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ORIGINAL PAPER

Space weather hazards and their impact on human cardio-health state parameters on Earth

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Abstract Recent multi-disciplinary heliobiological and biometeorological researches reveal that the human organism is sensitive to environmental physical activity changes and reacts to them through variations of the physiological parameters of the human body. In this study, electrocardiograms of functionally healthy persons, who were digitally registered at the Laboratory of Heliobiology located in the Medical Centre INAM (Baku, Azerbaijan), were studied in relation to different levels of cosmic ray activity and geomagnetic field disturbances. In total, 1,673 daily digital data of heart rate values and time series of beat-to-beat heart rate intervals (RR intervals) were registered for the time period July 15, 2006–March 31, 2008, which includes the period of December 2006, when intense cosmic ray events and strong geomagnetic disturbances occurred. The statistical significance of the influence of geomagnetic activity levels and cosmic ray intensity variations on heart rate and RR intervals was estimated. Results revealed that heart rate increase and RR intervals variations were more pronounced for high levels of geomagnetic activity and large cosmic ray intensity decreases, whereas very small or even minimum cosmic ray intensity variations did not affect heart rate dynamics. Moreover, heart rate increased on the days before, during and after geomagnetic storms with high intensities and on the days preceding, and following cosmic ray intensity decreases.

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1 Introduction

During the last several decades, many scientists have intensively worked on the possible impact of space weather variations on living beings. Since the mid-twentieth century, different individual and group investigations conducted at national and international levels have studied (either basic or clinical) how the Sun, processes in the Earth's magnetosphere, geomagnetic and cosmic ray activity can affect the physiological and cardio-vascular health state of humans (Kleimenova and Troitskaia 1992; Oraevskii et al. 1998; Dorman et al. 2001; Zhadin 2001; Cornelissen et al. 2002; Palmer et al. 2006; Dimitrova et al. 2009b; Babayev et al. 2012).

The possible influence of geomagnetic activity (GMA) and cosmic ray intensity (CRI) variations either on the human cardio-vascular state through variations of physiological parameters, such as heart rate (HR) and arterial systolic and diastolic blood pressure (Usenko et al. 1989; Stoupel et al. 1995; Ghione et al. 1998; Dimitrova 2008a, b; Dimitrova et al. 2009a), heart rate variability (Cornelissen et al. 2002; Oinuma et al. 2002) and the central and vegetative nervous system through changes of the human brain's functional state and psycho-emotional state (Babayev and Allahverdiyeva 2007) or on the frequency of myocardial infarctions, brain strokes and sudden cardiac deaths (Stoupel et al. 2005; Stoupel et al. 2006; Stoupel et al. 2007a) is being widely investigated.

Specifically as it is mentioned in the paper by Dimitrova (2008b), the mean systolic and diastolic blood pressure, as measured for a group of 86 healthy volunteers in Sofia (Bulgaria), statistically significantly increased during high GMA and CRI decrease. These results indicated that while the dynamics of arterial blood pressure reveals a compensatory reaction of the human organism for adaptation, HR for healthy people (particularly, at middle latitudes) can be regarded as a stable physiological parameter which is not so sensitive to environmental changes (Dimitrova et al. 2009a). Furthermore, it is found that the influence of the geomagnetic disturbances on the human health seems to vary from men to women (Stoupel et al. 2005; Dimitrova 2008a), and for people taking medications because of cardio-vascular complaints (Dimitrova 2006; Dimitrova 2008a).

A similar study was conducted for a group of aviators in Kosice (Slovakia) for the time period 1994–2002. Human physiological parameters (daily mean values of HR and arterial systolic and diastolic blood pressure) were analyzed in relation to GMA (using Ap and Dst geomagnetic indices) and CRI variations (Papailiou et al. 2011a, b, 2012). Results revealed that diastolic and systolic pressure decrease is related to high GMA levels (Papailiou et al. 2011b), while strong CRI decreases are accompanied by systolic pressure parameters decrease and diastolic pressure parameters increase (Papailiou et al. 2012). Furthermore, the decrease in blood pressure during and on the days before strong geomagnetic storms and large CRI decreases was usually followed by an increase in the days after the events, apart from cases where peak increases and decreases on different days for the same levels of GMA were registered, mostly for diastolic pressure parameters (Papailiou et al. 2011b, 2012). Heart rate is also connected to geomagnetic disturbances and CRI variations. Specifically, GMA increase and CRI decrease are associated to HR decrease and strong HR variations (similar to arterial blood pressure dynamic) on the days before, during and after the changes in the considered space weather factors (Papailiou et al. 2011a).

