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A NEW APPROACH TO HEALTH RISK ASSESSMENT BY MEANS OF HEART RATE VARIABILITY

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INTRODUCTION

A large scale of ergonomic disadvantages in any particular man-machine system may induce deterioration of human health well-being. Up to now the exact qualitative assessment of this deterioration remains still very complex. That is why, human factor research needs enrichment of methodological background. Heart rate variability (HRV) seems to be a reliable physiological criterion which can be used in this context in laboratory as well as in field experimental researches (3, 12, 22-24, 27).

The increased availability of methods for ECG signal-analysis based on computer techniques allows to derive the essential information hidden in the spontaneous fluctuations of heart rate in time and in frequency domains aspects (1, 3, 4, 6, 9, 10, 13, 14, 16-19, 21, 28). As a rule these fluctuations reflect the drift in autonomic balance (5, 7, 8, 22, 25, 26).

The two possible approaches to the quantification of heart rate variability (HRV) are: a/ Time-domain analysis based on descriptive statistics (2, 5, 9, 15, 20) and b/ Frequency-domain analysis (2, 15, 23, 29, 30) based on fast Fourier transform for obtaining power density spectrum of cardiointervals.

The aim of the study was to approbate the created by Danev (11) method for assessment of health risk (based on HRV analysis) for selected professions with different levels of workload.

METHOD

The software of the method is composed of five separate tests under a common menu. These tests are used for assessment of the following psychophysiological variables: number of ventricular premature heart beats; autonomic balance; levels of mental and physical stress; level of physical training (fitness) and probable health risk, which is based on the results obtained by the four preceeding tests.

The hardware is a portable electronic box. It transforms ECG signals into time periods (msec) between successive heart beats named cardiointervals (R-R intervals) and transfers them to PC or to tape recorder.

Subjects: 719 workers from different industrial branches were submitted to HRV analysis. All of them were practically healthy according to the results from questionnaire for psychosomatic complaints .

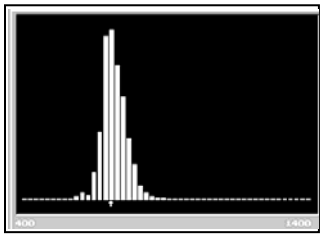
During the period of collection of cardiointervals (10 min rest) the subjects were instructed to close their eyes and to avoid noticeable body movements. Talking was restricted.

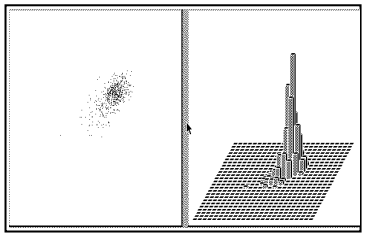
SHORT DESCRIPTION OF THE FIVE TESTS COMPOSING THE METHOD

TEST 1. Heart rhythm test. It is based on algorithm detecting sinus bradycardia and tachycardia as well as ventricular premature heart beats (extrasystoles). The detection criterion is time dependance between before- and after-extrasystolic length of cardiointervals. Fig. 1 illustrates a ventricular extrasystole.

Fig.1.

TEST 2. Tension test. It assesses the levels of sympathetic -to- vagal equilibrium in Autonomic Nervous System. The presumption is that chronically augmented sympathetic prevalence can increases coronary heart risk, hypertension or other cardiovascular pathology. Fig. 2a, 2b, 2c illustrate histogram, scattergram and power density spectrum of cardiointervals obtained by this test. From these figures the following HRV parameters are derived:





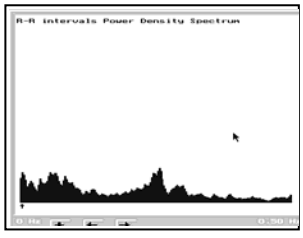


Fig.2a Fig.2b Fig.2c

1. Time-domain based: 1.1. Mean value of cardiointervals (X) (ms); 1.2. Short- and long-term HRV combined in time-domain index (TDI); 1.3. Amplitude of the Mode (AMo = the number of cardiointervals in Mo); 1.4 Mode (Mo) (msec); 1.5. Measured and age-related Tension coefficients (arb. un.); 1.6. Adaptation capacity derived from the

difference between the measured and age-related values of Tension coefficients (arb. un.);

2. Frequency-domain based: 2.1. Power density spectrum of cardiointervals in long, middle and short spectral bands (corresponding to the frequency area: 0.00-0.05 Hz; 0.05-0.15 Hz; 0.2-0.4 Hz in Ms/Hz); 2.2. Total spectral power: TP ms/Hz).

