendations. In the last, the ratio HF/ LF is considered basically. Parameter HF/LF is interpreted as a parameter of vegetative balance

On data of the spectral analysis of HRV, the following parameters are calculated: Index of Centralization -IC (Index of centralization, IC = (VLF +LF / HF) and index of activation of sub cortical nervous centers ISCA (Index of Subcortical Centers Activity, ISCA = VLF / LF). IC reflects a degree of prevalence of non-respiratory sinus arrhythmia over the respiratory one. Actually - this is quantitative characteristic of ratio between central and independent contours of heart rhythm regulation. The second index ISCA characterizes activity of cardiovascular subcortical nervous center in relation to higher levels of management. The increased activity of sub cortical nervous centers is played by growth of ISCA. With help of this index processes the brain inhibiting effect can be supervised. Moreover, according to European-American standards the relation LF/HF is calculated. At calculation of relative values of separate spectral components of total spectral power (TP) into which enter HF, LF and VLF. is accepted to 100%. Value ULF is examined separately as this parameter reflects basically activity supersegmental levels of regulation and by present time still more not enough.

3. Estimation of the HRV analysis results

For users of the KARDiVAR system conducting value, there is the interpretation of received results. Here follows three directions in estimation received by analysis of HRV:

1) Direct interpretation of obtained data according to scientific and theoretical presentations about connection of observable changes with different parts of autonomous nervous system, with state of vascular center and high autonomous centers, with stress level etc. Here each of calculated parameters is considered independently and then the common conclusion is formed.

2) Estimation of functional state of organism and degree of a tension of regulatory systems on the basis of analysis of a complex of parameters. At such approach there is taken into account not only value of each parameter and connections between them, and the conclusion is formed in clear for non-specialist terms of an estimation of health and stress level.

3) Special methods of the estimation (connected with functional testing and management of health). There is special software for comparison of results of research at different stages of functional tests or at different stages of treatment.

3.1 Direct (clinical and physiological) estimation of results

In User's Manual the complete list of HRV parameters with brief physiological interpretation of each parameter (calculated by software of the KARDiVAR system) is given. In practice, there is used only limited number of parameters, ensuring the sufficient information about functional state of organism. The other parameters are estimated only occasionally: - when it is necessary to specify a state of a specified part of regulatory system.

The list comprises main (the most frequently used) parameters of HRV and their direct, clinical and physiological interpretation, based on traditional knowledge of autonomic regulation of heart rhythm, participation in it of sympathetic or parasympathetic parts, of sub cortical cardiovascular center and higher levels of regulation, is submitted below:

1. **STANDARD DEVIATION** (SD) the simplest and most popular result of the HRV analysis   calculating an average square-law deviation of cardio intervals duration. It is a well-known standard statistical procedure. The values of SD are expressed in milliseconds (ms). The normal values of SD are within the limits of 40-80 ms. However; these values have aging-sexual peculiarities, which should be taken into account at estimation of results of measurement. SD is an extremely sensitive parameter of a condition of regulatory gears. However growth or reduction SD can be connected to independent regulation contour and with central. As a rule, growth SD specifies amplification of independent regulation, i.e. influence of breathing on heart rhythm, what is often observed in sleep. Reduction of SD is usually connected to

amplification of sympathetic regulation, which suppresses activity of an independent contour. Sharp reduction of SD is connected to significant tension of regulatory systems, when the process of regulation includes highest levels of management and it conducts the almost complete suppression of activity of an independent contour. The information, by physiological sense, similar to SD, can be received on parameter of total power of a spectrum - TP (Total Power). This parameter differs from SD; it characterizes only periodic processes in heart rhythm and does not contain so-called fractal part of processes, i.e. nonlinear and acyclic processes.

2. **RMSSD** - parameter of parasympathetic activity. This parameter is calculated on dynamic line of differences of values of consecutive pairs of cardio intervals and does not contain slow waves of heart rhythm. It is the pure state that reflects activity of an independent contour of regulation. As higher the value of RMSSD is so more active part of parasympathetic regulation. Norm of value of this parameter is within the limits of 20-50 ms. The similar information can be received on parameter pNN50, which is more sensitive at research of the persons with expressed sinus arrhythmia or with rhythm infringements.

