Coherence of heart rate variability and local physical fields in monitoring studies

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ABSTRACT

Technological advances have led to a substantial modification of the physical fields of the environment, which could affect the status of living organisms under their constant exposure. In this study, the activity of human cardiovascular system under the influence of a complex natural physical environmental factors investigated. The study was conducted on a representative homogeneous sample (44 persons aged 19 to 22 years) by simultaneous monitoring of electrocardiograms and natural physical fields in Tomsk (geomagnetic field, meteorological parameters – temperature, pressure and humidity, surface wind speed, the parameters of the schumann resonance – amplitude, frequency and quality factor of the first four modes in the range of 6 to 32 Hz, the power spectral density infrasonic background in the range of from 0,5 to 32 Hz). It was shown that among the set of parameters of physical fields present field that can resonate in the functioning of the human organism. The greatest coherence with heart rate variability detect variations eastern component of the geomagnetic field.

Keywords: geomagnetic field, schumann resonance parameters, heart rate variability, monitoring.

1. INTRODUCTION

The human body, being difficult open nonlinear system is very sensitive to the conditions of the surrounding environment. Like every living creature, he must perceive environmental signals, process them and react to them properly. It is generally recognized that the natural electromagnetic fields are significant environmental factor, as evidenced by numerous studies [1, 2].

Due to the lack of living tissue attenuation, low-frequency electromagnetic fields have an impact on all the organs, tissues, cells, molecules of bioobject. Research results biological effectiveness of electromagnetic fields of natural and artificial origin convincing evidence of sensitivity to them varying degrees of complexity organisms, as well as the presence of a variety of effects at the population level. Some of these studies are devoted to estimation the impact of external physical fields, including electromagnetic, on biorhythmic components of living organisms.

Nevertheless, the problem of estimating the parameters of complex natural environment physical fields, including natural electromagnetic fields as complementary environmental factors influence on the person currently unsolved. In the natural environment, the human body is affected by many external influences that make up the complex dynamic range of factors. The degree biotropic these factors has no unambiguous assessment. In this paper we studied the relationship between variations in the heartbeat period (RR-interval) rights and changes in the parameters of regional physical fields according to monitoring studies conducted in Tomsk.

2. EXPERIMENTAL

Monitoring heart rate variability was performed by recording an electrocardiogram of volunteers in terms of their typical activities from April 7 to June 11, 2009. The sample consisted of 44 healthy individuals aged 19 to 22 years. During the processing of monitoring data on consecutive three-minute intervals were considered as the main points of the variations of RR-intervals – an indicator mRR (the average value of the RR-interval), SDNN (standard deviation from the mean) and PNN50 (the proportion of intervals between adjacent RR-intervals exceeding 50 ms) – an indicator of the fastest high-frequency vibrations in the structure of the heart rate variability [3]. To eliminate the influence of heterogeneity of the group of volunteers on the results of the comparison carried out pre-standardization of daily data considered indicators of activity of the cardiovascular system for each volunteer (hereinafter referred to as indicators mRR_st, SDNN_st, PNN50_st).

The calculated values are put into temporary data matching the parameters of natural physical fields, the continuous-clock monitoring which is carried out at the Tomsk State University on the certificated equipment Research and Education Center "Physics of the ionosphere and the electromagnetic environment" employees of the Department of

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Space Physics and Ecology. Analyzed regional geomagnetic field (amplitude variation north, east and vertical components, respectively, X, Y and Z), meteorological parameters (temperature T, pressure P and humidity U, surface wind speeds S), the spectral power density of the background in the infrasound range from 0,5 to 32 Hz divided by 6 bands I1-I6 (0,5-1 Hz, 1-2 Hz, 2-4 Hz, 4-8 Hz, 8-16 Hz, 16-32 Hz) [4], the basic parameters of the Schumann resonances – the amplitude A, frequency F and the quality factor Q of the first four modes in the range from 6 to 32 Hz [5]. Each parameter of physical fields has been pre-filtered three-hour filter Hamming.

3. RESULTS

As a result, it found that the temporal dynamics of some physical fields has high coherence with the indicators of cardiovascular system activity (figure 1-4).

