Cosmic Rays Variations and Human Physiological State

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Abstract: It was obtained in our previous investigations that geomagnetic activity as an indirect indicator of solar activity correlates with some human physiological and psycho-physiological parameters. A lot of studies indicate that other parameters of space weather like cosmic rays Forbush decreases affect myocardial infarction, brain stroke, car accidents, etc. The purpose of that work was to study the effect of cosmic rays variations on human physiological status. It was established that the decrease in cosmic rays intensity was related to an increase in systolic and diastolic blood pressure and reported subjective psycho-physiological complaints in healthy volunteers.

Keywords: Forbush decreases, geomagnetic storms, human cardio-vascular and psycho-physiological state

Introduction

A variety of physical phenomena are associated with space weather, including cosmic rays (CR) variations and geomagnetic storms.

Galactic CR experience significant variations in response to passing solar wind disturbances such as interplanetary coronal mass ejections (ICME) and their accompanying shocks. Arriving at Earth, ICME shield and compress the magnetosphere, intensify the magnetosphere currents thus leading to a significant depletion of CR intensity (CRI) and producing geomagnetic storms. Forbush decreases (FD) are fast decreases in galactic CRI with amplitude from several percents to 20% or more, onset time about several hours to a day and relatively slow, about several days to weeks, exponential return to the normal values. The magnitude of FD depends on the ICME size, velocity, orientation, on strength of irregular magnetic field and on the state of the magnetosphere.

Ground level enhancements (GLE) are increases of the intensity of the secondary CR caused by nuclear cascades initiated in the Earth’s atmosphere by solar particles. GLE and FD are studied by worldwide neutron monitors (NM) network and muon telescopes.

The flux of galactic CR in the solar system is modulated by the solar activity (SA). Enhanced solar wind with its entrained magnetic field sweeps some of the galactic CR outwards. The overall or average rate of FD tends to follow the 11-year SA cycle, but individual events are related to solar events.

It was shown in our previous studies [1-3] that geomagnetic activity (GMA) could be considered as an indicator of space weather related to its influence on human physiological and psycho-physiological state. Other studies revealed similar GMA effects on arterial blood pressure (ABP), heart rate variability (HRV), electrical conductivity of biologically active points, etc. [4-10] as well as GMA effects on cardio-vascular diseases, myocardial infarctions morbidity and mortality, cardiac arrhythmia, brain strokes, occupational and traffic accidents [11-13].

However there is some inconsistency in the results obtained in the field [14-16] and different relationships between geomagnetic field (GMF) variations and human health were established. It might be due to the different cycles and/or stages of SA considered in the studies, different medical data rows, their length, periods of time, the origin (drivers) of the different geomagnetic storms, their intensity, duration, etc.

Some studies revealed that the most significant effects on myocardial infarctions, brain strokes, and traffic accidents were observed on the days of GMF disturbances accompanied with FD [13, 17-18] and especially during the declining phase of FD [17, 19, 20]. At the same time it was shown that very low GMA affects also adversely human cardio-vascular system [21-24]. It is suggested that the role of environmental physical factors becoming more active in low GMA, like CR (neutron) activity, should be object of further studies [25].

The purpose of that study was to investigate the effect of CRI variations on human physiological and psycho-physiological status.

Material and Methods

Data were obtained in 86 healthy volunteers, 33 males and 53 females, with an average age of 47.8± 11.9 years. Examinations were performed in Sofia (Latitude: 42°43' North, Longitude: 23°20' East). Data were gathered on every working day in autumn and spring in years of maximal SA and GMA (from 1 October 2001 to 9 November 2001 and from 8 April 2002 to 28 May 2002).

Systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR) were measured. Pulse pressure (algebraic difference between SBP and DBP) was calculated. ABP was registered by sphygmomanometric method to the single millimetre of Hg. Heart rate was palpatorically measured over arteria radialis as beats per minute and by counting for a full minute.

Data for some subjective psycho-physiological complaints (SPPC) were also collected. Volunteers filled in a questionnaire with three groups of questions: one concerned complaints related to the common functional state (general condition, working ability, sleep disturbances, weakness, absent-mindedness); another concerned cardiovascular system (heart thumping, arrhythmia, tachycardia); and the third concerned nervous system (headache, dizziness, vertigo, nausea).

Altogether 2 799 registrations for each of the physiological parameters under consideration were obtained for the both periods of examinations.