3. **INDEX OF REGULATORY SYSTEM TENSION** (Stress Index) characterizes activity of sympathetic regulation gears, the state of a central contour regulation. This parameter is calculated on the basis of analysis of the diagram of cardio intervals distribution - histogram. The activation of a central contour of regulation (i.e. amplification of sympathetic regulation during exercises) is displayed by rhythm stabilization and reduction of disorders of cardio intervals durations, increase of numbers of the same type of duration (uniformity) of intervals (growth of AMo). The analysis of the histogram form or the method of variational pulsometry evidently demonstrates this process in kind of narrowing histogram with growth of amplitude of a mode. Quantitatively, this could be expressed as the relation of height of histogram to its width. This parameter has received the name of an index of regulatory systems tension (Stress Index SI). On fig.5 are submitted two histograms according to prevalence of activity of sympathetic and of parasympathetic parts of autonomous nervous system. Histograms can be submitted by different ways and can be differently analyzed. Calculation SI- it is only one of approaches to interpretation and estimation of the histogram (variational pulsogram). In norm SI varies within the limits of 80-150 c.u. This parameter is very sensitive to amplification of sympathetic tone. Small load (physical or emotional) increase SI 1,5-2 times. At significant loads it increases 5-10 times. By illness with constant tension of regulatory systems, SI in rest can be equal to 400-600 c.u. By coronary heart disease and with myocardial infarction, SI in rest reaches 1000-1500 c.u.
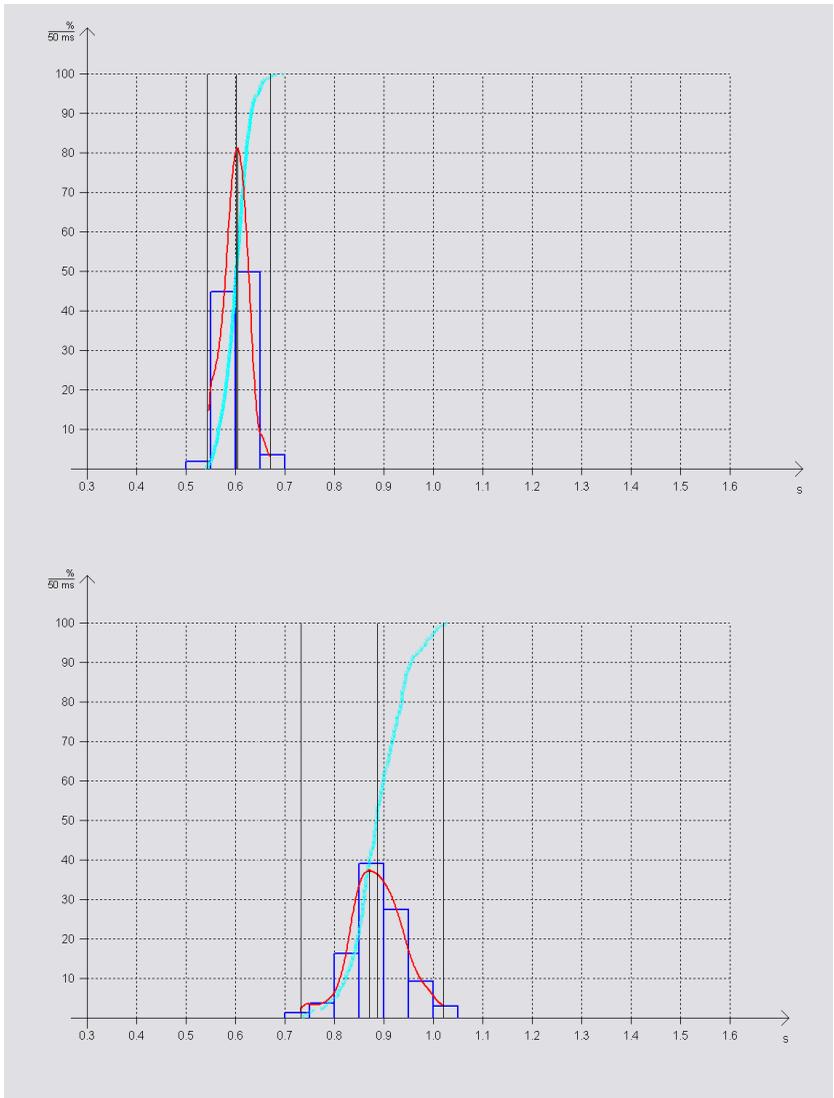
Fig. 5. Variational pulsogram normotonic (below) and symphatotonics (above) types

4. **HIGH-FREQUENCY POWER OF HRV SPECTRUM** (Respiratory Waves). The activity of parasympathetic (vagal) part of autonomic nervous system, as one of components of autonomic balance, can be estimated by degree of suppression of activity of an independent contour of regulation, which is represented by spectrum in absolute and percentage kind. Usually respiration waves (HF-high frequency) make 15-25 % of total power of a HRV spectrum. Decrease of this part up to 8-10 % specifies displacement of autonomic balance to sympathetic prevalence.

