ISSN 2669-0330 (online)
ĮŽVALGOS. Jaunųjų tyrėjų darbai
2021 Nr. 2, p. 72-82

ELECTROSKIN CHARACTERISTICS AND MONITORING HUMAN'S FUNCTIONAL STATES

Kasani Samhitha
Supervisors: PhD Strakhova O, Professor Ryzhov O.
Zaporizhzhia State Medical University,
Mayakovsky ave., 26, Zaporizhzhia, Ukraine

Abstract

In the presented work, the possibility of using an integral criterion is considered - measuring the electrodermal characteristics of microzones located on certain parts of the human body (ECH MZ) to assess the functional state (FS) of a person working in an ergatic computer system. The results showed significant differences in the parameters of heart rate variability (HRV) and ECH in a number of MZs after a lesson held in such a learning environment. There is a significant correlation between HRV and ECH parameters.
Keywords: ergatic system, human functional state, electrodermal characteristics, heart rate variability

Introduction

The development of the worldwide information network has led to the emergence of ergatic systems "man - computer" in our social and professional life. The curricula of all universities use the means of information computer technologies in preparing for classes, completing educational tasks and monitoring the assimilation of knowledge the issues of preserving the health of persons in the existing conditions become relevant; compensation for possible negative effects of ergatic computer systems on people. Therefore, it is advisable to focus on the features of a person's work in the computer ergatic learning environment created by such interaction of people, technical means and information technologies [1].

Purpose of work

To study the influence of a person's stay and work in an ergatic computer environment on a change in his functional state.

Materials and methods

For the study, a group of 157 volunteers was randomly selected - university persons aged 18-19, 71 boys and 86 girls. A training session in a computer class was taken as a model of work in an ergatic environment. Dosed cognitive loads for them were 4-hour training sessions held at the Department of Medical and Pharmaceutical Informatics in a computer ergatic environment. Classes included acquaintance with theoretical material, preparation for implementation of practical work only on a computer. Persons had to fully complete the tasks offered to them and pass the final computer testing to assess the quality of the learning task assimilation. The study was carried out at the same time of day - from 12.00 to 16.00, in order to avoid the influence of circadian rhythms on the general condition of the subjects.

The research program for persons' FS and its changes in the teaching ergatic computer environment included the registration of heart rate variability (HRV) using the Cardiolab complex

(KhAIMedica, Kharkov); measurement of electrodermal characteristics of microzones (ECH MZ) with the device for measuring ECH "Rada-5", Moscow.

The measurements consisted of two stages. The first recordings of human FS indices by the above methods were carried out before starting work in the ergatic system and receiving cognitive load by the subjects, the second - after the end and final testing.

Each HRV recording was carried out according to the standard technique used for operators; recorded 5-minute intervals [2]. The measurements of the ECH of the MZ were carried out according to the method of the standard vegetative test "CITO", in the MZ - "sources"; recorded the maximum reading of the measuring device in each measurement [3]; the measurement result is a percentage of the maximum - the calibration signal for each given volunteer.

The results were statistically evaluated using the STATISTICA 6.0 program.

Research results

We assumed that quiet work in an ergatic system can lead to functional stress, which, in all likelihood, has the character of specific fatigue of varying degrees [4, 5]. The parameters used to control PS for such purposes over the past 30 years have been measurements of cardiovascular activity. This approach is based on the formulated by R.M. Baevsky's concept, according to which the analysis of physiological mechanisms of regulation of the heart rate makes it possible to obtain information about the functional state of the whole organism [6]. Violation of the autonomic regulation of the cardiovascular system is an early sign of a breakdown in adaptation of the body to stress and leads to a decrease in performance [7].

Since the functional systems of the human body are mutually consistent, as another method that controls the change in the state of many body systems, the method of measuring electrodermal characteristics in microzones on the human body, the so-called acupuncture points, was chosen. In accordance with the theory of acupuncture diagnostics, developed in the twentieth century by scientists from many countries (Macheret, Nakatani, Nechushkin, Podshibyakin, Portnov, Samosyuk), the electrical parameters of certain microzones correspond to the current functional state of certain organs and systems of the human body.