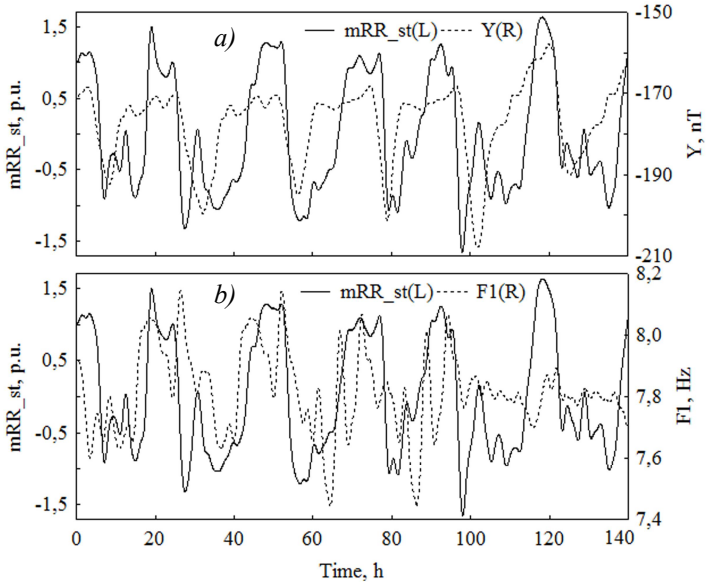

Figure 1. Detail of the dynamics of the heartbeat period and variations in the eastern component of the geomagnetic field *(a)*, the frequency of the schumann resonances first mode *(b)*.

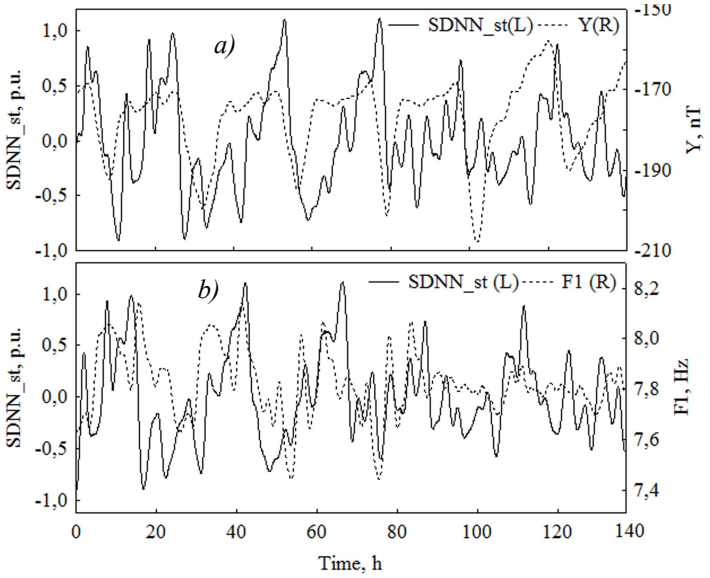

Figure 2. Detail of the dynamics of the standard deviation of the heartbeat period and variations eastern component of the geomagnetic field *(a),* the frequency of the schumann resonances first mode *(b)*.

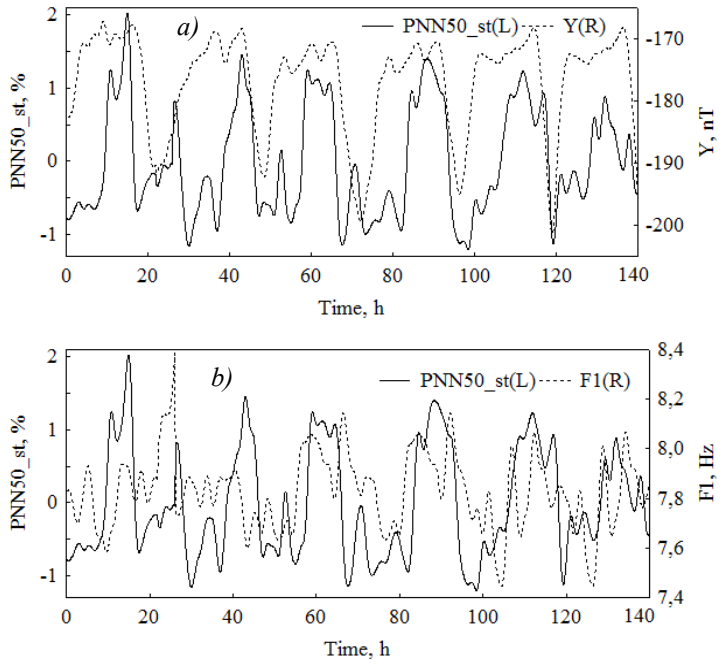

Figure 3. Detail of the dynamics of PNN50 and variations of the geomagnetic field components *(a)*, the frequency of the schumann resonances first mode *(b)*.