TEST 3. Stress test. It is based on algorithm deriving main HRV components maximally informative towards Physical or Mental stress reaction, multiplied by their coefficients of weight. The results obtained from some thousands of investigated individuals allow to select the most relevant algorithms for assessment of stress and to determinate age-related values of stress coefficients.

Physical and mental stressors influence in different way the time- and the frequency-domain based HRV parameters. This allows to distinguish (in some way) between physical and mental stress reactions and to combine them in Total stress (fig.3).

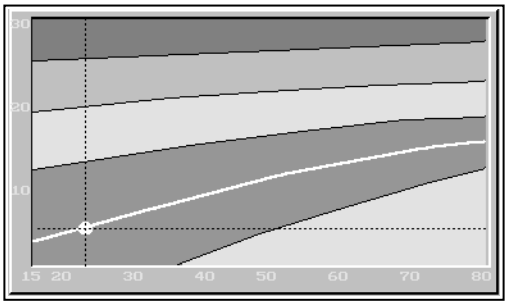


Fig. 3.

Physical, Mental and Total stress are presented separately in co-ordinate system in which the age-related values are situated on as a white line. The measured values of Stress coefficients are presented as a white spot. Its position towards white line indicate the amount of stress accumulation.

Individuals showing accumulated stress (for a period of time longer than one month) are considered to be exposed to a higher degree of stress related health risk.

The accuracy of Stress test when examining persons below 18 and over 70 years is insufficient due to the increased interindividual differences within these age groups.

The values of stress coefficients may fluctuate from one day to another, but usually they are rather constant.

In order to exclude some of the not related to the stress accumulation temporary influences it is advisable to provide more than only one measurement (two days later).

TEST 4. Training test. It assesses the cardiovascular reaction to the orthostatic stress caused by changing posture from sitting to standing up five times consecutively. Postural changes induce a drift in momentary heart rate (cardiotachogram) and power density spectrum of R-R intervals. Both phenomena are used for assessment of the ability of the cardiovascular system to react to orthostatic influence.

Training test is used for controling the level of immobilization and obesity. Both are very significant cardiovascular risk factors.

The average tachogram (fig. 4a) is a graphical presentation of the mean cardiotachogram derived from the five sitting/standing periods. The spectrum (fig. 4b) is a graphical presentation of the power density spectrum of collected R-R intervals in the same periods. The parameters reflecting the shape of the spectral function are: total spectral power, maximal spectral amplitude, long waves related spectral power and middle waves related spectral power.

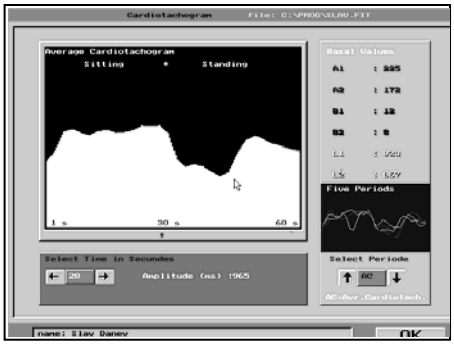


Fig. 4a

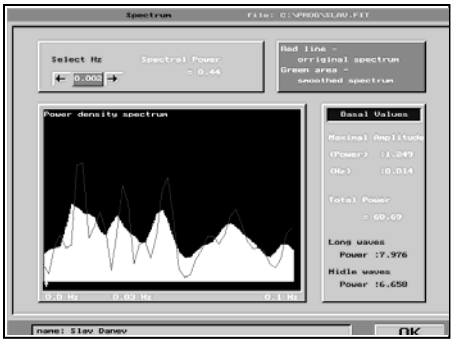


Fig. 4b

From both (average tachogram and spectrum) the following indices are derived: 1. Cardiac coefficient - informs about contraction force of the myocardium; 2. Vascular coefficient - informs about the baroreceptor sensitivity which can be decreased as a result

of hypertension or atherosclerosis; 3. Training index - a global assessment of the individual ability to react to orthostatic stress.

Usually the untrained persons demonstrate a lower speed of heart rate acceleration and recuperation as well as an increased difference between sitting/standing heart rate.

TEST 5. Health risk. Its assessment is based on the results obtained by the four tests described above.

Health risk is computed in percents and informs about the probability some pathological processes to appear. Subjects with chronically elevated Health risk over 65 % are identified as belonging to group with increased HRV - based health risk.