Stoupel et al. (2005) studied the possible links between the monthly numbers of acute myocardial infarction (in the pre-troponin analysis era) in general, in women and man separately, with solar, geomagnetic and cosmic ray activity. A significant inverse correlation with solar activity and GMA indices and a correlation with the accompanying cosmic ray activity level were found. Recent investigations (Stoupel et al. 2006; Stoupel et al. 2007a) conducted for heliobiological data from Baku (Azerbaijan) for the time period from 2003 to 2005 have revealed that the number of sudden cardiac deaths and the incidents and pre-admission mortality from acute myocardial infraction increased on the days of the highest and the lowest daily levels of GMA as well as on the days with high levels of cosmic ray activity, recorded by the ground based neutron monitors.

Moreover, on the basis of statistical data on several million medical events in Moscow and in Saint-Petersburg, a sufficient influence of geomagnetic storms (accompanied by a Forbush decrease in CRI) on the frequency of myocardial infractions and brain strokes was found (Villoresi et al. 1995). The most remarkable and statistically significant effects have been revealed for the declining phase of the Forbush decrease, when the average number of infarctions and brain strokes increased by (10.5 $\pm$ 1.2) % and (7.0 $\pm$ 1.7) %, respectively (Dorman 2005).

Concerning the geomagnetic and cosmic ray activity levels and their relation to the human cardio-health state, in this paper, “direct indicators” of these potential influences were considered. Direct indicators are physiological parameters, which can be objectively verified and which are acquired either in vivo directly on the subject (i.e., heart rate and its variability) or in vitro by laboratory diagnostics or tissue investigations. It should be noted that most of the “direct indicators” also vary significantly with factors other than GMA (Palmer et al. 2006).

In this paper, three collaborating scientific groups from Athens (Greece), Baku (Azerbaijan) and Sofia (Bulgaria) have studied the potential effects of environmental, physical activity changes (geomagnetic field disturbances and CRI variations through Forbush decreases) on the cardio-health state of functionally healthy humans. A modern heliobiological and cardiologic experiment conducted at a middle latitude region during the descending and near-minimum phase of 11-year solar activity cycle (when cosmic ray activity increased) provided the digital data of electrocardiograms which are used in this study. The investigation focuses on how HR dynamics and RR intervals (the time elapsing between two consecutive RR waves in the electrocardiogram) could be influenced by variations in GMA and CRI.

2 Data and methods

2.1 Medical data

The relevant heliobiological (medical) measurements were conducted with a permanent group consisting of functionally healthy men and women (average age of the group members was 31.6 years) from Baku, Azerbaijan (geographic coordinates: latitude: 40° 23′ North; longitude: 49° 51′ East). Digitized electrocardiograms were registered during one and the same daytime (morning) on working days and Saturdays in the Laboratory of Heliobiology located in the Medical Centre INAM (Baku), from July 15, 2006 to March 31, 2008. In total, the number of obtained digital recordings, which were subjected to analysis, was 1,673 and referred to such cardiologic parameters as RR intervals (time series of beat-to-beat HR intervals or HR period in ms), minimal RRmin, maximal RRmax, average RRavg and HR values.

In order to minimize the effects of other parallel objective and subjective factors (environmental conditions, artificial electromagnetic fields, etc.), the registrations were conducted in a special isolated room, which was designed for medical examinations, providing also the possibility for full relaxation of the persons examined. None of the members of the group were informed about current space weather conditions before and during the measurements. In addition to all mentioned above, the physiological and psycho-physiological state of these persons was also taken into consideration, and in case of complaints (stress, emotional experiences, an additional pathology—influenza, cold, etc.), their measurements were neither conducted nor considered. These small and rare gaps did not significantly affect the results of the experiment.

