

*Originalni članci/
Original articles*

REVIEW OF STUDIES ABOUT SPACE
WEATHER EFFECTS ON HEALTHY
PERSONS*

PREGLED STUDIJE O UTICAJU VREMENA
NA ZDRAVE OSOBE*

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Ključne reči

Solarna aktivnost, Geomagnetna
aktivnost, fiziološko stanje, krvni priti-
sak, promenljivost pulsa

Abstract

A review of collaborative studies about probable effects of space weather on healthy volunteers at middle latitudes during different stages of solar activity (SA) cycle has been performed. Results revealed that the average values of arterial blood pressure (ABP), heart rate (HR) and heart rate variability (HRV) parameters of the examined healthy volunteers at different geographic places vary under geomagnetic activity (GMA) increases and cosmic ray intensity (CRI) decreases and on the days preceding, during and following geo-effective solar events.

INTRODUCTION

All living beings are inextricably bound up with the environment. Man has evolved and accommodated to the natural factors. Sudden and sharp changes in our surroundings are accompanied by respective adaptation reactions. It is well known that meteorological variations affect our functional status. Similar effects have been established for space weather using different parameters as solar activity (SA), geomagnetic activity (GMA) and cosmic rays (CR). Our team has performed several investigations in the field and participated in the analyses of such data and results at different geographical regions situated at middle latitudes. The purpose of this article is to compare and generalize the analyzed and published results obtained from the investigations of healthy subjects during different cycle phases of SA and GMA.

Conducted investigations

Examinations may be divided into four groups taking into consideration locality of healthy volunteers and phases of solar activity.

1. The first group consisted of 86 functionally healthy volunteers. They were examined in Sofia, Bulgaria every working day during maximal SA and GMA (autumn in 2001 and spring in 2002). Arterial blood pressure (ABP) and heart rate (HR) were measured. Data about subjective psychophysiological complaints (SPPC) were gathered (1-8).

2. The second group was examined every working day, including Saturdays for 2 years (2006 - 2008) during declining SA phase in Baku, Azerbaijan. Electrocardiograms

(ECG) of healthy volunteers were registered. HR and RR-intervals from ECGs were analyzed (9-12).

3. Physiological parameters of 4018 Slovak aviators, obtained during their regular medical checks for 9 year period (1994 - 2002), spanning minimal, increasing and maximal SA were analyzed. ABP and HR were measured in rest as well as under different degrees of physical load (13-15).

4. Physiological registrations of healthy volunteers in Sofia during declining SA phase were also performed (16-18):

4.1. A group of 14 functionally healthy subjects was examined in the spring of 2009 in Sofia. ABP, SPPC and 5-minutes ECGs were registered.

4.2. ECGs of two healthy volunteers for a whole year period (2008 - 2009) were registered and analyzed. The volunteers performed 5-minutes ECG registrations twice daily: in the morning (immediately after awakening) and in the evening (before falling asleep). ECGs had 5-minutes length to provide reliable data for heart rate variability (HRV) analyses. HR is the number of heart contractions and HRV is the variation of these contractions, i.e. RR-intervals variations in ECG.

RESULTS

1. Results from the group of 86 volunteers in Sofia during solar maximum

Results from these investigations (1-8) revealed that systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP) and SPPC were statistically significantly increased with GMA increase. The average values of the

group were higher by about 10% and 1/3 from the examined subjects had reported SPPC during severe geomagnetic storms.

Physiological parameters variations were registered from the day before until two days after geomagnetic storms development. Fig. 1 shows SBP dynamic of the group.

Similar changes in physiological parameters (SBP, DBP, PP and SPPC) were established at cosmic rays intensity (CRI) decrease. They were observed on the days before, during and after registered Forbush decreases, Fig. 2.

