"Physics of Auroral Phenomena", Proc. XXVI Annual Seminar, Apatity, pp. 253-256, 2003

Polar Geophysical Institute

PILOT EXPERIMENT ON ESTIMATION OF THE HUMAN ORGANISM RESPONSE TO GEOMAGNETIC DISTURBANCES IN SPITSBERGEN

S.A. Chernouss, V.F. Grigoriev, O.V. Antonenko *(Polar Geophysical Institute of the KSC of RAS)*

Abstract. Preliminary results of the pilot experiment on monitoring Heart Rate Variability (HRV) parameters of volunteers at PGI observatory in Barentsburg are under discussion. Time series of HRV spectral parameters were compared with local K-indices time series. The comparison shows that in some cases a good correlation of both time series is taking place, but in other cases the correlation is poor. The level and tendency of HRV reaction to geomagnetic disturbances are rather individual and depend on the current state of the tested organism. It is found out that this individuality varies not only in value, but in tendency too. The key role of Autonomic Nervous System (ANS) in opposite reaction of different volunteers under the same level of geomagnetic field considered. Growth of geomagnetic activity causes the violation of the balance between sympathetic and parasympathetic influences. The reason is a decrease in the effectiveness of the heart rhythm regulation. Comparison of data obtained in Kola Peninsula and Spitsbergen shows similar results but the experiment in Barentsburg gives us a better possibility to perform studies of the impact of geomagnetic disturbances on human health, because of wider dynamic range of geomagnetic field fluctuations.

Introduction: background for the experiment performance

Winterers and temporary expedition staff in Spitsbergen archipelago are subject to extreme impacts of the environment, which include not only low temperatures, complex of hard hydro-meteorological conditions, the lack of oxygen, seasonal photo-periodicity (Polar night and Polar day), but extreme variations of geocosmic agents as well. A considerable number of studies (the reference list includes more than hundred papers, including dozens of monographs and surveys) deal with the man's health in the North and in the Arctic areas (including the region of the Polar Cap, where Spitsbergen is situated). There exist special terms, such as Polar medicine, Polar Stress syndrome etc. Concerning Spitsbergen in particular, there were carried out screening estimations of the state of health of miners and other personnel of Barentsburg and Pyramid mines during several years within the framework of a large-scale experiment (International Russian-Norwegian programme Svalbard-2 [1,2]). The results of these studies revealed drastic changes in the immune, endocrine, cardiovascular systems, disturbance of physiological regulatory mechanisms, all this being a «price» migrants have to pay «for getting adapted». It was shown that photoperiodicity and the season (to a smaller degree) have a considerable physiological effect. The influence of environmental factors on winterers' health seems undoubted and is presented in a large number of publications, e.g. (3-10). Complex experiments, performed in Arctic and Antarctica (including the ones in the Polar Cap: drifting stations, Mirny observatory etc., in the auroral zone: Norilsk, Molodezhnaya observatory etc., and sub-auroral zone (Karelia) have displayed a great number of both qualitative and quantitative trends. Even such simple techniques as inquest, examination of people applying for medical help and emergency cases occurrence have displayed a possibility of Helio-Geophysical disturbance effect on people's health (e.g. in Spitsbergen (8)). Such event-based approach is justified and may be applied at the initial stage of studies. One has to note that phenomena of Helio-Geophysical nature persist on a time scale varying from a few seconds to a few days. They have seasonal and multi-year variations and what is really needed for such an estimation is not screening (i.e. measurements, carried out several times per year with groups of people being tested) but monitoring of variations of both geocosmic agents and biomedical parameters. Such monitoring has been limited by the absence of instruments necessary for quantity estimations, however, at present, with computer technologies coming, the situation has been changing significantly. There has been found a possibility of comparing the measured time variations of both geocosmic (affect agents) and medico-biological («acceptors in an organism») parameters. From a physicist point of view, a search for correlation, functional relations and regularities is reduced to the analysis of time series of geocosmic variations and biomedical parameters, whereas selection, representation and subsequent interpretation of data depend on the level of geophysical and biological qualification of experimenters. Thus, one of the most important conditions for proposed bio-geophysical experiment is monitoring of the measured parameters, namely, the ones characterising the functions of both the entire organism and some of its systems. These parameters or indices should be selected on the basis of modern concepts concerning the response of both the entire organism and individual systems and in such a way as to clear up the cause - effect relationship following the scheme **stimulus - object - reaction** (13). The stimulus is variations of external factors. The equipment for biomedical measurements should be adapted to observatory studies of time series of Helio-Geophysical parameters. Based on these ideas, there was performed a pilot experiment in 2002 at Barentsburg with the purpose of estimation of human organism response to variations of geomagnetic activity.