2.2 Geomagnetic activity data

The geomagnetic Dst-index data from the World Data Centre for Geomagnetism, Kyoto (http://swdcwww.kugi.kyoto-u.ac.jp/) were used in this study for the considered period. GMA was divided into four levels (I0, I, II, III) according to the average daily Dst-index values as shown in Table 1. This table also presents the corresponding number of HR and RR measurements for each GMA level. Level "I0" (positive values for Dst-index) was introduced because for the time period under study, there were quite many days with very low GMA. Inclusion of these very low levels of GMA in our study is also based on the aforementioned results that very weak fluctuations or almost the lack of fluctuations in the geomagnetic field can also have adverse effects on the human health state (Palmer et al. 2006; Stoupel et al. 2007a). During the considered period, a major space weather event was recorded on December 15, 2006 when Dst-index had a value of −99 nT and the CRI decrease was approximately −4 %.

Similar separation/gradation (I0, I, II, III, IV) is shown in Table 1 for the other GMA index used in this study, the Ap-index. These data were handled from the Space Weather Prediction Centre at NOAA, Boulder, USA (http://www.swpc.noaa.gov/ftpmenu/indices/old_indices.html).

2.3 Cosmic ray data

Daily values of pressure-corrected data of the hadronic component of the CRI obtained from the Neutron Monitor Station (Super 6NM-64) of the University of Athens (geographic coordinates: latitude: 37° 58′ North; longitude: 23° 47′ East) were used. This

Table 1 Dst-index and Ap-index levels and values and the corresponding number of measurements of cardiologic parameters

Ap/Dst levels	Dst-index values, nT	Number of measurements	Ap-index values	Number of measurements
I0	$Dst \geq 0$	494	$Ap < 8$	986
I	$-20 < Dst < 0$	966	$8 \leq Ap < 15$	409
II	$-50 < Dst \leq -20$	208	$15 \leq Ap < 30$	248
III	$Dst \leq -50$	5	$30 \leq Ap < 50$	21
IV			$Ap \geq 50$	9

station is located at altitude of 260 m above sea level and detects particles with a cut-off rigidity of 8.53 GV. It has been operational since November 2000 providing high quality real-time CRI data to the Internet (http://cosray.phys.uoa.gr). These data have time resolutions of 1 h, 1 min and 1 s, and the statistical error is smaller than 0.3 % on hourly data (Mavromichalaki et al. 2001; Mavromichalaki et al. 2005). It is important to note that the latitudinal location of the Athens Station is quite close to the latitude of Baku, where the experiment was conducted.

Cosmic ray intensity data were normalized to the mean value of CRI for the time period July 15, 2006–March 31, 2008. CRI variations during the examined period ranged from −4 to +1 %. It denotes maximal decreases in cosmic ray activity up to −4 % and increases up to 1 %. CRI was divided into six levels by step of 1 %: −4 %, −3 %, −2 %, −1 %, 0 %, 1 %, respectively.

2.4 Statistical methods

The statistical method, the ANalysis Of VAriance (ANOVA) (statistical package STATISTICA, ver.6, StatSoft Inc., 2001), was applied to establish the statistical significance levels (p) of the effect of GMA levels and CRI variations on the HR and RRmin, RRavg and RRmax (for the whole group and for each person in this group). The effect of GMA levels and CRI variations up to three days before and after the respective events (geomagnetic storms development and CRI decreases and increases) on the examined HR and RR parameters (RRmin, RRmax and RRavg) was also investigated by the help of ANOVA and the method of superimposed epochs.

p values were calculated for the days before (−), during (0) and after (+) geomagnetic storms and CRI variations. 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. Different significant levels have different advantages and disadvantages; smaller *p* gives greater confidence in the determination of significance, but causes greater risks of failing to reject a false null hypothesis.