In this study hourly, pressure corrected data about intensity in percents of CR secondary nucleonic component of SVIRCO neutron monitor (http://www.fis.uniroma3.it/~svirco/pag_2.html) was used. The station is located in Rome at the sea level at latitude 41°86' North and longitude 12°47' East. Rigidity cut-off of SVIRCO is 6 GV.

Fig. 1a and Fig. 1b show hourly CRI and hourly Dst-index variations for the both periods of examinations. Data about GMA were got from WDC, Kyoto (http://swdcwww.kugi.kyoto-u.ac.jp/index.html). It is seen from Fig. 1a and Fig. 1b that there were no CRI increases (above 0%) but only CRI decreases (below 0%) during the periods under consideration.

Table 1 shows that during the examinations CRI decreases were in the range 3-9%. The table represents also the number of the respective physiological measurements, which were accomplished for the different levels (percents) in that range of CRI variations.

TABLE 1

CRI decrease in percents and the number of physiological measurements

CRI decrease, %	3	4	5	6	7	8	9
Number of measurements	194	715	930	627	253	39	41

ANalysis Of VAriance (ANOVA) was performed to investigate the influence of CRI variation on the group examined. A *Post-hoc analysis* (Newman-Keuls test) was also used to establish statistical significance of the differences between the average values of the measured physiological parameters at the separate factors levels. The method of superimposed epochs and ANOVA were used to study CRI effect up to 3 days before and 3 days after their variations on the physiological parameters. The chosen level for statistical significance was $p \leq 0.05$.

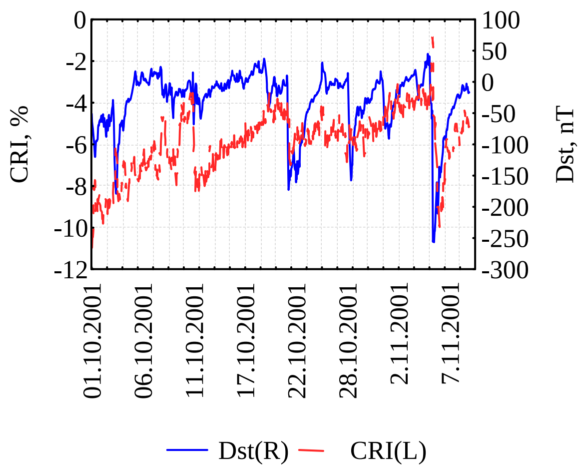

Fig. 1a. Hourly CRI and Dst-index variations during examination period from 1 Oct 2001 to 9 Nov 2001.

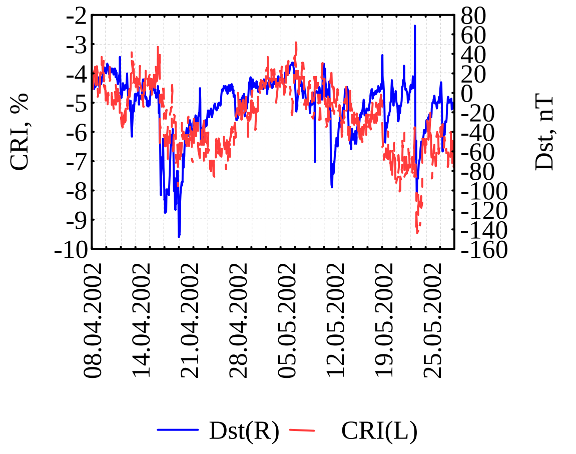

Fig. 1b. Hourly CRI and Dst-index variations during examination period from 8 Apr 2002 to 28 May 2002.

Results

ANOVA applied for the study of CRI influence on the physiological and psycho-physiological parameters revealed statistically significant effect on SBP (p=0.000), DBP (p=0.000), PP (p=0.010) and SPPC (p=0.002). It was not established significant influence on HR (p=0.152). Fig. 2 shows the mean values of SBP and DBP for the group examined under different CRI variations (axis X is the decrease of CRI in percents) during the period of examinations. Vertical bars in the figure denote 95% confidence intervals (CI). It is seen that SBP and DBP increased with the decrease of CRI. The maximal increment for SBP for the group was 10.5% and for DBP 11.4%. Post hoc analyses revealed that SBP and DBP were significantly higher during CRI decrease with 8% and 9% in comparison to CRI decrease with 3÷7%.

Fig. 3 shows dynamic of PP and HR. PP increased also with the decrease of CRI, having the highest value at 8% CRI decrease. The largest variation for that physiological parameter was 10%. HR had no clear dependence on CRI. HR decreased at 4% and 8% decrease of CRI and kept almost one and the same value under other CRI conditions with the largest variation of 2.8%.