Equipment and methods

The paper presents results of preliminary experiment on the investigation of the human organism response, manifested through the parameters of the heart rate variability (HRV) to external effects. The tested persons were volunteers working in Barentsburg. There were carried out 413 measurements in a group of 38 tested people.

For mathematical analysis of HRV we applied the technique that mostly meets the above requirements. It was introduced into practice by Soviet scientists (11, 14) to control cosmonauts' health state during an orbital flight. At present this technique is widely spread and approved by experts from the European Association of Cardiology and North-American Association of rhythmology and electrophysiology (12), who had developed unified requirements to the units of measurement, method and equipment for HRV registration. According to Baevsky (11), the human organism, undergoing continuous stress effects can be considered as a dynamical system, continuously adapting to the environmental conditions by cost of functional resources: stress of regulatory mechanisms, variation of the level of functioning of individual systems and the entire organism. Since the cardiac-vascular system is connected via neuro-reflex and neuro-humoral mechanisms to other regulatory mechanisms, one can judge about the integral character of the redistribution of the controlling information flows in the organism as a whole by changes in operation of the sinus node. According to (11), certain information on the condition of cardiac-vascular system of the organism, its internal reserves, its capabilities to adapt itself to external effects can be obtained from a rhythmogram, which is a time series of cardiac intervals. According to (11, 12), from a rhythmogram, as a result of its statistical and spectral analysis, one can calculate indices, characterising various states of individual systems of the organism. These indices were verified in numerous papers (see references in (11)) on the basis of clinical diagnosis. In the present study, we have used the Cardioanalysor VR developed within international standards for measurements and estimation of HRV. The age of the tested persons varied from 24 to 45. Measurements with the Cardioanalysor VR were carried out daily (except for the weekends) in the quiet state for nearly the same time intervals during morning hours in order to avoid any dependence of the readings on circadian rhythms. The most carefully verified HRV characteristics are the values of spectral power in the following spectral intervals: VLF - very high frequency (< 0.04 Hz) - the level of central regulation; LF - low frequency (0.04 - 0.15 Hz) - sympathetic branch of autonomic nervous system (ANS); HF - high frequency (0.15 - 0.4 Hz) - parasympathetic branch of the ANS. That is why, it is spectral characteristics that were used in analysing the results. Local K-indices of geomagnetic activity at Spitsbergen were used as a marker of Helio-Geophysical disturbances. The choice of the K-index as a marker is stipulated by the supposition that the response of the human organism could obey the psycho-physiological Weber-Fechner law (i.e. logarithmic response to the action of external stimuli.) Since K-index has a scale close to the logarithmic one, at the present stage of research it seems more reasonable to use this index than continuous measurements of geomagnetic variations.