3 Results

The time period covered by the experiments referred to the descending and near-minimum phase of long-lasting solar activity cycle 23 and was characterized mainly by low GMA (Mavromichalaki et al. 2008). The most significant space weather event was registered on December 15, 2006 when Dst-index had a value of −99 nT and Ap-index reached 104. Meanwhile the CRI decrease was more than −4 % (Mavromichalaki et al. 2008; Papailiou et al. 2009). Nevertheless, it was quite interesting to investigate how HR dynamics and changes in RR intervals could be influenced by different (high- and low level) variations in GMA and CRI. The analyses have been performed for each person of the group separately and for the whole group (to study so called “collective effect”). In this paper, only selected and typical figures (either for separate persons or for whole group) are provided to describe the general picture. Results of analysis of a large amount of figures, which are not included in the paper because of the limited space, were used for the conclusions.

ANOVA was used for obtaining the significance levels (p) of the effect of GMA level and the percentage of CRI variations on HR and RR intervals. *p* values were calculated for the days before (−3rd, −2nd and −1st day), during (0) and after (+1st, +2nd and +3rd day) geomagnetic storms occurred, and CRI variations were registered.

Tables 2 and 3 show p values for CRI and GMA potential effect (significance levels: p values) on all physiological parameters for the days before (−), during (0) and after (+) CRI and GMA variations for those of the examined persons whose HR and RR intervals were statistically significantly affected by CRI and GMA variations on some of the days under consideration. RRavg for the majority of persons was statistically significantly affected by CRI variations mostly for the days before (−3rd and −2nd day), during (0) and after (+2nd day) the event. Statistically significant results also refer to parameters RRmin and RRmax on the days before (−3rd and −2nd day), during (0) and after (+1st, +2nd day) the event (Table 2). For GMA and geomagnetic indices Ap and Dst, mostly, the results for days −3rd and −2nd are statistically significant for all parameters (Table 3).

Figure 1 is an example for HR and RRavg dynamics in relation to CRI variations for one of the persons in the group (p4). For larger CRI decreases (from −3 to −2 % decreases), HR values were higher in contrast to RR intervals values, which decreased. RRmax and RRmin had the same behavior as RRavg for strong CRI decreases. Variations of HR and RRavg under CRI changes were about 21 % as it can be seen in Figure 1, and the results presented in Table 2 for day 0 show that these effects were statistically significant ($p = 0.0003$).

HR and RRavg variations in relation to GMA through Ap- and Dst-index levels (as they were divided in Table 1) revealed that higher GMA levels (GMA increase, i.e. Ap-index values increase and Dst-index values decrease) were accompanied with HR increase and RRavg decrease. More specific analyses revealed that HR increase and RR decrease are connected to high GMA (levels III and IV of the Ap-index classification and level III of the Dst-index classification). Figure 2 is an example of HR and RRavg dynamics for one of the persons in the group (p4) under GMA variations, estimated by Ap-index. As can be seen from Fig. 2 deviations of cardio-vascular parameters were about 11 %.

Analysis of HR variations before (−), during (0) and after (+) geomagnetic disturbances with different intensities and CRI variations for different individuals of the group revealed that HR of different persons had peak increments on some of the days before, during and after days with high GMA and CRI decreases (more than −2 %). HR dynamics for the whole group under changes of Ap, Dst and CRI levels on the days before (−), during (0) and after (+) occurrence of geomagnetic storms and Forbush decreases are shown, respectively, on Fig. 3. It appears that HR varies significantly and obtains peak

Table 2 Significance levels (p values) of CRI potential effect on all physiological parameters for the days before (−), during (0) and after (+) CRI variations

Days	p values (% CRI decrease)						
	$RRavgp_1$	$RRavgp_4$	$RRmaxp_4$	$RRminp_1$	$RRminp_4$	HRp_1	HRp_4
−3	0.03878*	0.03878*	0.19476	0.02936*	0.02936*	0.04109*	0.0003*
−2	0.01175*	0.00013*	0.01338*	0.01107*	0.00014*	0.02374*	0.0002*
−1	0.19345	0.19345	0.40637	0.16417	0.16417	0.21960	0.003*
0	0.03916*	0.00031*	0.00576*	0.08669	0.00026*	0.04282*	0.0003*
+1	0.06004	0.74668	0.69609	0.03539*	0.90353	0.11133	0.00007*
+2	0.02587*	0.00011*	0.00129*	0.03984*	0.00020*	0.05431	0.00012*
+3	0.13795	0.25258	0.46216	0.36634	0.46453	0.16539	0.0002*