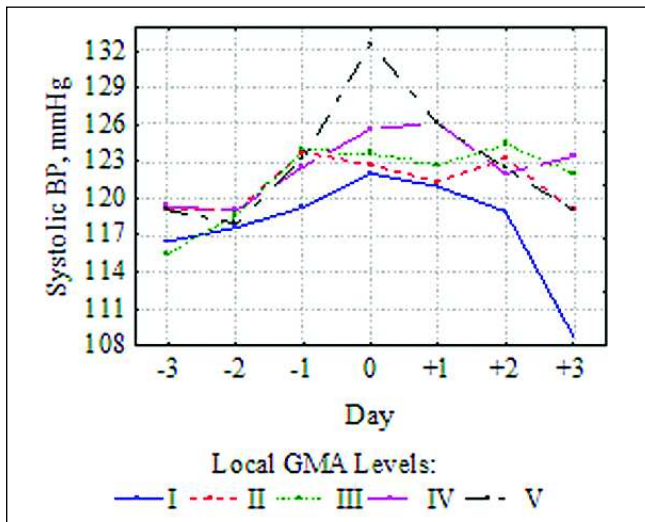


Fig. 1. GMA effects on SBP on the days before, during and after geomagnetic storms

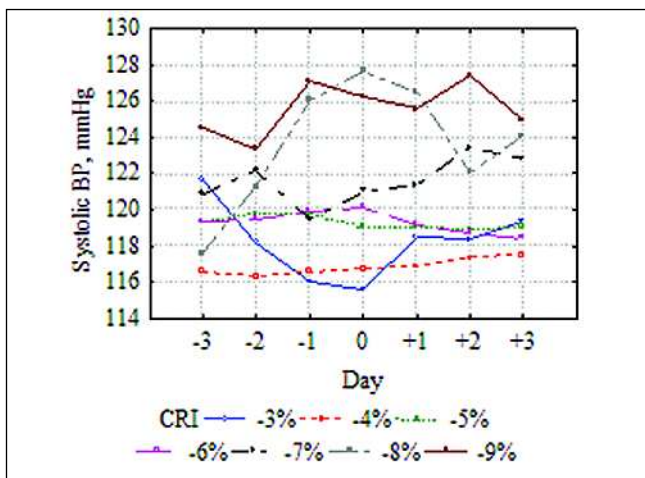


Fig. 2. CRI effects on SBP on the days before, during and after CRI decreases

The following conclusions can be drawn from the investigations of healthy subject in Sofia during solar maximum:

- Average values of SBP, DBP, PP and SPPC increased during geomagnetic storms and there was a quantitative exposure-response relation between increment of physiological parameters and geomagnetic field (GMF) – the more GMF intensity was, the more average values of physiological parameters increased.

- Variations in physiological parameters under GMA changes were not only statistically significant but biologically significant too: ABP and PP increased above 10% and percentage of the persons with SPPC reached 30% under changes of all of geomagnetic indices under consideration.

- The changes obtained in the examined physiological parameters were registered from the day before until the second day after geomagnetic storms development.

- Similar variations in the physiological parameters were established for CRI decreases.

2. Results from ECGs of Baku volunteers during declining solar activity cycle

Statistically significant effects of GMA on HR were not established as it was for the HR of Sofia volunteers. A trend for decreasing the group average value of HR on the days of

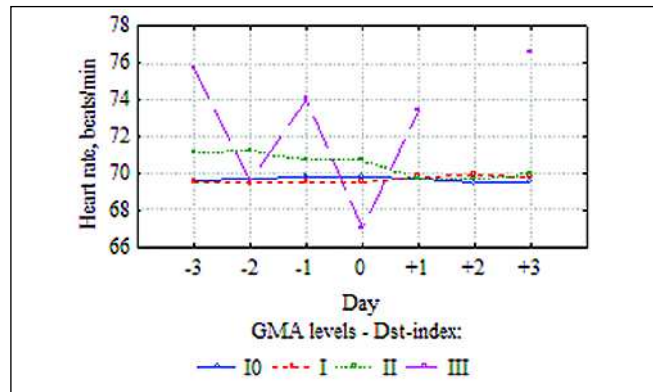


Fig. 3. GMA effects on HR on the days before, during and after geomagnetic storms