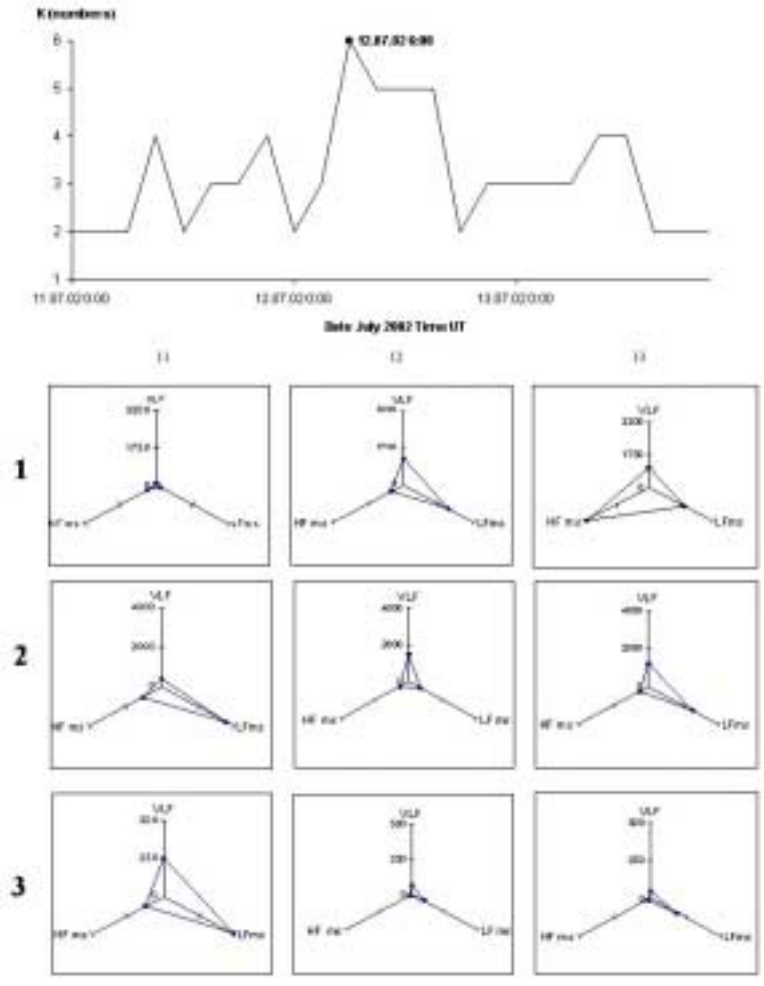

Fig.1 Examples of changes of spectral parameters of the variability of cardiac rhythm (vector diagrams) versus the level of geomagnetic disturbances in Spitsbergen for three volunteers from Barentsburg.

Results of the experiment

A comparison of time series of geomagnetic field variations represented by local hourly K-indices with the time series of various parameters of the HRV has been made. It has been shown that there is a significant correlation of those HRV parameters with K-index, however, the parameter of the HRV exhibiting correlation is not necessarily the same for different persons being tested. Moreover, with different tested