* Statistically significant

p_i denotes examined person in the group

Table 3 Significant levels (p values) of GMA potential effect on all physiological parameters for the days before (−), during (0) and after (+) GMA variations

Days	p values (Ap levels)				p values (Dst levels)			
	$RRavgp_1$	$RRmaxp_7$	$RRminp_3$	HRp_1	$RRavgp_1$	$RRmaxp_4$	$RRminp_4$	HRp_1
−3	0.04688*	0.91999	0.56347	0.02306*	0.00382*	0.00905*	0.00414*	0.00138*
−2	0.01353*	0.00848*	0.00533*	0.00864*	0.00377*	0.25477	0.04496*	0.00320*
−1	0.49318	0.64871	0.82570	0.56138	0.84544	0.79558	0.53306	0.85588
0	0.41165	0.42060	0.52161	0.35169	0.67324	0.33487	0.04118*	0.77558
+1	0.29242	0.28428	0.76431	0.13997	0.06208	0.96717	0.96435	0.12495
+2	0.15321	0.31604	0.56264	0.23987	0.11469	0.35886	0.08748	0.18013
+3	0.50128	0.05294	0.00062*	0.71170	0.85522	0.79373	0.80154	0.85657

* Statistically significant

p_i denotes examined person in the group

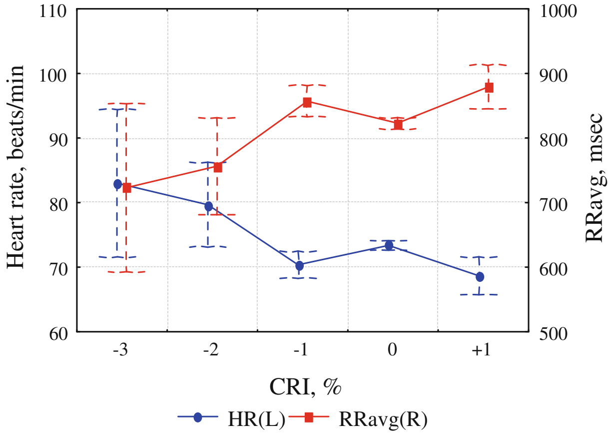

Fig. 1 CRI effect on heart rate and RRavg (±95 % CI) for the person p4 in the group. (Legend: "*L*" denotes Left axis, "*R*" denotes Right axis)

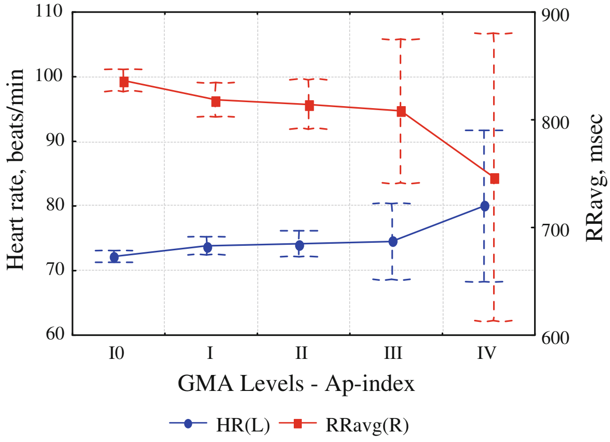

Fig. 2 GMA effect, estimated by Ap-index, on heart rate and RRavg (±95 % CI) for the person p4 in the group. (Legend: "*L*" denotes Left axis, "*R*" denotes Right axis)

values for high GMA as well as for the largest CRI decreases which were registered during the examination period. More specifically, as it is shown in Fig. 3 (upper panel) for Ap-index for level IV, HR slightly decreased on 0 and +1st day and then increased on +2nd day and reached its maximum value on +3rd day. For level III of the Ap-index classification, HR values were higher from −3rd to 0 day in comparison with the HR values on the days after these moderate storms. For lower levels of GMA, estimated by Ap-index (I0, I and II), no significant variations were registered. Regarding Dst-index level, there were peak increases of HR for the highest registered GMA level (level III) on −3rd, −1st and +1st day and decrease on 0 day (Fig. 3, middle panel). For level II of Dst-index classification, HR values from −3rd till 0 day were higher in comparison with the HR values on the days after these weak storms (+1, +2 and +3 day). HR is almost constant on all of the considered days for low and very low GMA, estimated by Dst-index. Moreover, HR varies significantly for strong CRI decreases (from −4 to −2 %) as can be seen in Fig. 3 (bottom