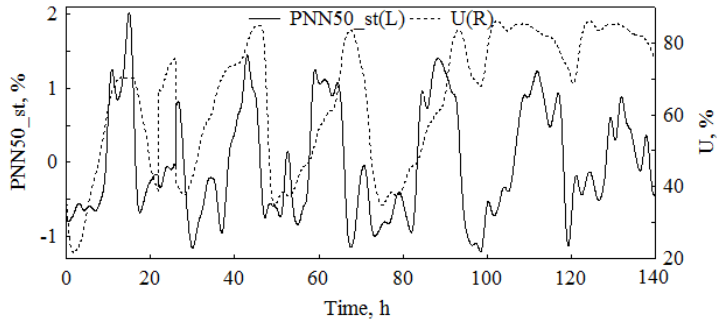

Figure 4. Detail of the dynamics of PNN50 and variations in humidity.

To analyze the relationship between several independent variables (predictors) and the dependent variable is the best multiple regression analysis. In our case, as the dependent variables are the indicators of activity of the cardiovascular system, and as predictors – the parameters of the physical fields. As a result of the regression analysis for each dependent variable were determined weights the influence of independent variables and their statistical significance.

Partial or private correlation - a correlation between two variables at a "fixed" the influence of the other variables included in the analysis. The importance of its use follows from the fact that, as a rule, multiple causes interact and have a joint effect on the studied trait. The calculated correlation coefficients and partial regression coefficients showed that all analyzed physical fields of the environment can be divided into two groups – with major and minor degrees of consistency with the heart rate variability. The first group may include an east component of the regional geomagnetic field Y, and the temperature T, humidity U, pressure P, the frequency F1 (≈ 7,8 Hz) and amplitude A1 of the schumann resonances first mode, subsonic pressure variations I1, which corresponds to the frequency range of 0,5 Hz to 1 (table 1). All other parameters have small correlation value and can be referred to the second group. For indicator mRR overall coefficient of determination was 0,56, for SDNN 0,26, for PNN50 0,2.

Table 1. Results of the regression analysis of indicators of the cardiovascular system activity from the parameters of the physical fields.

	mRR			SDNN			PNN50		
	B	Std. Err.	Partial Cor.	B	Std. Err.	Partial Cor.	B	Std. Err.	Partial Cor.
Int.	-19,124	1,089		-14,054	0,733		-20,545	1,049	
Y	0,025	0,000	0,404	0,005	0,000	0,121	0,017	0,000	0,306
T	-0,034	0,001	-0,199	0,005	0,001	0,040	-0,016	0,001	-0,097
U	0,012	0,001	0,175	0,008	0,000	0,172	0,012	0,000	0,182
P	0,022	0,001	0,144	0,015	0,001	0,146	0,023	0,001	0,155
F1	0,323	0,038	0,059	-0,083	0,026	-0,023	0,102	0,037	0,019
A1	0,007	0,001	0,066	-0,003	0,001	-0,037	0,002	0,001	0,021
I1	-0,754	0,056	-0,093	0,242	0,038	0,045	-0,072	0,054	-0,009

Note: B – regression coefficient, Std. Err. – error of the regression coefficient, Partial Cor. – the partial correlation coefficient, Int. – constant component. All options are valid with a probability of 95%.

In addition, cross-correlation analysis showed that the maximum correlation study parameters observed if negative lag (table 2). This result suggests that at first there is a change of environment parameters, and then to changes in heart rate variability.

Table 2. The cross-correlation coefficients and the corresponding value of the lag for the studied parameters.