As a result of the research, the most strongly changed after the lesson in the ergatic computer system indicators of ECH MZ and HRV of persons were determined, and a correlation was established between the indicators of HRV and EKH MH and changes in these indicators. (Tables 1, 2, 3)

The percentage difference shown in the last column of Table 1 is calculated using the formula:

$$Diff=\frac{100*\boldsymbol{MVSR\ af}}{\boldsymbol{MVSR\ bef}}-100 \qquad (1)$$

Table 1. Average values of HRV indicators.

Indicator	**Unit of measurement**	**Values before class**		**Values after class**		**Difference**
		MVSR bef	**±m**	**MVSR af**	**±m**	**%**
SDNN	**ms**	**63.56**	8.35	**68.39**	9.03	**7.60**
RMSSD	**ms**	**41.98**	6.34	**49.02**	8.58	**16.79**
pNN50	**%**	**20.49**	5.30	**24.37**	5.96	**18.93**
HRV Ti	**b / r**	**14.26**	1.63	**15.66**	1.52	**9.84**
TP	**ms2**	**4736.65**	1401.39	**5474.51**	1656.50	**15.58**
VLF	**ms2**	**1774.93**	840.10	**2024.27**	835.56	**14.05**
LF	**ms2**	**1732.42**	463.62	**2027.90**	556.31	**17.06**

Indicator	**Unit of measurement**	**Values before class**		**Values after class**		**Difference**
HF	**ms2**	**1155.26**	369.89	**1300.73**	409.70	**12.59**
AMo	**%**	**35.37**	3.25	**32.93**	2.89	**-6.91**
ID (SI)	**b / r**	**109.12**	20.70	**95.05**	16.62	**-12.89**
Ectopic complexes	PC	**2.26**	0.65	**2.66**	1.03	**17.85**
W	**ms**	**152.42**	22.98	**171.78**	29.01	**12.70**
IVR	**b / r**	**151.44**	24.64	**134.93**	19.34	**10.91**
VLOOKUP	**b / r**	**5.67**	0.61	**5.29**	0.55	**-6.73**
L / W	**b / r**	**3.35**	0.40	**3.10**	0.43	**-7.50**
LF / HF	**b / r**	**3.16**	1.14	**3.36**	1.17	**6.33**

As can be seen from Table 1, the statistical characteristics of the dynamic series of RMSSD, pNN5O, HRV Ti, SDNN, as well as the number of ectopic complexes as a result of training in the conditions of the ergatic system have grown significantly.

The indicators of HRV - SDNN and TP - characterize the general level of regulation of the autonomic nervous system, LF - the state of the sympathetic ANS, and RMSSD, pNN50 and HF - the parasympathetic ANS and are considered the most informative in the analysis of HRV. An increase in SDNN indicates an increase in autonomic regulation, which is usually associated with a weakening of sympathetic regulation.

Efferent vagal activity is an important component of the HF-component, the LF-component serves as a marker of sympathetic modulation [2]. Indicator LF / HF, reflective some aspects of the activity of the autonomic nervous system are associated with the functioning of the stem and limbic structures of the brain. An increase in the representation of the slow-wave part of the heart rate spectrum, according to RM Baevsky, indicates an increase in the activity of the intersystem level of heart rate control [4].

In the course of the study, an increase in the statistical indicators of the variation series of HRV cardio intervals, an increase in the power of the wave spectrum in all ranges and a decrease in the indicators of variational pulsometry, with a slight prevalence of sympathetic regulation over parasympathetic (an increase in the index LF / HF by 6.33%).

RMSSD and pNN50% indicators are determined mainly by the influence of the parasympathetic division of the ANS and are a reflection of sinus arrhythmia associated with breathing.