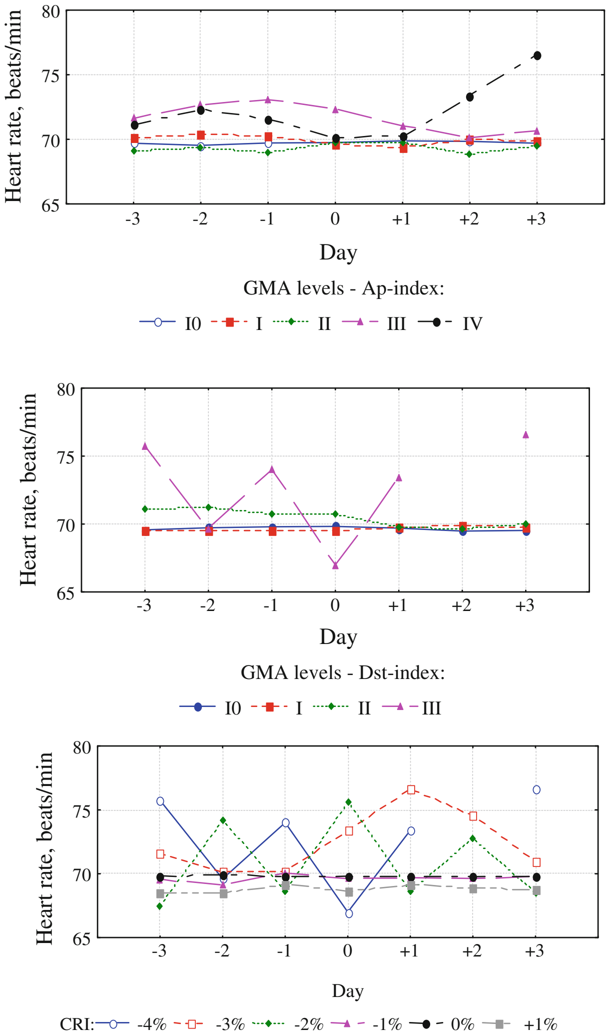

Fig. 3 GMA effect estimated by Ap-index (*upper panel*), Dst-index (*middle panel*) and CRI effect (*bottom panel*) on heart rate of the whole group for the days before (−), during (0) and after (+) the corresponding variations

panel). During strong CRI decreases (−4 and −2 %), HR had peak increases on some of the days before, during or after the CRI decrease, while for CRI decrease −3 % HR increased for the period from day 0 till +2nd day after the event.

Variations of RRavg were very similar: analysis of the RRavg variations for the whole group for the different levels of GMA (estimated by Ap and Dst-index) and CRI variations (%), respectively, on the days before (−), during (0) and after (+) changes in the studied environmental physical activity factors revealed that RRavg decreased significantly on some of the days before, during and after high GMA level and strong CRI decreases, which were registered during the examination period. Specifically for higher values of GMA level, the parameter RRavg shows decrease (Papailiou et al. 2010).

RRmin variations for the whole group on the days before (−), during (0) and after (+) changes in the monitored space weather parameters are presented, respectively, in Fig. 4. As it is seen, they were affected in a similar way as HR. RRmin had lower values on the days before, during and after moderate storms regarding Ap-classification (level III for Ap-index) in comparison with the RRmin values registered on the days before, during and after very low, low GMA and weak storms (levels I0, I and II). For the highest registered Ap-index level (level IV), RRmin decreased also on these days except on 0 and +1 day (Fig. 4, upper panel). Strong similar variations were also observed for the highest level of the Dst-index classification (level III) as it was shown in Fig. 4 (middle panel). RRmin dynamics in relation to CRI decreases are shown in Fig. 4 (bottom panel). As it has already been mentioned weak decreases (−1 %), no CRI variations (0 %) or weak positive variations (1 %) do not seem to affect significantly the physiological parameters while for CRI decreases $-2 \div -4$ % RRmin had significant peak variations.