SPPC increased with the decrease of CRI and 26.8% of the persons examined reported SPPC during CRI decrease with 9% (Fig. 4).

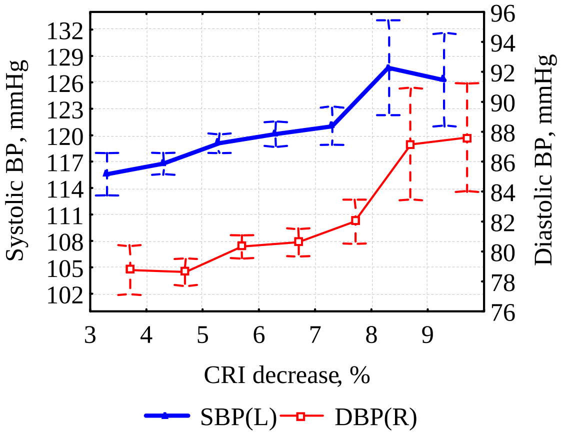

Fig. 2. CRI effect on SBP and DBP (±95% CI).

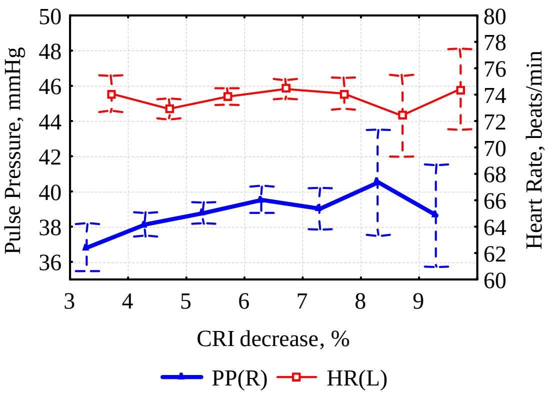

Fig. 3. CRI effect on PP and HR (±95% CI).

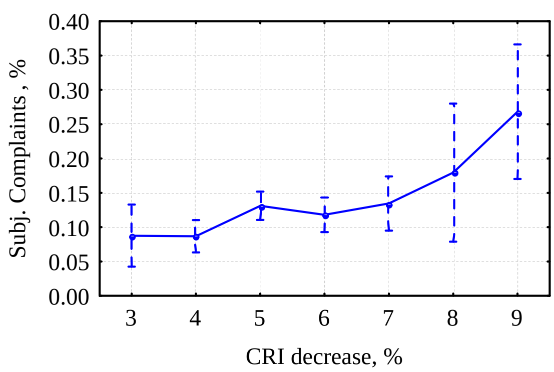

Fig. 4. CRI effect on SPPC (±95% CI).

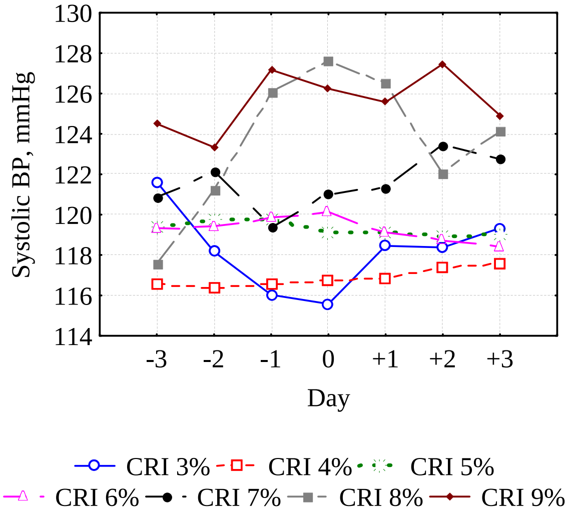

Fig. 5. CRI effect on SBP before, during and after CRI decreases.

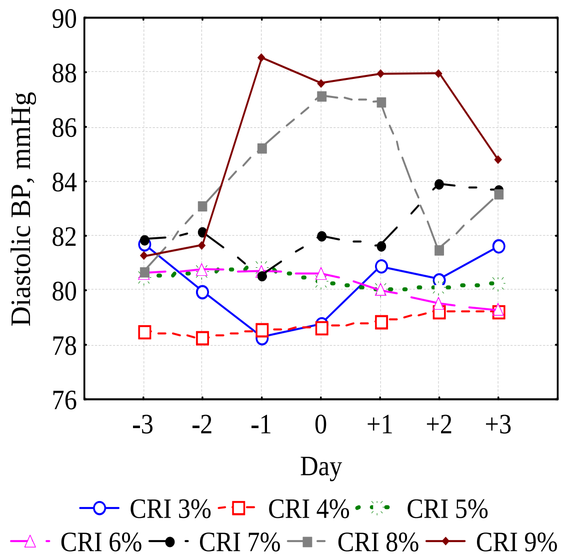

Fig. 6. CRI effect on DBP before, during and after CRI decreases.