The total power TP of the frequency spectrum from 0.015 to 0.15 Hz, which expresses the total activity of the influence of the autonomic nervous system on the heart rate, increased by almost 16% the growth took place in all ranges of the spectrum. Growth in range VLF made 14%; it reflects an increase in the activity of the slowest circulatory regulation system – humoral-metabolic.

Low-frequency part of the spectrum, LF, reflects a change in the state of the sympathetic regulation of the cardiovascular system of a baroreflex nature, which is activated under stress. It increased by 17%. High frequency vibration power HF grew by almost 13%. It depends on psychological emotional stress, characterizes the influence of the higher autonomic centers on the cardiovascular subcortical center and can be used as a reliable marker of the degree of connection between the autonomous levels of blood circulation regulation and suprasegmental levels, including the pituitary-hypothalamic and cortical levels. Despite the increase in indicators of both sympathetic and parasympathetic regulation of the cardiovascular system, the sympatho-vagal index, LF / HF, characterizing the ratio or balance of sympathetic and parasympathetic influences on the heart rhythm, grew by only 6.33% it indicates a slight shift in the autonomic balance towards the dominance of the sympathetic division of the ANS, which is characteristic of the stress state of the body. A decrease in the total activity of fast regulatory mechanisms and a decrease in the contribution of parasympathetic regulation to the processes of autonomic support of cognitive activity can also be observed with an emotionally negative coloration of such activity in the ergatic system [5], in our case - with poor performance of the task and the person's expectation of a low assessment of the work performed by him.

Variation heart rate measurements have decreased markedly. The amplitude of the fashion, AMO, reflecting the stabilizing effect of centralization of heart rate control, showed a decrease in the number of cardio intervals corresponding to the mode value, as a percentage of the sample size, by almost 7%. The index of tension in regulatory systems decreased by almost 13% this is a very sensitive indicator to the state of the ANS; it characterizes the activity of the sympathetic division of the ANS. Noticeably, the indicator of the width of the scatterogram has grown by 12.7%W, which means an increase in its dispersion, and, consequently, a decrease in the contribution of non-respiratory arrhythmia.

The index of the vegetative balance of the IVR and the vegetative index of the rhythm of the CPR significantly decreased.

ECH MZ showed a significant change in indicators. In accordance with the generally accepted method of processing the results of measurements of the ECH MZ, we can say that the average values of measurements of the right and left sides decreased by a total of 7% at the end of the lesson compared to the beginning. However, this does not give an idea of which systems, represented by the parameters of microzones, turned out to be the most loaded when working in an ergatic computer system. Based on the rule to compare only statistically homogeneous data (as, for example, it is done when processing an ECG signal), we applied the method of calculating the mean values for each MZ separately [8]. This made it possible to obtain informative results.

The ECH values of the MZ, measured at the beginning and at the end of the lesson, are presented in Tables 2 and 3. The difference shown in the last column of these tables is the relative change in the resulting ECH indicators in relation to the initial percentage; it was calculated by the formula:

$$\text{Diff}=\frac{100*\text{Maf}}{\text{Mbef}}-100 \qquad (2)$$

Table 2. Average values of ECH measurements of MZ of the right side of the body

MZ	Mbef	± m	Maf	± m	Diff.,%
P	34.0	3.5	31.8	3.6	-6.52
MC	35.4	3.4	34,7	3.3	-2.10
C	26.6	3.1	24.8	3.3	-6.81
IG	24.6	3.8	22.8	3.8	-7.42
TR	12.7	3.8	9.1	3.6	-28.74
GI	14.8	3.7	12.1	3.7	-18.30
RP	59.9	4.3	56.6	4.6	-5.53
F	64.3	4.7	63.7	4.4	-0.95
R	38.6	5.9	33.0	5.9	-14.43
V	56.1	4.5	50.3	4.2	-10.24
VB	22.0	3.9	18.6	3.9	-15.38
E	31.5	4.9	32.6	5.2	3.42