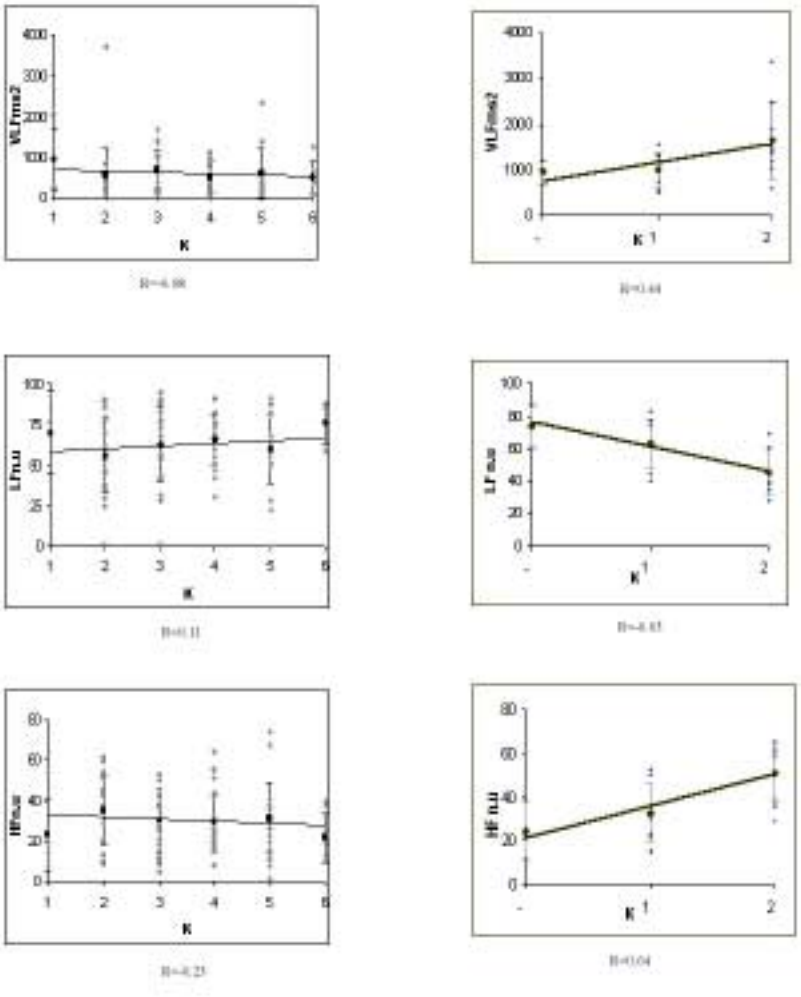

Fig.2 Spectral parameters of cardiac rhythm variability averaged over a group of volunteers (left) and for a single volunteer (right) versus local K-index.

persons the same indices, e.g. the stress index (SI) and spectral indices of the activity of the autonomic nervous system branches (HF, LF) may change oppositely under the same variation of the magnetic field. From this point of view, an effort to find a correlation between the mean values of the HRV readings for the whole group of tested persons and geomagnetic indices failed. At the same time, the measured individual readings of HRV (different for different tested persons) display significant levels of correlation with K-indices. Such a paradox can be explained by different initial functional state of the tested persons, by differences in functional reserve and different accentuation of the ANS. Fig.1 shows K-index variation in Spitsbergen (top panel of the Fig.1) and changes of spectral parameters (VLF, LF, HF) presented as vector diagrams. Plotted on the axes are the spectrum power, characterising the response of the central nervous system (VLF), sympathetic (LF) and parasympathetic (HF) branches of the ANS. The data are presented prior to the disturbance (11.07), on the day of disturbance (12.07) and after it (13.07). Volunteer 1's response to the local geomagnetic disturbance of July 12, 2002 is, obviously manifested in the change of the ANS accentuation from parasympathetic to sympathetic one. As to Volunteer 2, on the contrary, his sympathetic influence is minimum compared to the parasympathetic one. Volunteer 3 evidently exhibits a decrease of the total power on July 12 with accentuation kept, while the power restores in the subsequent period (13.07) just for one of the ANS branches. This pattern is a clear demonstration of individual responses of the organism to geomagnetic disturbance. Such type of reaction suggests that if one averages the HRV measurement results over the whole group of the tested volunteers, it is hard to expect any common manifestations. Fig.2 (left) gives Barentsburg volunteer spectral parameters in Spitsbergen, averaged over the volunteer group, versus geomagnetic activity. It is obvious, that there is absolutely no dependence (correlation coefficients are close to 0), which had to be expected. It is interesting to examine whether the statistic curve will sharply change, if averaging is performed not by the group of volunteers but by the time series of measurements for the same organism. Fortunately, data of this kind have been obtained in the Polar Geophysical Institute at Apatity (Fig.2, right). (The data sets obtained with individual volunteers in Spitsbergen are not sufficient to build dependencies similar to Fig.2 for separately tested persons). It is evident, that changes of spectral components of the cardiac rhythm in correlation analysis for an individual person are clearly manifested in all three spectral ranges. Explanation of the lack of any correlation when averaging over the whole group of volunteers is that their basic functional state and reserve are strictly individual. Besides, changes in the HRV with variation of geomagnetic activity can have opposite trends for different organisms: for some of them certain spectral parameters grow with geomagnetic activity increasing, while for others they drop. If such data taken together are correlated with indices of geomagnetic activity, then it is quite natural to obtain zero correlation. This is especially evident in detection of the ANS states, since depending on ANS basic accentuation (sympathetic and parasympathetic) variations in its parameters (LF, HF) are asymmetric. Fig.3 provides the temporal dependence of the three spectral parameters of a volunteer as indicated by the measurements taken in Barentsburg near the time of a strong geomagnetic disturbance, versus the local K-index. The thin line shows variation in K-index, the thick one -