RRmax variations for different levels of GMA (according to the Ap-index classification) are shown in Fig. 5 (upper panel). In general, RRmax had lower values for levels III and IV in comparison with the RRmax values for levels I0, I and II, especially on −1st and 0 day for level III and +2nd and +3rd day for level IV. Exception with increase of RRmax values was −1st and 0 day for level IV and +3rd day for level III. Similar behavior is noticed for level III of the Dst-index classification (Fig. 5, middle panel) and CRI decrease −4 % (Fig. 5, bottom panel). RRmax was significantly lower on the days before and after the biggest events except for the period from −2nd till 0 day when RRmax values were comparable with the values calculated for RRmax for the other levels of the studied factors.

It is interesting to note that on the day before (−1st day) the highest GMA (regarding both Ap- and Dst-index) and largest CRI decreases, RRmin and RRmax did not have unidirectional variation. It might be indicative for probable arrhythmia; however, additional examinations and studies should be performed to clarify this result.

4 Discussion and conclusions

Heliobiology is the branch of science that deals with the impact of solar activity and related effects on living organisms (Palmer et al. 2006; Babayev and Allahverdiyeva 2007). Heliobiological studies have shown that living beings, including humans, have the ability to adapt to normal variations of GMA (Dimitrova 2008a). But, any deviations from this normal level, either extremely high or extremely low fluctuations in the GMA, will undoubtedly have an effect on the brain, the cardio-vascular, nervous and other biological systems of living organisms (Palmer et al. 2006; Babayev and Allahverdiyeva 2007; Stoupel et al. 2007a).

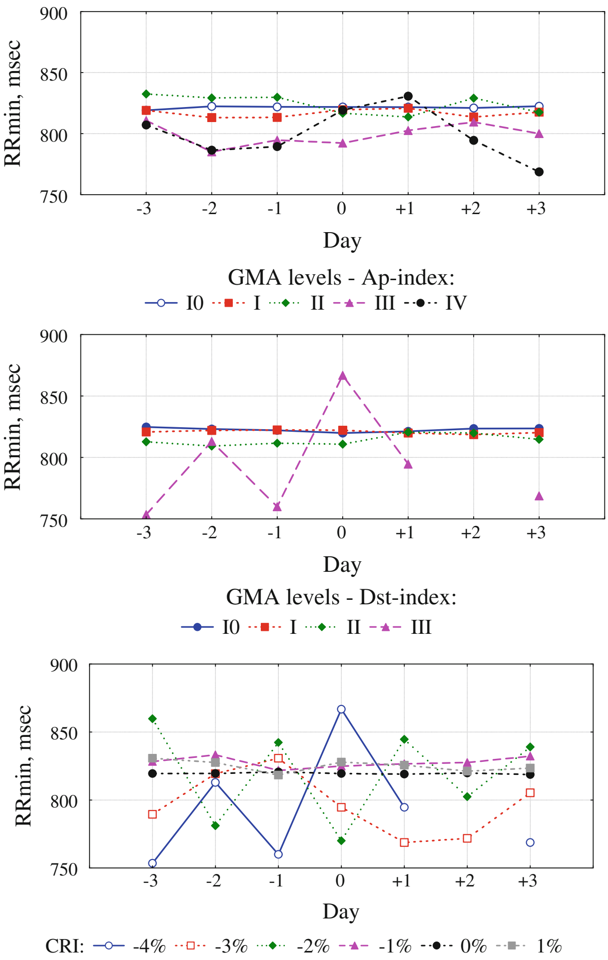

Fig. 4 GMA effect estimated by Ap-index (*upper panel*), Dst-index (*middle panel*) and CRI effect (*bottom panel*) on RRmin of the whole group for the days before (−), during (0) and after (+) the corresponding variations