If the value of HF falls below than 2-3 % it is possible to speak about sharp sympathetic prevalence. In this case, the parameters RMSSD and pNN50 also decrease. On the contrary, the increase part of respiration waves in HRV spectrum testifies the amplification of parasympathetic tone. The similar case is demonstrated in the diagram of a spectrum on fig. 6.
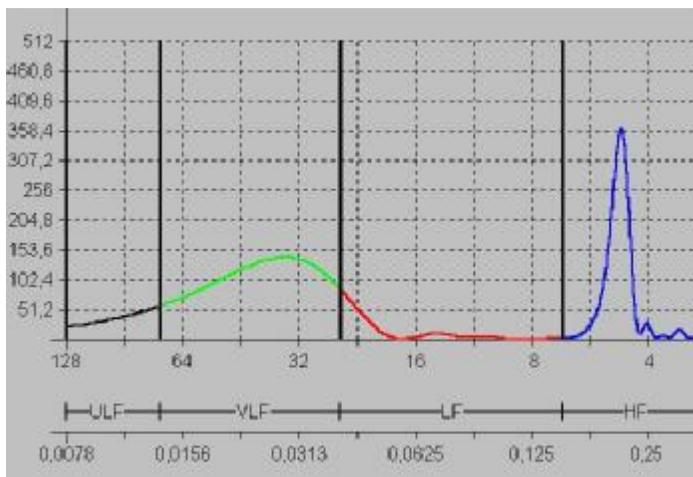
Fig. 6. Spectral function with prevalence of a high-frequency component (HF).

5. **LOW FREQUENCY POWER OF HRV SPECTRUM** (Slow waves of 1st order or vasomotoric or Mayer waves). This parameter (LF-Low Frequency) characterizes a state of vascular tone regulation system. In norm, sensitive receptors of sinocarotide zone detect the changes of values of blood pressure; perceive afferent nervous impulses acting in vascular sub cortical center. Here are carried out the afferent synthesis (processing and analysis of the acting information) and then the vascular system signals of management act. This process of the vascular tone control with feedback on musclefibres of vessels is carried out by vasomotoric center constantly. The time, necessary for vasomotoric center on operation after reception, processing and transfer of the information, varies from 7 to 20 seconds; on the average it is equal to 10 seconds. Therefore, in the heart rhythm there is possible to find out waves with frequency close to 0,1 Hz, which have received the name of vasomotoric waves. These waves were observed by Maer (at first time) with co-

authors (1931), and consequently they sometimes refer to as by Maer waves. The power of slow waves of 1st order determines activity of vasomotoric center. Transition from position "laying" (supine) to position "standing" (upright) usually conducts to substantial growth of power in this range of heart rhythm fluctuations. The activity of vasomotoric center falls with age and at persons of elderly age this effect is practically not present. Instead of slow waves of 1st order, power of slow waves 2nd order is increased. It means that the regulatory process of blood pressure control is carried out by participation of nonspecific gears, by activation of sympathetic part of autonomic nervous system. Usually in norm, percentage of vasomotoric waves in supine position makes from 15 up to 35-40 %. The substantial growth of vasomotoric waves power (see fig.7). Recognition of amplification of sub cortical vascular center can be caused currently by reactions of vessels (for example, of psycho-emotional character), propensity to hypertension, and raised sensitivity of vascular center to various stress factors (vascular dystony). Follows to mention also the parameter of dominant frequency in range of vasomotoric waves: usually it is within the limits of 10-12 seconds. Increase to 13-14 seconds can specify delay of processing of the   information in vasomotoric center or in delay of transfer of the information to system of baroreflex regulation.
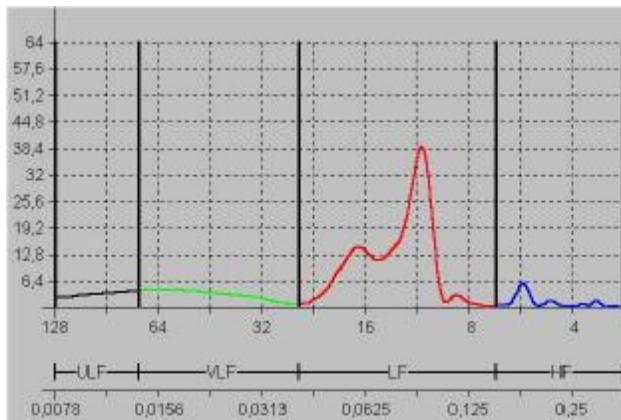

Fig. 7. Spectral function with prevalence of a low-frequency component

6. **VERY LOW FREQUENCY POWER OF HRV SPECTRUM** (Slow Waves of 2nd order). Spectral making heart rhythm in range 0,04-0,015 Hz (25-70 s) in opinion of many foreign authors (Pagani M., 1989, 1994, Maliani, 1991) characterizes sympathetic activity. However, this is simplified interpretation of this parameter. In this case we should speak about more complex influences from parts of suprasegmental(VLF).levels of management, as the amplitude VLF is closely connected with psycho-emotional tension (Kudrjavtseva, 1974). Data of N.B. Chaspekova (1996) have authentically shown that VLF reflects cerebral ergo tropic influence on lower levels of management and permits to judge functional state of a