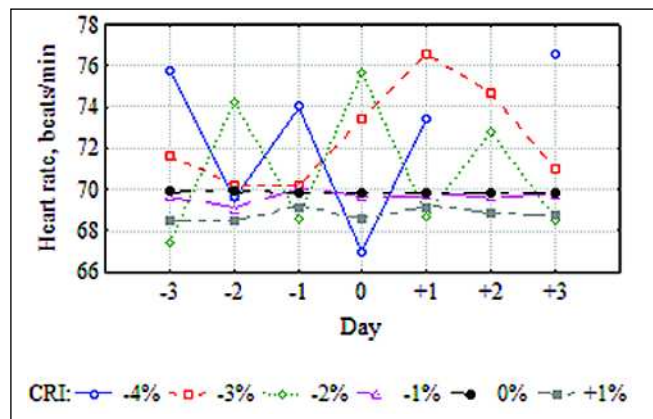


Fig. 4. CRI effect on HR on the days before, during and after CRI variations

the registered storms was revealed. However it is interesting that there were HR peak increases on the preceding and following days, Fig. 3.

It appears that HR varies significantly and obtains peak values for high GMA as well as for the largest CRI decreases which were registered during the examination period, Fig. 4.

Detailed analyses (9-12) of ECG data of Baku volunteers during declining SA cycle can be summarized as follows:

- It has been shown that GMA and CRI variations could be considered as one of the indicators of space weather, which play a role in regulating environmental factors in human homeostasis, particularly, cardio-vascular health state.

- The effects were more pronounced for
 - high levels of GMA (when geomagnetic storms occur) and
 - strong CRI decreases.

3. Results from Slovak aviators group

It was obtained that the physiological parameters took their minimum value at high GMA levels and at strong CRI decreases, Fig. 5. Exception was DBP, which was maximal during strong CRI events.

Considering the days of geomagnetic storms development results revealed that all of the physiological parameters had peak fluctuations immediately around the days of moderate and major storms. Fig. 6 shows dynamic of DBP in rest (without physical load) of the group.

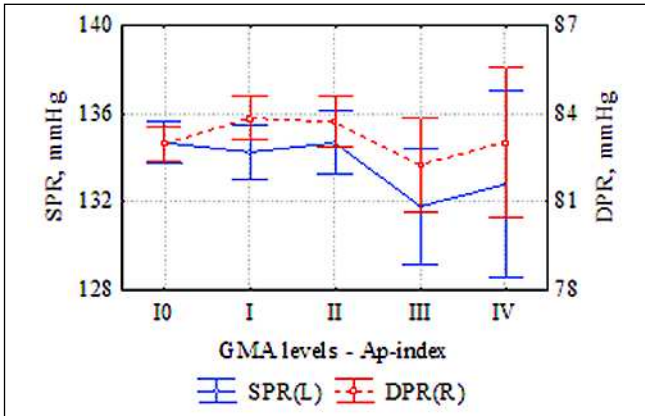


Fig. 5. GMA effect on SBP and DBP in rest ($\pm 95\%$ CI)

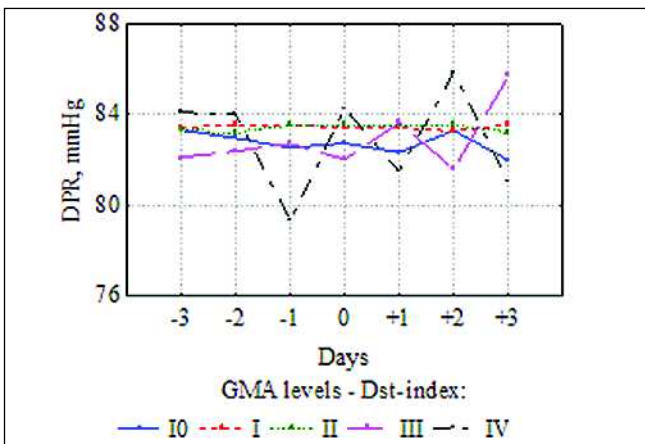


Fig. 6. GMA effect on DBP before, during and after geomagnetic storms

Analyses of the CRI effects showed that on the days before Forbush decreases physiological parameters decreased and after the respective days they increased.

Elaborated analyses (13-15) pointed to the following conclusions:

- High GMA levels were associated to HR, SP and DP decrease on the days of geomagnetic storms.
- Strong CRI decreases were associated to HR and SP decrease but DP increase.
- HR, SP and DP varied significantly on the days before, during and after increased GMA and CRI decrease.
- For moderate and major storms the sharp decrease, noticed on the days before or during geomagnetic storms, was usually followed by a sharp increase on the days after the storms. In some cases peak increases or decreases on different days for the same GMA levels were registered. The first trend concerns mainly HR and SP parameters, while the second refers to DP parameters.