Table 3. Average values of ECH measurements of MZ of the left side of the body

MZ	Mbef	± m	Maf	± m	Diff.,%
P	33.2	3.1	32.0	3.2	-3.54
MC	32.1	3.4	33.5	3.5	4.33
C	28.1	2.9	27.4	3.4	-2.60
IG	26.3	3.2	22.5	3.3	-14.5
TR	13.4	2.2	9.3	2.2	-30.8
GI	14.6	2.5	10.9	2.4	-25.7
RP	56.2	3.8	54.2	4,0	-3.61
F	64.5	4.19	64.1	3.85	-0.63
R	38.8	5.01	33.3	5.36	-14.1
V	55.9	4.55	53.7	4.54	-3.99
VB	23,7	3.41	20.4	3.15	-14.2
E	35.1	5.69	33,7	5.75	-3.93

A significant difference between the initial and final measurements was revealed in several MZs: IG, TR, GI, R, VB. The ECHs of the right and left sides of the body changed in a similar way, while maintaining the direction of changes (decrease or increase in values on both the right and left sides of the body).

The distribution of the parameters of the ECH MZ is normal, and the HRV is abnormal; therefore, we determined the strength of the correlation between the parameters of HRV and ECH MZ using a nonparametric method - determining the Spearman rank correlation coefficient, in which the calculation does not require any assumptions about the nature of the distributions of features in the general population... Correlation values, which are of interest for further research, were obtained for the parameters of the ECH MZ and HRV, measured after the lesson. The values of the correlations, the level of significance for which was less than 0.05, are presented in Table 4. Calculations are rounded to the second decimal place.

Table 4. The values of the Spearman correlation coefficient between some indicators of HRV and ECH MZ

Correlated parameters	Spearman	p	Correlated parameters	Spearman	p
Right cut & HRish	-0.58	0.01	Reference res. &TPres	-0.65	0.00
Right cut & VLFres	0.57	0.01	Reference res. &HRish	-0.70	0.00
Right cut & LFNORM	-0.56	0.01	Reference res&VLFres	0.69	0.00
Right cut & HFNORM	0.56	0.01	Reference res &MOrez	0.71	0.00
Right cut & LF / HFres	-0.56	0.01	Reference res. &TPres	-0.72	0.00
Right cut & ICres	-0.52	0.02	V right cut &HRin	0.50	0.02
Right cut & MOrez	0.61	0.00	V right cut & RMSSD	-0.50	0.02
Right cut & TPres	-0.62	0.00	V right cut & PNN50	-0.51	0.02
MC right cut &HRish	-0.66	0.00	V right cut &FNORM	0.58	0.01
MC right cut &VLFres	0.65	0.00	V right cut &FNORM	-0.58	0.01
MC right cut &MOrez	0.63	0.00	V right cut & LF / HF	0.58	0.01
MC right cut &TPres	-0.65	0.00	V right cut & BAP cut	-0.53	0.01
Reference res. &HRish	-0.70	0.00	V right cut & MO cut	-0.55	0.01
Reference res&VLFres	0.69	0.00	V right cut & SI cut	0.52	0.02
Reference res. &TPres	-0.65	0.00	Left Cut &HRin	-0.50	0.02
Reference res. &HRish	-0.70	0.00	Left cut & MO cut	0.56	0.01
Reference res&VLFres	0.69	0.00	Left cut & TP cut	-0.53	0.01

To determine the closeness of the relationship between an arbitrary numbers of ranked features, a multiple correlation coefficient (concordance coefficient) was used. It is applicable when a set of objects is characterized not by two, but by several sequences of ranks, and it is necessary to establish a statistical relationship between several variables.

The concordance coefficient between the HRV indices and the ECH values of the MZ of both the right and left sides of the body is 0.75 ÷ 0.87 with a rank correlation coefficient $r = 0.74 \div 0.87$; $p < 0.01$.