brain at psychogenic and organic pathology of a brain. On data of A.N. Fleischman, VLF is very good indicator of management of metabolic processes (1996). Thus, VLF characterizes influence of highest autonomic centers on cardiovascular sub cortical center and can be used as a reliable marker of a degree of connection of independent (segmental) regulation levels of cardiovascular regulation with suprasegmental, including that of pituitary-hypothalamic and level of brain. In norm power of VLF makes 15-30 % of total power of a HRV spectrum. At amplification of sympathetic activity, caused by influences high autonomic centers the values of this parameter can reach 60-70 % (see fig. 8).
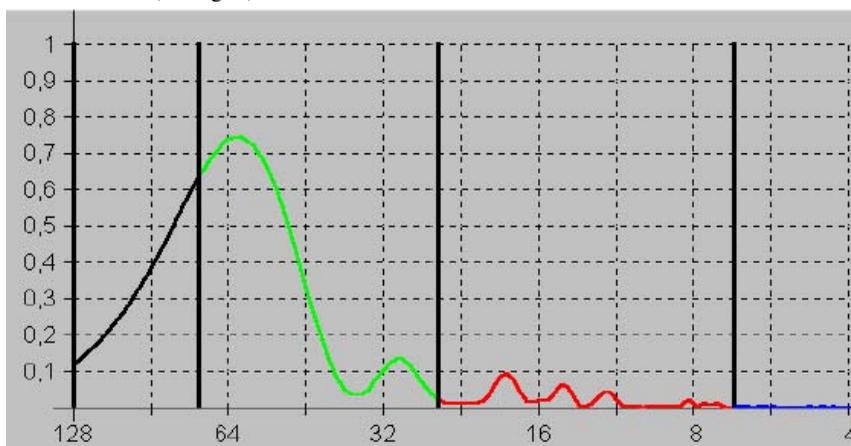

Fig. 8. Spectral function with prevalence of very low-frequency component

7. **ARRHYTHMIA** - parameter of presence and degree of arrhythmic cardiac beats. Briefly, the arrhythmias are connected with heart rhythm disorders in sense of reduction or excitation of myocardial nervous system. Basically we can distinguish intraventricular and supraventricular extraordinary beats - extra systoles, or blocking of excitation of myocardium resulting in functional or organic infringements. Irrespective of kind of rhythm disorders the number of arrhythmias is important and can be expressed in % of total number of cardiac beats. Normally arrhythmias should not exceed 1-2 % of total heart beats, i.e. on 100 heart beats 1-2 arrhythmias. If there is increased number of the arrhythmias - it is the attribute of pathology development - necessary to pay attention to this parameter with concern care.

The KARDiVAR system possesses the important advantage, allowing registrated simultaneously three standard leads of an electrocardiogram and in addition unipolar. It enables visually already during research to see arrhythmic reductions and then in details to analyze their features at viewing the written down electrocardiogram. Important the recogniization not only quantities arrhythmic reductions, but its source. Supraventricular arrhytmias as a rule, are less dangerous, than intravemtricular and blockade.

At arrhythmia estimation, it is especially important to take into account so-called „critical thresholds" - limiting values of a parameter. The excess of which requires the immediate reference to doctor. The software has effective means for recognition of arrhythmias. The parameter of arrhythmias number is given out separately (NArr). It is important, at first, due to the clinical importance of arrhythmias; at second, due to the fact that(for mathematical analysis of heart rhythm) the individual arrhythmias are excluded from HRV analysis, cannot be counted to heart rhythm variability. If the record of RR-intervals comprises more than 2-4 % of arrhythmias, especially if they are not occasional but in groups, the whole line of parameters is not calculated. Then the HRV analysis depends completely on spectral analysis. One of effective and evident ways of supervision and estimation of arrhythmias is a method of correlation rhythmography (construction of scatter gram). On fig. 9 are submitted two scatter grams, which illustrate presentation of arrhythmias estimation by this method.

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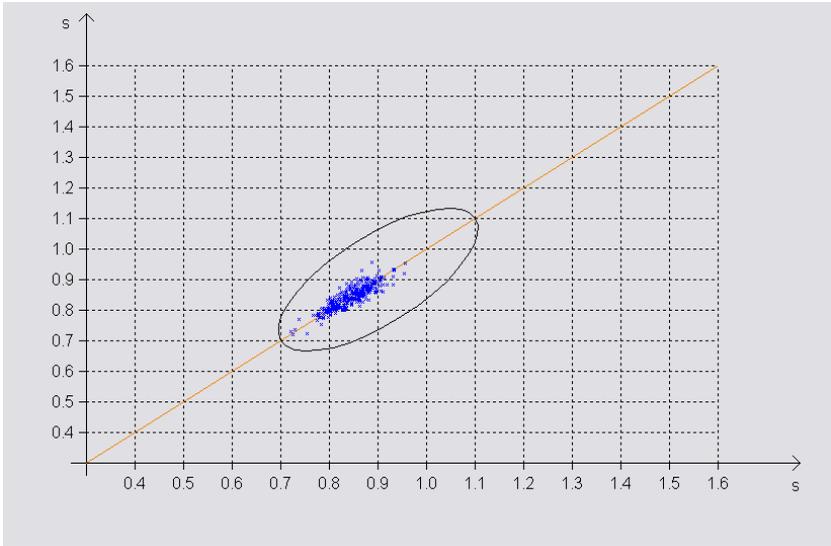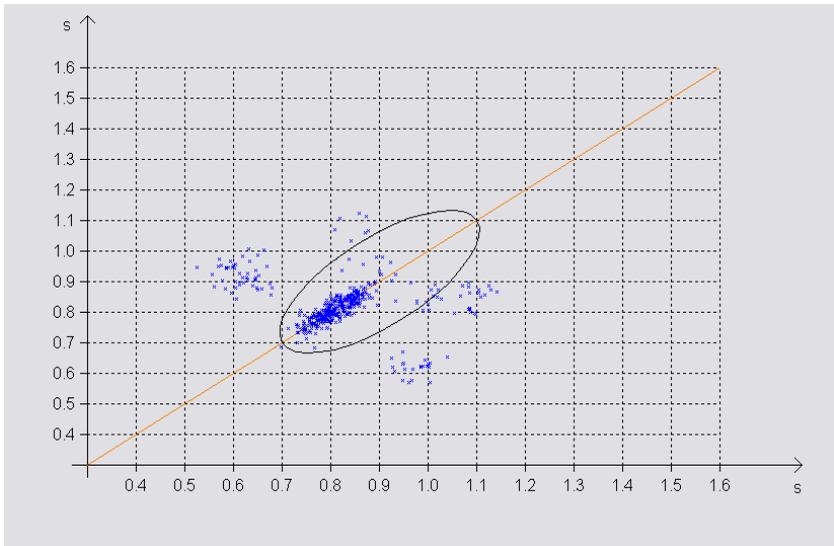
Fig. 9. An arrhythmia estimation bya method correlation rhythmography. Below correlation rhythmogram (scattergram) at the patient with expressed arrhythmia