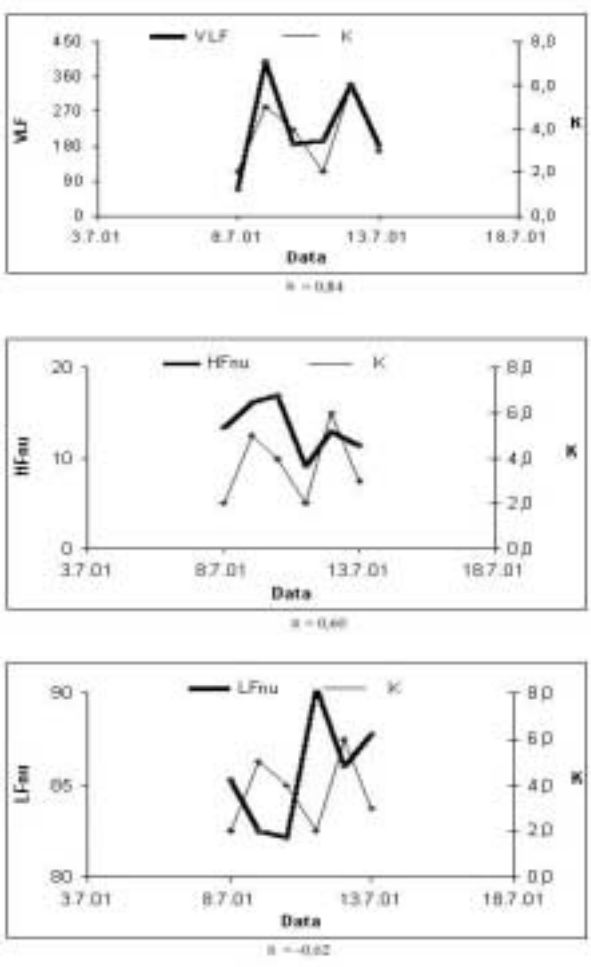

Fig.3 Time series of changes of spectral parameters of the variability of the cardiac rhythm and variations of the geomagnetic field in Spitsbergen around an intense disturbance for one of the volunteers

changes in the spectral parameters of the HRV. The best correlation is found for VLF (84%), for LF and HF the correlation did not exceed 60%. The main peculiarity found from comparing the middle and lower panels in Fig. 3 is that the ANS branches' response to the external effect has opposite trends: changes of HF are in phase with the geomagnetic disturbance, whereas changes of LF are in anti- phase. With a volunteer having an opposite accentuation of ANS the situation can be just opposite. Thus, it is necessary to take into account the «autonomic picture» of the tested persons when performing biomedical monitoring on the basis of HRV analysis.