- For the strongest Forbush effects the decrease of HR, SP and DP parameters, noticed on the days before CRI decreases, was usually followed by an increase on the days after CRI decreases.

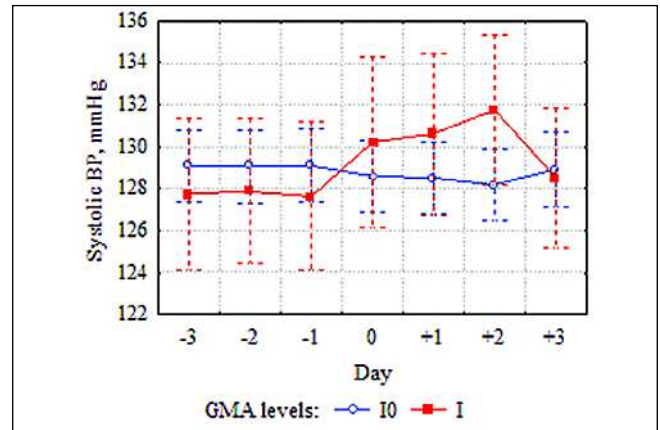


Fig. 7. GMA effects on SBP of the group on the days before, during and after geomagnetic storms ($\pm 95\%$ CI)

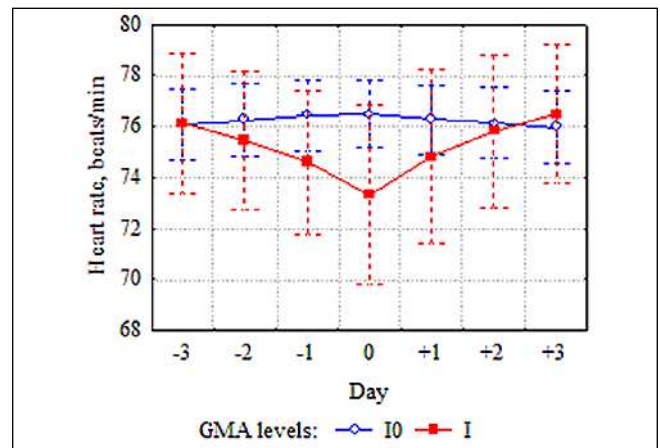


Fig. 8. GMA effects on HR of the group on the days before, during and after geomagnetic storms ($\pm 95\%$ CI)

4. Results from Sofia's volunteers during declining solar activity cycle

4.1. Group of healthy volunteers

The average SBP, DBP and SPPC values of the group increased from day 0 to +2nd day of the registered weak storms during the period of examinations, Fig. 7. However there was a trend for decrease of HR of the group on the day of weak geomagnetic storms, Fig. 8.

Although HRV parameters of the group were not statistically significantly affected by the weak storms, they varied significantly on the days immediately before, during and after weak storms.

4.2. Results from ECGs data for a period of one year

It is interesting that both persons did not reveal quantitative linear dependence on the geomagnetic storms with different intensities. Both subjects increased HR during major storms and on the days before and after the respective major storms and the 1st person increased HR also during weak storms. However both persons decreased HR during moderate storms (Fig. 9, Fig.10).

HRV indices for both persons had peak fluctuations on the days immediately before, during and after registered moderate and major storms.

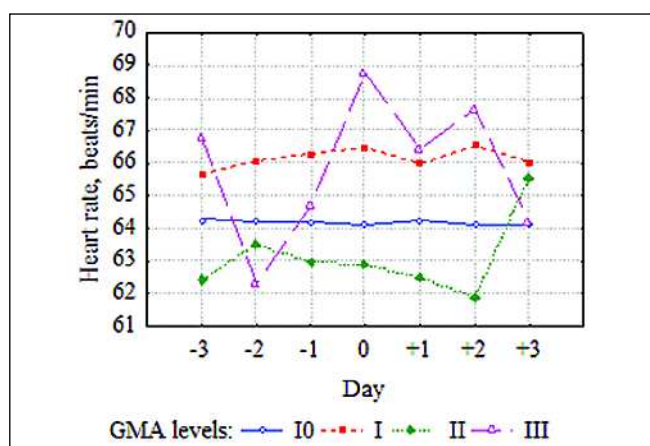


Fig. 9. GMA effects on HR of the 1st person on the days before, during and after geomagnetic storms