3.2   Estimation of the body functional state

The complex estimation of HRV can be carried out with help of index activity of regulatory systems (IARS). It is calculated in numbers by special algorithm, taking into account statistical parameters, parameters of histogram and data of the spectral analysis. IARS permits to differentiate various degrees of the regulatory systems tension.

IARS was offered first in beginning of 80's (Baevsky and oth., 1984) and has appeared rather effective in estimation of body adaptability. The algorithm of its calculation was gradually improved and to present time new algorithm, taking into account values of all main HRV parameters is developed:

The calculation of IARS is carried out on algorithm taking into account following five criteria:

- Total effect of regulation (Level of circulation system function) on heart rate (HR),

- Stability of regulation on SDNN and parameter Arrhtthmia.

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- Autonomic balance on complex on complex of parameters: SI, pNN50, HF.

- Activity of the sympathetic vascular center (regulating vascular tone), on on power of a spectrum of slow waves of 1st order (LF),

- Degree of management centralization and activity of the cardiovascular subcrustal nervous centers on an index of centralization (IC) and a spectrum of slow waves of 2-nd order (VLF).

On each of enumerated criteria the estimation on 5 points scale is carried out (+ 2; + 1; 0; -1; -2). Accordingly, the numbers "1" and "2" reflect a moderate or expressed deviation in positive or negative direction. The results of this similar estimation can be expressed by the textual conclusions in total.

Criterion of an estimation	Textual conclusions
Level of circulation system function	Tachycardia, bradycardia
Stability of regulation	Increased stability, presence of arrhythmias
Autonomic balance	Prevalence of sympathetic or parasympathetic tone
Activity of the sympathetic vascular center	Increase or decrease of vasomotoric center activity
Degree of management centralization	High or low activity of suprasegmental levels of regulation; increase or decrease of activity of high autonomic centers

The values of IARS are expressed in numbers from 1 up to 10. The point estimation of IARS is a sum of point estimations of the 5 above-stated criteria. The module of a sum of numbers with markings [+;-] are so determined. However, number of negative and positive numbers, included in a total number, is usually underlined in brackets (for example: IARS = 6 (+ 4; -2). On the basis of analysis of IARS can be determined following functional states:

1. State of an optimal tension of regulatory systems, necessary for maintenance of active balance of organism with environment (norm: IARS = 1-2).

2. State of a moderate tension of regulatory systems, when for adaptation to an environmental influence the organism requires to activate additional functional reserves. Such state arise during adaptation to physical activity, at emotional stress, and/or by influence of the adverse ecological factors (IARS = 3-4).

3. State of an expressed tension of regulatory systems, which is connected to active mobilization of protective gears, including increase of activity of sympatho-adrenal system and pituitary-suprarenal system (IARS = 4-6).

4. State of overstrain of regulatory systems with insufficiency of defense and adaptive gears, their inability to fulfill the supply of adequate reactions of organism

on influence of the factors of an environment. Here the superfluous activation of regulatory systems is already not supported by appropriate functional reserves (IARS = 6-8).