Several of the most strongly correlated with each other (Spearman's correlation coefficient up to 0.72, $p < 0.01$) were found for HRV and ECH of MZ. The most pronounced was the correlation dependence with the HRV indicators of changes in the following microzones: MC, C, P, V, and VB. However, the microzones most strongly correlated with the HRV indices had not the most pronounced changes in their values at the end of the lesson.

As a result of the lesson, the activity of both sympathetic and parasympathetic divisions of the ANS increased the frequency of extrasystoles increased, non-respiratory arrhythmia increased, and the electrical activity of certain MZ decreased. A correlation was established between changes in HRV and ECH of the MZ.

Maintaining a stable working capacity requires the mobilization of resources, which leads to a shift in the autonomic balance towards sympathotonia and is associated with an increase in the load on the regulatory centers. Realism, an adequate assessment of one's own capabilities, successful forecasting of events create the prerequisites for a rational distribution of functional resources and minimization of their expenditure, which makes it possible to stabilize and optimize the current FS.

Conclusions

Training in an ergatic environment is a significant functional load for a number of FS of the human body. Heart rate variability parameters reflect the reactions of the cardiovascular system to these loads. Thanks to the method of registration of changes in the ECH MZ, it is possible to determine the functional systems of the body that are most susceptible to the influence of ergatic computer systems and environments. Changes in the ECH MZ can be taken as a way to obtain reliable criteria for changes in the state of various organs and systems of the human body under the influence of his work in the ergatic system "man - computer".

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Summary

In the course of the study, it was revealed that under the influence of a person's work in a computer system, changes in his functional state occur.

These changes are determined using the method of recording heart rate variability. The variability parameters were recorded before the beginning of human work in the ergatic system and after its completion. The way of recording HRV parameters is "operator", i.e. registration of five-minute HRV intervals in the "sitting" position of the subject. By comparing the key indicators of heart rate variability, the most changed indicators were determined. They turned out to be the frequency characteristics of the heart rate: TP - total activity of the influence of the autonomic nervous system on the heart rate; LF is the level of activity of the vasomotor center; HF - activity of the humoral-metabolic system of regulation of blood circulation; an increase in the value of this parameter is a vegetative sign of anxiety and is observed during stress; VLF - the level of activity of the parasympathetic link of regulation.

It was found that characteristic changes occur in all frequency ranges, which indicates multidirectional changes in the work of the higher nervous and humoral centers that control the activity of the heart. Changes in such HRV parameters as SDNN, pNN50%, RMSSD reflect the multidirectional changes in the sympatho-parasympathetic balance of the body as a result of work in the ergatic system.

Simultaneously with the measurements of the HRV parameters, the parameters of the electrocutaneous characteristics were measured in order to find out whether there is a relationship in the changes in the HRV characteristics and the state of the electrocutaneous parameters at the control points. The control microzones were "source points" known from the theory of acupuncture, "meridians" that "control" the activity of organs.

Measurements of electrocutaneous characteristics were carried out according to the author's method developed at the Department of Informatics of Zaporizhzhia State Medical University.

When conducting a comparative analysis of changes in the parameters of HRV and ECH MZ, it turned out that these indicators have a close correlation, and always change in the same way. Since the general principles of the interrelationships of various body functions are based on the concept of biological objects as systems, the measurement of the electro cutaneous characteristics of the control microzones can be taken as methods of monitoring the functional state of people exercising systemic supervision over their changes.

Knowing the permissible limits of changes in the controlled parameters of HRV, and the level of correlation of these indicators with the parameters of the ECH MZ, it is possible to set the limits of change in the parameters of electro cutaneous characteristics, and be guided by their measurements in assessing the parameters of the functional state of people.

Considering that, in accordance with the theory of acupuncture, control points allow assessing the state of not only the cardiovascular, but also other systems of the body, a method of measuring the parameters of electro cutaneous characteristics, and assessing their current changes is a promising method for monitoring the state of human health in many parameters, organs and body systems.