	Y		T		U		P		F1		F2		F3		F4		I1		I2	
	R	lag	R	lag	R	lag	R	lag	R	lag	R	lag	R	lag	R	lag	R	lag	R	lag
mRR	0,266	-11	-0,282	-11	0,288	5	-0,050		0,082	-30	0,060		0,107	-110	-0,186	-53	-0,132	-42	-0,116	-90
SDNN	0,085		-0,103	-48	0,104	-37			0,031	-39	0,033	-66	-0,031	-19	-0,082		-0,052	-64	-0,037	-63
PNN50	0,199	-41	-0,215	-31	0,222	-14	-0,040		0,079	-60	0,059		0,093	-110	-0,157	-94	-0,098	-60	-0,089	

Note: Y – eastern component of geomagnetic field variations; T – temperature environment; U – humidity; P – atmospheric pressure; F1, F2, F3, F4 – frequency of the first, second, third and fourth modes respectively schumann resonances; I1, I2 – infrasonic pressure spectral power in the frequency bands 0.5-1 and 1-2 Hz.

4. CONCLUSION

Thus, obtained during the investigation results show that the relationship between variations in the human heartbeat period and changes in the parameters of physical fields is significant enough, in the case of each of the parameters considered, it is different. The largest association was found with variations of the eastern component of the geomagnetic field – the partial correlation coefficient for the average heartbeat period totaled $R \approx 0,4$. This result is consistent with the literature and suggests that variations in regional geomagnetic field are able to find an echo in the functioning of the cardiovascular system of the person. In addition, the correlation with such parameters as the frequency of the frequency of the schumann resonances first mode (≈ 7,8 Hz), and the power spectral density of the background in the infrasound range of 0,5 to 1 Hz is an important result, because the frequencies of these parameters coincide with the frequency of the internal the rhythms of the human body. The high correlation found dependencies, as well as the overall coefficient of determination equal to 0,56 for the indicator mRR, responsible for the overall level of functioning of the cardiovascular system, says that the natural physical fields of the environment should be seen as complementary factor that can find a significant echo in the functioning of the human organism. Changing the RR interval is the human body's response to the impact of natural environmental factors. The strength of its impact is determined by the general state of the organism and its individual systems involved in adequate response. The degree of functional adequacy is directly proportional to the magnitude of influence (load) factors. The greater the quantity (load) factors, the lower the resistance of the functional systems of the organism. The less intense impact factor, the greater the resistance of the functional

systems of the body. The adaptation process is implemented in all cases where in the system human-environment there are significant changes, leading to a breach of the adequacy of their relationship. Since human and the environment are in dynamic equilibrium, their relationship is constantly changing, constantly carried out and the process of adaptation. Since major changes heartbeat period variability associated with the variability of the mean value, it can be argued that the mechanism of the effect of physical fields variations on the cardiovascular system functioning due to nonspecific indirect influence through the central nervous system. A more detailed study of the response and its causes appears necessary task for research in this area.

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REFERENCE LINKING

[1] Pobachenko, S.V., Kolesnik, A.G., Borodin, A.S., and Kaliuzhin, V.V., "The contingency of the parameters of the human brain electroencephalograms and electromagnetic fields of the Schuman resonator based on monitoring studies," Biofizika 51(3), 534-538 (2006).
[2] Shitov, A.V., Borodin, A.S., Tuzhilkin, D.A., and Apryatkina, M.L., "Influence of Physical Fields of Active Geological Faults on the Human Cardiovascular System," Izvestiya, Atmospheric and Oceanic Physics 50(7), 696-711 (2014).
[3] Dabrovski, A., Dabrovski, B., and Piotrovich R., [Sutochnoe monitorirovanie ECG (Daily monitoring ECG)], M.: "Medpraktika" (1998). [in Russian].
[4] Solov'ev, A.V., Provotorov, D.S., Bocharov, A.A., and Voznesenskaya, K.V., "Seasonal And Diurnal Variations Of Background Infrasonic Pressure Oscillations In The Frequency Range 0.01–32 Hz In The City Of Tomsk," Russian Physics Journal 55(8), January, 943-950 (2013).
[5] Derevyannykh, A.A., Kolesnik, S.A., "Seasonal and diurnal regularities of the Schumann resonance parameters in different regions of the earth," Russian Physics Journal 55(8), January, 937-942 (2013).