5. State of exhaustion (asthenization) of regulatory systems. The activity of managing gears is importantly reduced (insufficiency of regulatory gears); the characteristic attributes of pathology are present. Here the specific changes distinctly prevail over nonspecific (IARS = 8-10).
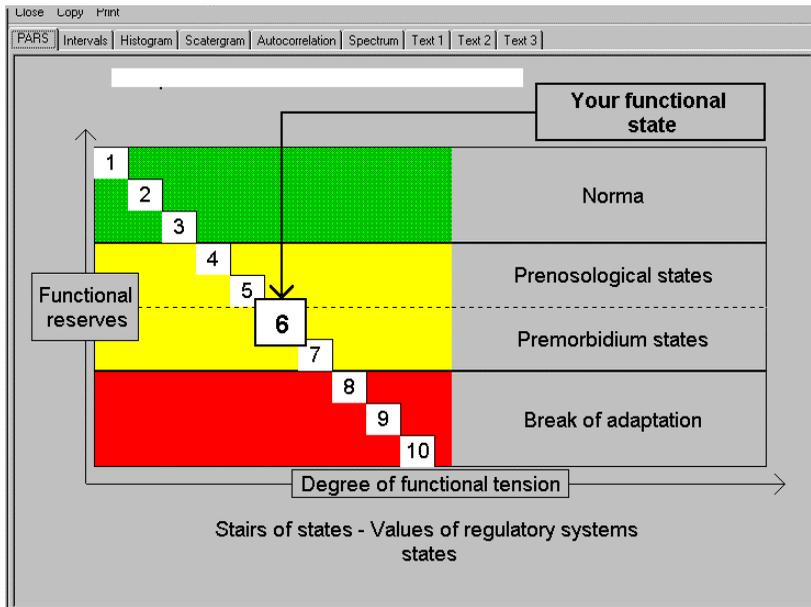

Fig. 10. An estimation of functional states of an organism according to the HRV analysis . System "Traffic light"

The obtained results are presented on the screen and then printed. These conclusions are accompanied by the diagram in kind of "ladders of states", developed in area of prenosological diagnostic (Baevsky, 1979, Baevsky, Berseneva, 1997). Three zones of functional states for presentation are presented as kind of "traffic light" (see fig. 10), and each of point of estimations is accompanied by the text information. The scale "traffic light" is well clear to each person, whether it is a driver or pedestrian. GREEN - means that everything is all right; it is possible to move further without fears. It is not required to take any special measures on preventive maintenance and treatment. YELLOW - specifies necessity of raised attention to health. In this situation the functional state of organism is that demands: „is necessary to stop and to look round, before to move further ". By other words, here there is the necessity to carry out the health supporting and preventive measures in relation to

own health state. RED shows: "further to move is impossible", it is necessary to carry out serious measures concerning health. It is highly required the diagnostic, then appropriate treatment of probable diseases. Allocation of green, yellow and red zones of health permits to characterize a functional state of the person from the point of view of risk of development of illness. For each step "ladders of state" (diagnosis) of a functional state of degree of a regulatory systems tension is stipulated. Moreover, there is the possibility to determine one of 4 functional states of prenosological diagnostic or classification:

- State of norm or state of satisfactory adaptation

- State of a functional tension

- State of overstrain or state of unsatisfactory adaptation

- State of exhaustion of regulatory systems or failure of adaptation.

For evident and convenient presentation to the surveyed persons (patients), the results of HRV analysis and the estimation of results in structure of software of the KARDiVAR system, there is presented the specialized program OUT DOC. On fig. 11 a sample of distribution on edited document, received with help of this program, is submitted. As it is visible, the document consists of three columns. In first column a scale "traffic light" with individual IARS value and with detailed estimation of each of its five components is submitted. In second column, a sample of ECG record, complete cardiointervalogram and table of digital values with indication of limits of norm is given. The special place borrows "CONCLUSION", placed in the bottom part of the second column (further down more detailed explanation). In third column, there the variational pulsogram, scatter gram and spectrum are submitted, received by analysis of cardiointervalogram).
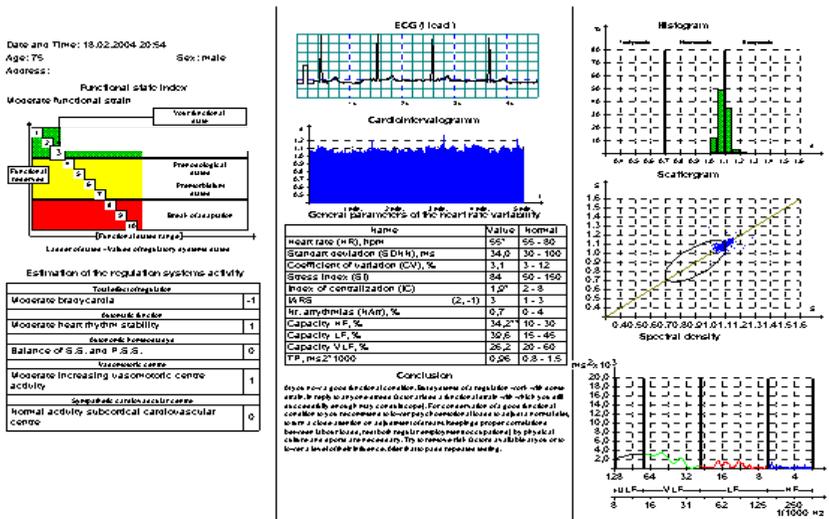
Fig. 11. A sample of a complex estimation of results of the HRV analysis with the help of the "VARICARD-KARDi" software.