APPROBATION OF THE METHOD IN INDUSTRY

A. Relation between Health risk and work - related strain.

The approbation of the method in industry was done by following up professions with different levels of work - related strain, which was determined by a questionnary (expert assessment) including items concerning: energoexpenditure; weightliftings; pulse rate at work; mental stress inducing tasks; attention; psycho-motor tasks; density of work-related signals; volume of operative memory; neuro-emotional strain; responsibility; monotony; imposed pace etc. and was presented in %. According to the obtained results the investigated work groups were classified as follows: heavy workload (group I)-miners; considerable workload (group II)-air traffic controllers (ATC) and spinning machine operators; moderate workload (group III)-pesticides spraying workers (PSW), radio and TV station workers (RTVW) and operators from electrical power stations. The groups were statistically equilibrated in age aspect.

From fig. 5 is evident that mean group values of Health Risk correspond to the level of workload (correlation coefficient is statistically significant $r=0.79$, $p<0.05$). This means that HRV analysis discriminate the level of work-related strain.

B. HRV analysis and morbidity rate

All investigated persons were divided into three experimental groups according to their individual Health risk value: group I - high; group II - middle; group III - normal (table 1).

The prognostic value of Health risk towards the development of pathological processes was tested by computing the morbidity rate within the selected groups, followed up for a period of three years (prospective study). As it can be seen from table 1, the individuals with an increased value of health risk (over 65.0 %) demonstrate a higher tendency towards an increase of morbidity rate. Fig. 6 compares Health risk value (%) and morbidity rate (%) connected with cardiovascular, respiratory, digestive and nervous systems pathological processes within selected groups. The distribution of the diseases and morbidity rate for each physiological system are substantially extended in group I (miners) being with the highest value of Health risk, followed by spinning machine operators and ATC. The most frequent diagnoses were hypertension, coronary heart disease and gastritis. A relatively high percent of morbidity rate connected with respiratory system was observed in all examined groups. Air traffic controllers showed a moderate tendency towards manifestation of neuroses.

CONCLUSION

It was found (11) that the autonomic balance (measured by HRV) could be chronically altered towards sympathetic prevalence due to chronical action of work-related stressors. This alteration correlates positively with morbidity outcome, which confirm the predictive force of the derived by the method HRV - based Health risk value. That is why Health risk assessment based on HRV analysis may contribute to the early detection of the individuals being at the margin between "health" and "disease", and in this way to help psychophysiological approach to the human factor research in ergonomics.

In order to increase the reliability of this detection we carried out some long-term lasted prospective studies including different industrial branches in Bulgaria aimed to determine the sensitivity, the specificity and the predictive value of HRV regarding morbidity outcome. First we obtained consensus concerning the most favourable HRV measuring procedure (10 min rest in supine position) between 8.0-12.0 a.m. Second, we determined the most informative time- and frequency-domain based HRV measures. Third, we established their age-related values from 7 348 measured persons. Fourth, we succeeded in industrial production of HRV hardware which proved to be very reliable, not expensive, small and fulfil CE (for European Community) restrictions for electrical security. It works with all kinds of IBM PC. Fifth, we created different kinds of HRV software, working under DOS or Windows.

TABLE 1. DISTRIBUTION OF DISEASES (%) AND MORBIDITY RATE (%) IN THREE WORK GROUPS WITH THREE LEVELS OF HEALTH RISK VALUE

		GROUP I	GROUP II	GROUP III
		N = 161	N = 227	N = 331
		mean age = 41.1	mean age = 39.5	mean age = 43.5
HEALTH RISK VALUE		68.5 % ± 12.3	64.5 % ± 8.7	54.6 % ± 7.4
DISTRIBUTION OF THE DISEASES IN %				
1.	**CARDIOVASCULAR SYSTEM**			
1.1.	CORONARY HEART DISEASE	7.4	5.7	1.3
1.2.	HYPERTENSION DISEASE	15.5	11.1	4.9
MORBIDITY RATE (%)		22.0	16.5	4.6
2.	**RESPIRATORY SYSTEM**			
2.1.	PNEUMONIA	4.2	2.3	1.2
2.2.	CHRONIC UPPER RESPIRATORY INFECTIONS	19.2	8.7	3.1
2.3.	ACUTE UPPER RESPIRATORY INFECTIONS	29.1	30.7	22.1
2.4.	INFLUENZA	37.2	26.3	19.1
MORBIDITY RATE (%)		88.0	70.5	54.6
3.	**DIGESTIVE SYSTEM**			
3.1.	GASTRITIS	11.1	9.3	7.3
3.2.	ULCER DISEASE	5.5	4.0	1.2
MORBIDITY RATE (%)		16.0	13.0	7.0

4.	**NERVOUS SYSTEM**			
4.1.	NEUROSES	1.8	6.9	0
MORBIDITY RATE (%)		1.0	6.5	0

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