The established changes in cardiologic parameters deserve attention from a medical point of view. They indicate that geomagnetic field and CRI variations might be related to cardio-vascular diseases morbidity and mortality as it has been shown by different indirect investigations using epidemiological medical data (Cornelissen et al. 2002; Stoupel et al. 2007b). For example, in Stoupel et al. (2007b) the monthly deaths, distribution for a period of 192 months in the Republic of Lithuania in relation to solar, geomagnetic and cosmic ray activity was studied. The number of monthly deaths (total, stroke, non-cardiovascular and suicides) significantly correlated to cosmic ray activity and inversely correlated to solar and geomagnetic activity. Cornelissen et al. (2002) studied mortality from myocardial infarction for a 29-year period in Minnesota and found an approximate 10.5-year cycle, similar to that of solar activity. They showed that the incidence of mortality due to myocardial infarction increased in Minnesota by 5 % during years of maximum solar activity compared to years of minimum solar activity (there is an additional risk of

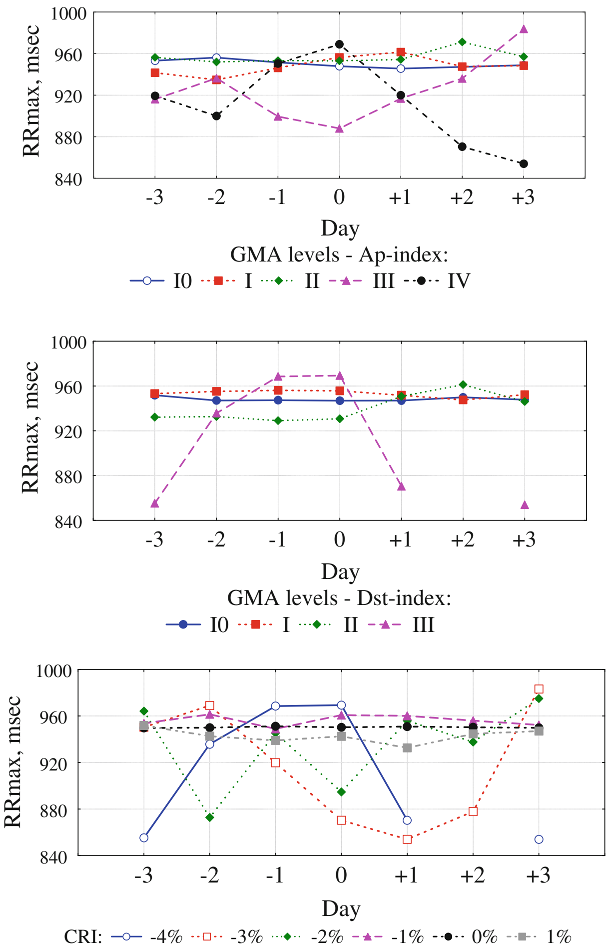

Fig. 5 GMA effect estimated by Ap-index (*upper panel*), Dst-index (*middle panel*) and CRI effect (*bottom panel*) on RRmax of the whole group for the days before (−), during (0) and after (+) the corresponding variations

myocardial infarction during solar maximum compared to solar minimum, which implies an additional risk during high levels of GMA).

Furthermore, previous studies have shown that systolic and diastolic blood pressure, pulse pressure and subjective psycho-physiological complaints of examined healthy volunteers (Dimitrova 2008b; Dimitrova 2009) as well as human HR (Mavromichalaki et al. 2008; Dimitrova et al. 2009a) increased under high GMA and strong CRI decreases.

This paper is an outcome of three different collaborative research teams and focuses on the possible relation between geomagnetic and cosmic ray activity and digitally measured human cardiologic parameters. 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 external (environmental physical activity) factors in human homeostasis, particularly, cardio-vascular health state. Moreover, CRI decreases together with GMA index (Ap- and Dst-index) variations have been analyzed in regard to HR and RR interval variations. RR intervals and HR showed opposite correlations which proved the reliability of conducted measurements. The most interesting and common result that has been revealed is that HR and RR interval variations appear to be connected to geomagnetic disturbances and CRI variations. The effects are more pronounced for high levels of GMA (when geomagnetic storms occur) and strong CRI decreases.

However, because the possible space weather conditions influence on human health is a rather sensitive subject, it is of great importance to conduct further complex and synchronic investigation of solar, geomagnetic and cosmic ray activity effects on human physiological and cardiologic parameters at different latitudinal and longitudinal areas and at different levels of environmental physical activity.

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