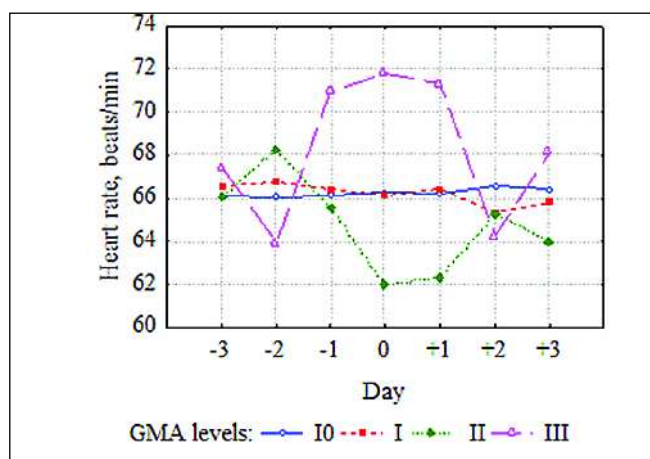


Fig. 10. GMA effects on HR of the 2nd person on the days before, during and after geomagnetic storms

Different responses of the two persons to GMA changes reveal that individuals try to accommodate to space weather variations. It supposes that the type of adaptation reaction depends on the personal features and initial state of the persons' functional state, which can vary from day to day according to every day activities and suggests that even healthy persons could be adversely affected from sharp environmental factors variations in some cases (when they are more physically and/or psychically loaded and respectively more vulnerable).

Detailed results of the examined volunteers in Sofia during declining solar activity cycle (16-18) can be summarized as follows:

- Results revealed strong variations of HRV parameters of the group from the day before (-1st day) till three days after (+3rd day) weak storms, which were registered during the time of investigation.

- ABP and SPPC of the group increased statistically significantly from 0 day till +2nd day. There was a trend for decrease in heart rate on 0 day.

- Personal everyday measurements of the two volunteers for a period of 1 year revealed that morning measurements were more sensitive to space weather variations in comparison to evening measurements. Both persons reacted in different way to geomagnetic storms with different intensities. They decreased heart rate during moderate storms but increased this parameter before, during and after major storms. HRV parameters varied significantly also on these days.

CONCLUSIONS

Comparison of the obtained results from the performed investigations of healthy persons at different geographical regions at middle latitudes and during different SA cycle phases lead to the following conclusions:

1. The results from physiological examinations during different stages of solar activity cycle reveal different dependences but all related to adaptation variations of physiological parameters towards physical environment factors on the days before, during and after geo-effective solar events.

2. The results suggest that healthy people manifest an adaptation reaction to accommodate to space weather variations. This reaction is not threatening to their physiological and cardio-health state but within the normal range. However persons with diminished compensatory abilities are more vulnerable to environmental factors' variations and it would be useful to be aware to take precaution measures in time to avert negative physiological reactions and in this way to avoid probable clinical consequences.

3. The results show that further investigations should be performed in this direction. The determination of the impact degree of the solar activity factors on the cardio-vascular parameters will make it possible to recommend under which changes of the respective factors it would be desirable to apply counter-measures. More investigations are needed to confirm these adverse effects and to determine those heliogeophysical factors features which most strongly affect human physiology state. If the effects of space weather are confirmed in different examinations at various latitudes and longitudes then it would help for timely applying a prophylactic measures to avert unfavorable reactions of vulnerable persons.

Sažetak

Dat je pregled kolaborativnih studija o mogućem uticaju vremena na zdrave volontere na srednjim nadmorskim visinama u toku različitih faza solarne aktivnosti (SA). Rezultati su otkrili da srednja vrednost arterijskog krvnog pritiska (ABP), puls (HR) i promenljivost pulsa (HRV), parametri pregledanih zdravih volontera sa različitih geografskih područja, variraju sa porastom geomagnetne aktivnosti (GMA) i opadanjem intenziteta kosmičkog zračenja (CRI).

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