Discussion and conclusion

The preliminary results of the experiment on monitoring parameters of the cardiac rhythm variability in Spitsbergen demonstrated that for most of the tested people these parameters vary with geomagnetic activity. The level and trend of the HRV response to geomagnetic field variations are individual and may depend on the current functional state of the organism. It was found that this effect depends on the accentuation of the ANS. Thus, on the basis of regular measurements, we have demonstrated a possibility of estimation of the current functional state of the organism in order to identify the personnel being subject to the effect of Helio-Geophysical disturbances. Useful or harmful action of the external factor may be estimated only at the individual level. That is why, in further studies, it is extremely desirable to carry out a similar investigation with a group of tested people homogeneous by biomedical indices. Spitsbergen appears to be a perfect site for such an experiment, because the amplitude range of geomagnetic variations characterised by K-index in there exceeds significantly the same range in the Kola Peninsula. One can appreciate how important for an organism and the state of health the above measurements are by comparing variations of spectral parameters of HRV and geomagnetic disturbances with those during an impact of extreme loads on the organism. Having such a study performed, a specific task of identifying a group of risks among the polar researchers with respect to the effects of geocosmic agents can be treated.

Literature

1. Tkachev A.V., Dobrodeeva L.K., Boyko E.R., The seasonal effect on hormonal, immunnological and biochemical indeces in Svalbard inhabitants, Int. Conf."Effect of Cold on Human Organism", Oulu, Finland, Feb.10-11,1995, #42.
2. L.K.Dobrodeyeva, A.V.Tkachiov, E.V. Tipisova, S.L. Kashutin, Immunological peculiarities with people, working in Spitsbergen Archipelago. Russian Physiology Journal, 1998, 4(1-2), 119-124.(in Russian)
3. N.R.Deryapa, I.F.Ryabinin, Adaptation of man in the polar regions of the Earth, Leningrad, Medicine Publ. 1977, 299 p. (in Russian)
4. N.A.Agadjanyan, A.I.Yefimov, V.L.Khruschiov, G.M.Kuptsov, Chronophysiological aspects of man's adaptation to the conditions of the Arctic//Chronombiology and Medicie,- M.:Medicine Publ., 1989, p.144-157, (in Russian)
5. N.K.Belisheva, A.N.Popov, N.V.Petukhova, L.P.Pavlova, K.S.Ossipov, S.E.Tkachenko, T.I.Baranova, Qualitative and quantitative estimation of geomagnetic field variations effect on the functional state of the man's brain// Biophysics.-1995.- Issue 5.- P.1005-1012.
6. Chernouss S., Vinogradov A., Vlassova E., Geophysical hazards for human healthin the circumpolar auroral belt: evidence of a relationship between heart rate variations and electromagnetic disturbances, Natural Hazards, v.23, Kluver Academic Publ., 2001, p.121-135.
7. V.N.Shepovalnikov, S.I. Soroko, Meteosensibility of man. Bishkek, ILIM, 1992, 247 p. (in Russian)
8. O.I.Shumilov, E.A.Kassatkina, O.M.Raspopov, Heliogeomagnetic activity and the level of extremal situations in the Polar cap, Biophysics, V.43, issue 4, p.670-676, 1998.
9. S.A.Chernouss, M.V.Kuznetsova, Yu.V.Fedorenko, E.Yu.Vlassova, A.N.Vinogradov. Experimental opportunities of estimation of the influence of geophysical situation on man's health in the Arctic conditions. Proc. «Anthropogenic impact on the nature of the North and its ecological consequencies. Apatity, 1999, p.15-171.
11. R.M.Baevski, Physiological measurements in the outer space and the challenge of their automation. M.Nauka Publ., 1970. 231 p. (in Russian).
12. Heart Rate Variability: Standards of measurements, physiological interpretation and clinical use, Et.Heart , v.17, 1996., p.354-381.
13. G.V.Plekhanov (editor), Introduction in electromagnetic biology, Tomsk, TSU publ., 1979, 163 p. (in Russian)
14. V.M.Petrov et al. Influence of changes of the Earth's magnetic field on the functional state of man in cinditions of a space flight in Proc. Computer electric cardiography at the edge of centuries, Abstracts of presentations, Moscow, 1999, p.112-114