Physiological state of Slovak aviators in relation to geomagnetic disturbances and cosmic ray intensity variations

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Abstract. **It is already known to the scientific community that the human physiological state and in particular the human cardio - health state can be influenced by geomagnetic field and cosmic ray intensity variations. Many researches have concluded that the human organism is sensitive to environmental changes and reacts to them through a series of variations of its physiological parameters such as systolic blood pressure, diastolic blood pressure, heart rate, etc. Three different scientific groups, from Athens (Greece), Kosice (Slovakia) and Sofia (Bulgaria) have performed a joint investigation concerning the influence that geomagnetic disturbances and cosmic ray activity might have on the physiological state of 4018 Slovak aviators. All the above groups have been working on separate studies, in the last years, regarding this subject achieving significant results. This study refers to the time period from 1^{st} January 1994 till 31^{st} December 2002. Daily data concerning mean values of heart rate and diastolic and systolic blood pressure, which were registered during the medical examinations of the Slovak aviators, were related to daily variations of cosmic ray intensity, as measured by the Neutron Monitor Station on Lomnicky Stit (http://neutronmonitor.ta3.sk/realtime.php3) and daily variations of Dst and Ap geomagnetic indices. All subjects were men in good health of age 18 - 60 years. The most interesting events (Forbush decreases, GLEs and geomagnetic storms) registered during the time period under consideration, were examined separately and in more details. This is only a part of the results of the recently established and extended co-operation of the above mentioned groups. Hopefully this cooperation will continue and further investigation will lead to new and reliable results.**

Keywords**: cosmic rays, human physiological state, geomagnetic effects**

I. Introduction

Solar and geomagnetic variations like the other environmental changes can influence the human physiological state and can be partially responsible for changes or fluctuations of physiological parameters in human organism. Over the last few years many scientific groups have conducted researches regarding the effect that geomagnetic disturbances and cosmic ray intensity (CRI) variations may have on human cardio - health state [1], [2], [3], [4].

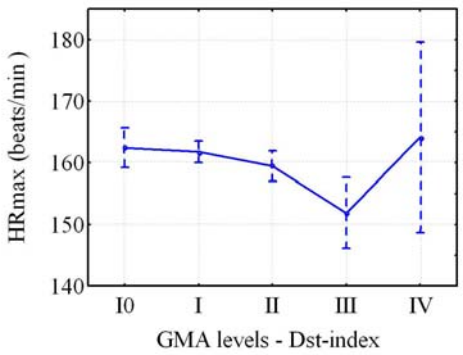

Fig. 1: Effect of GMA estimated by Dst-index on HRmax ($\pm 95\%$ CI, p=0.013*)

Many studies show that space weather parameters (through Forbush decreases and solar activity) can influence human physiological parameters such as heart rate, diastolic and systolic blood pressure, etc. More specifically it seems that heart rate (HR) increases during CRI decreases and high geomagnetic activity [5]. Also the capability of a person to react correctly to the enviromental circumstances can be affected and this in turn could lead to man - related accidents [6].

This work is a result of the collaboration of three different scientific groups, from Athens (Greece), Kosice (Slovakia) and Sofia (Bulgaria) and studies the influence that geomagnetic activity (GMA) variations and CRI variations might have on human cardio - health state. Kosice group gathered and kindly provided the medical data for a group consisting of 4018 healthy Slovak aviators for the time period from 1^{st} January 1994 until 31^{st} December 2002. It is important to continue this collaboration in order to have stronger results.

II. Data and Method

The measurements used in this study refer to a group of 4018 Slovak aviators. The group consisted only of men, aging from 18 to 60 years, all in good health. Daily mean values of heart rate (beats/min) in rest without load

TABLE I: Dst - Index levels and Number of days

Dst levels	I0	I	II	III	IV
Dst-index, nT	$Dst \geq 0$	0<Dst <-20	$-20 \leq Dst < -50$	$-100 \leq Dst \leq -50$	Dst <-100
Number of Days	206	702	359	65	9

TABLE II: Ap - Index levels and Number of days

Ap-index levels	I0	I	II	III	IV
Ap-index values	Ap <8	$8 \leq Ap$<15	$15 \leq Ap$<30	$30 \leq Ap$<50	$Ap \geq 50$
Number of Days	615	349	269	78	30

(HRR), heart rate in 1st degree of load (HRFDL), heart rate in 2nd degree of load (HRSDL), maximum heart rate achieved by load (HRMAX) were registered for the time period from 1^{st} January 1994 until 31^{st} December 2002.