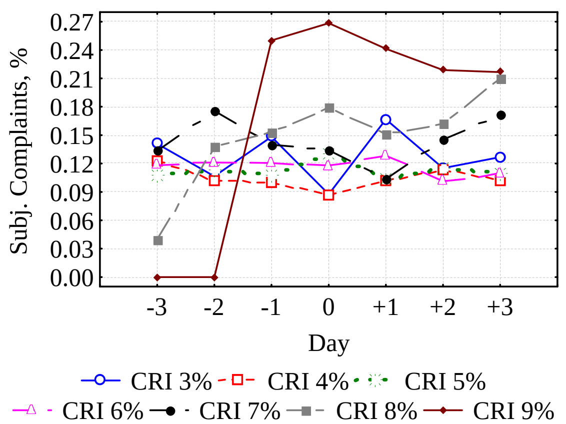

Fig. 7. CRI effect on SPPC before, during and after CRI decreases.

ANOVA revealed statistically significant influence on SBP and DBP (p=0.00) from -3rd day till +3rd day of different CRI decreases. Fig.5 and Fig.6 show dynamic of SBP and DBP for the different CRI decreases on the days before (-), during (0) and after (+) different variations in CRI. It was established by Post hoc analyses and it can be seen in Fig. 5 and Fig. 6 that SBP and DBP mean values of the group increased significantly from -1st till +3rd day when CRI decreased with 8-9% and ABP was high also on the days, before, during and after CRI decrease with 7%.

It was established by ANOVA statistically significant influence on PP not only on 0 day (p=0. 010) but also on +1st day (p=0.023) and on +2nd day (p=0.05). The mean PP value of the group was highest from -1st to +3rd day when CRI decreased with 8% and on -3rd and +3rd day of CRI decrease with 9%.

HR was not significantly affected on the days before, during and after CRI decreases.

ANOVA revealed statistically significant influence on SPPC on 0 day (p=0.002), on +1st day (p=0.01) and on +3rd day (p=0.009). Reported subjective complaints in the group were largest from -1st to +3rd day of CRI decrease with 9% (Fig. 7).

Discussions

The examinations performed and the results obtained revealed that physiological and psycho-physiological state of the examined group were affected by CRI variations. It was established that SBP, DBP, PP and reported SPPC in healthy volunteers under consideration increased with the decrease in CRI and on the days before and after CRI decreases.

The fact that the group increased ABP on average with about 11% and 27% from the persons felt some psycho-physiological discomfort should not be neglected. The changes in ABP can be regarded as a kind of organism compensatory reaction as a consequence to environmental variations. However SPPC increment reveals that although of the attempts to compensate, a functional deficit of separate systems starts and it is shown in the different subjective complaints. The increase of ABP and SPPC deserve attention from a medical point of view and enhance biological, clinical and social importance of the influences examined.

Data rows on the basis of several millions medical events in Moscow and in St. Petersburg revealed significant influence of geomagnetic storms accompanied with CR FD on the myocardial infarction morbidity, brain strokes, car accidents and road traumas [13, 17-19]. The most remarkable and statistically significant effects were observed during days of geomagnetic perturbations defined by the days of the declining phase of FD in CRI [20]. During these days the average number of traffic accidents, infarctions, and brain strokes increased respectively with (17.4±3.1)%, (10.5±1.2)% and (7.0±1.7)%. More studies are needed to confirm the trends obtained for the changes in human physiology and cardio-vascular morbidity and mortality.

Conclusions

- The results obtained indicate that human physiological and psycho-physiological status can be affected by CRI decreases.
- Systolic and diastolic blood pressure, pulse pressure and subjective psycho-physiological complaints of the examined healthy volunteers increased with the decrease of cosmic rays intensity.
- Significant changes in the heart rate of the examined persons under different comic rays intensities were not established.
- Arterial blood pressure values of the group and reported subjective psycho-physiological complaints were highest from -1st till +3rd day of the largest decreases in cosmic rays intensities.
- Performing such investigations at different latitudes and longitudes will be helpful for clarifying the relationships between space weather parameters and human health. It might be useful for timely application of different countermeasures (pharmacological, regime and preventive measures) to avert the probable unfavorable physiological reactions, especially for sensitive and vulnerable persons.

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