"Conclusion" is the most effective and original result of HRV analysis. There (for each of 10 possible functional states - 10 points received by calculation of IARS) the separate text of the conclusion is stipulated. This text consists of two parts. In first part an estimation of a functional state is formulated and is explained. In second part the recommendations are given about preventive maintenance, about healthy way of life. Suitable is to choice the terms of next measurement. In application the all "conclusion" texts submitted. It is important to note, that there is the basic opportunity of editing the conclusions (to be given to measured person) and, by next measuring, to compare the new texts of the conclusions. However, such editing is necessary to do very cautiously and with participation of the appropriate experts. The fixed conclusions, brought in the program, are the results of long-term work of the conducting experts on prenosological diagnostics and are approved by experience of numerous inspections.

3.3 The dynamic control of body functional state by results of the HRV analysis

For estimation of results of preventive and medical influence (to improve health state), the very important is possibility to compare data from periodical HRV analyses measurements (comparison of data about regulatory systems states by regular periodical control measurements). The special program "Dynacont" (DYNamic CONtrol) permits to receive the diagrams of dynamics on beforehand chosen dates of inspections.

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       This program is very suitable to control course of treatment and its efficiency, and to detect changes of functional state of organism. On fig. 12 a sample of diagram showing three parameters in different times of measurement is submitted. Diagrams may be constructed in various time scales upon request, as well as corresponding tables with modifications of amplitudes according to request of the investigator. The program "Dynacont" allows to allocate (to the printed document) necessary parameters for the control, and to specify time periods of controls. This method improves possibilities of watch direct reactions of the patient on different influences, incl. therapy effects.

Date and Time: 22.07.2006 08:57

Age: 54   Sex: male

Address:

Comment:

Ⓐ   **Table of parameters**

Date and time of examination	Position or stage	HR, bmp	Mean, ms	Max, ms	Min, ms	MxDMn, ms	Moda, ms	AModa, %	SI	TP, ms2*1000	PARS
20.07.2006 09:14:04	Сидя	80	754	909	688	221	769	50,3	148	403,23	4
21.07.2006 08:34:50	Сидя	74	792	849	730	119	796	95,2	502	481,25	5
22.07.2006 08:45:52	Сидя	76	792	849	730	119	796	95,2	480	481,25	5
23.07.2006 09:33:12	Сидя	75	804	865	736	129	819	51,6	244	475,46	5
24.07.2006 08:30:26	Сидя	73	820	888	725	163	824	67,5	251	669,35	3
25.07.2006 08:31:58	Сидя	70	860	925	761	164	870	64,2	225	590,87	4
26.07.2006 08:31:58	Сидя	70	860	925	761	164	870	64,2	225	590,87	4
27.07.2006 17:25:42	Сидя	74	813	868	745	123	821	67,6	336	431,65	3
28.07.2006 11:36:56	Сидя	65	921	1003	804	199	925	55,5	151	953,19	2
29.07.2006 11:36:56	Сидя	65	921	1003	804	199	925	55,5	151	953,19	2
30.07.2006 09:19:14	Сидя	80	754	909	688	221	769	50,3	148	403,23	4

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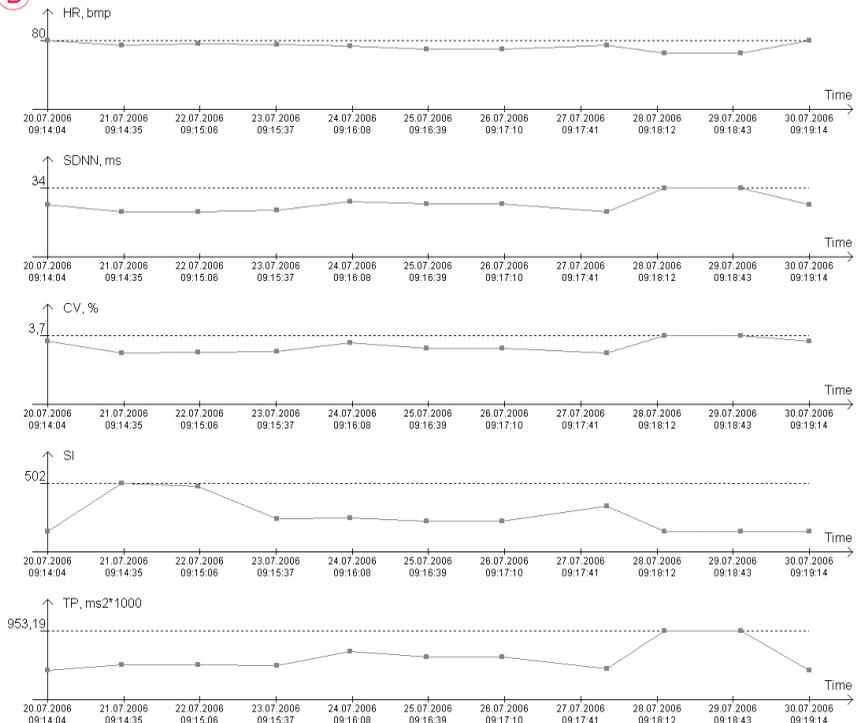
Fig. 12. Use of the special program "Dynacont" for an estimation of dynamics of body functional state changes . A - the table of the data and the diagram of the chosen parameters changes; B - representation simultaneously several diagrams of dynamics at the choice of the user