Daily, pressure corrected, data of the CRI obtained from the Lomnicky Stit Neutron Monitor (SNM-15) of the Department of Space Physics, Institute of Experimental Physics, Kosice, Slovakia were used. This station is located 2634 m above sea level and detects particles with a cut - off rigidity of 3.84 GV. It has been operational since December 1981 providing high quality data (archive, current data) through the internet in digital form (http://neutronmonitor.ta3.sk/). During the period under consideration CRI variations were in the range -16% - +7%. There were 40 days when CRI decreased more than 10% and a lot of days with CRI increases.

The geomagnetic index Dst from the World Data Centre for Geomagnetism, Kyoto (http://swdcwww.kugi.kyoto-u.ac.jp/) was used for the time period under study. GMA was divided into five levels according to Dst-index values as shown in Table I. Data for Ap-index came from Space Weather Prediction Centre at NOAA, Boulder, (http://www.swpc.noaa.gov/ftpmenu/indices/old_indices.html). Gradation of GMA levels according to Ap-index is shown in Table II. Tables I and II show also the number of the days with different GMA levels for the considered period. It is seen that there were several major and severe geomagnetic storms (level IV) then as well as a lot of days with very low GMA (level I0).

The statistical method of the ANalysis Of VAriance (ANOVA), (statistical package STATISTICA, ver.6, StatSoft Inc., 2001) was applied to establish the statistical significance of the effect of GMA and CRI variations on HR. In general, the purpose of ANOVA is to test for statistical significance between means through comparing variances. The chosen level for statistical significance in the used data analysis software system STATISTICA is set to p <0.05 and the same value is used for interpreting the results.

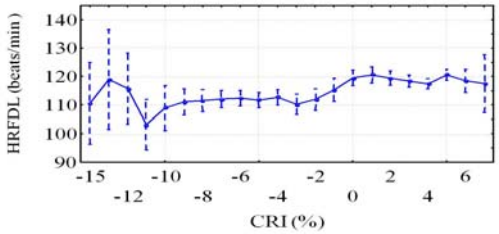

Fig. 2: Effect of CRI on HRFDL ($\pm 95\%$ CI, p=0.000*)

III. Results and Discussion

Variations of HRR, HRFDL, HRSDL, HRMAX were analyzed using ANOVA, in relation to the different levels of GMA and CRI decreases. Table III shows the correlation coefficients between the different parameters. HRR and HRmax decreased with Ap levels increment and got the maximal values during very low and highest GMA according to Dst-index. The results about HRmax were statistically significant. The averaged values of HRmax of the group for the different Dst-index levels is shown in Fig. 1. Vertical bars in the figures denote 0.95 confidence intervals (CI). In a similar way HRFDL and HRSDL seems to increase during very low GMA and geomagnetic storms.

The results revealed statistically significant increase for HRmax, HRFDL and HRSDL during the largest increases and decreases of CRI, see for example Fig. 2. It was obtained in previous studies for other groups of healthy persons that during strong CRI decreases HR increased [5] as well as systolic and diastolic blood pressure and subjective psycho-physiological complaints [7]. It has been shown that acute myocardial infarctions increased both on the days of lowest and highest levels of GMA [8], [1]. In [9] it was suggested that the role of environmental physical factors becoming more active in low GMA, like CR activity, should be object of further studies.

A series of recent studies prove that solar and geomagnetic conditions may be responsible for a number of responses of the human organism and may be con-

TABLE III: Correlation coefficients between GMA and CRI parameters and the physiological parameters under examination. Results marked with * are statistically significant

	Ap	Ap level	Dst	Dst level	CR%
HRR	-0.0591* , p = 0.030	-0.0707*, p = 0.010	0.0486, p = 0.075	-0.0439, p = 0.108	0.0165, p = 0.547
HRFDL	0.0414, p = 0.129	0.0214, p = 0.434	0.0022, p = 0.937	-0.0059, p = 0.830	0.2497*, p = 0.00
HRSDL	0.0264, p = 0.334	0.0016, p = 0.952	0.0070, p = 0.797	-0.0162, p = 0.554	0.2343*, p = 0.000
HRmax	-0.0718*, p = 0.009	-0.0906*, p = 0.001	0.0746*, p = 0.006	-0.0750*, p = 0.006	0.0751*, p = 0.006

nected to many diseases, mostly cardiovascular diseases and diseases of the nervous system, especially strokes, myocardial infarctions, etc.

This paper is a result of the collaborative research of three different countries and focuses on the possible relation between GMA and human cardiologic parameters. HR variations have been analysed in regard to CRI decreases and Ap- and Dst- indices variations. As it appears HR variations seem to be connected to very low GMA when CR activity increases and high GMA accompanied with Forbush decreases. This cooperative study will continue and further investigation will lead to new and reliable results

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