4.   Practical application of the KARDiVAR system

The KARDiVAR system is the device for measurement of a stress level, estimation of functional states of regulatory systems and body adaptability. It does not concern to a group of medical devices, though it can be used in clinical practice for estimation of efficacy of treatment. Areas of application of the KARDiVAR system is in applied physiology, preventive medicine, health resorts, sport medicine, physiology of labor, psychophysiology and in a broad sense valeology - a science about health and methods of its preservation.

The KARDiVAR system should be applied in all cases when necessary to supervise a stress level and its influence to level of health, when necessary to know which "price" pays organism for adaptation to conditions of an environment and load coming from inside of organism .

Some specific areas of application of the KARDiVAR system are submitted bellow:

1. Research of practically healthy people, who are exposed constantly to psycho-social, emotional or industrial stress, as operators of complex systems (dispatchers, drivers of trains, pilots, operators of complicated security systems, businessmen conducting active business life, persons of mental work, administrative workers etc). It is here important to know as far as functional reserves of each separate person depends greatly on fact whether "charges" do not exceed adaptation to influencing factors of real body adaptability.

2. Research of various groups of practically healthy people, which live or work in adverse conditions as the workers of a chemical manufactures, inhabitants of region with extremely adverse ecological conditions and other population of the people with high risk of overstrain and exhaustion of regulatory systems. For reception of the necessary information it is enough to carry out inspection on 50-100 persons from each risk group and to compare these data to appropriate control groups with determination of aging/sexual peculiarities.

3. Research of the people regularly under busy physical loads with the purposes of maintenance of the health, and also persons visiting fitness-clubs. It is necessary especially in relation to persons of elderly age, where there is the risk of overstrain increased by uncontrolled use of physical exercises. This is to concern the groups of the people, which are busy by tourism or who independently apply various preventive means without specialist advice.

4. An estimation of a functional state of organism in process of health support by use of the various biological food additives or homeopathic means, but also by preventive use of diverse medical preparations. As it is known, in these cases individual selection of doses of biologically active substances and medicinal preparations is especially important to receive optimal effect.

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5. An estimation of body adaptability during recovery after diseases, periodic determination of a degree of a regulatory systems tension for prevention (warning) of possible complications.

KARDiVAR system. Methodical recommendations.

Conclusion

The KARDiVAR system is by a modern mean of practical realization of the newest achievements in the field of research and estimation of a control of physiological functions in organism of the person. The complex provides reception of large number of HRV parameters, various parts describing a state of autonomous regulation of cardiovascular system. However, not too many doctors and experts from other areas, interested in study of health, know about new opportunities of an estimation of a functional state of organism of the person, opening new dimensions - the last years - due to technological progress. Therefore alongside with description of the KARDiVAR system and instruction to the user, extremely important is the information on scientific bases of a method and the ways of its practical use. Though, such information is contained in hundreds of journal publications and number of the monographies - but to collect it, to allocate the most important materials, to define gravity of published data - for practical work of the experts can only be a certain.

The stated above methodical materials are concentrated as kind of presentation to the user of the KARDiVAR system; whole necessary information for teleological application of methods of the HRV analysis based on scientific-reasonable estimation of received results. This information is submitted under certain sight from positions of the theory of adaptation and doctrine about health. But the results of the HRV analysis can be considered also from other positions, including the plan of standard clinical approach to estimate autonomic balance and role of sympathetic and parasympathetic parts of autonomic nervous system in pathogenesis and clinical symptoms of various diseases.

The present methodical recommendations generalize experience of long-term application of methods of the HRV analysis for estimation of the stress level and body adaptability in preventive medicine and at mass medical surveys (Baevsky, Berseneva, 1997). There (the all main rules), submitted in the standards of measurements of European Cardiological Society and North-American Electrophysiological Society (1996) and in Russian methodical recommendations for HRV analysis are discussed. (Baevsky, Ivanov, Chirejkin, 2001). However, the extensive opportunities of the KARDiVAR system much surpass the methodical approaches, as described in literature, and submitted briefly in these methodical recommendations. The KARDiVAR system will be further developed in methodological and technological items. In accordance to experience of most active users of the KARDiVAR system, and to accumulation of new knowledge of HRV analysis, and in accordance with further development of the software, these methodical recommendations will be expanded and supplemented.

This first version of the methodical recommendations follows to consider as a manual guide on primary development of a method and as the instruction for correct and reasonable practical application of the KARDiVAR system.

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