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ORIGINAL ARTICLE

Impact of space weather on human heart rate during the years 2011–2013

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Abstract During the last years a possible link between different levels of solar and geomagnetic disturbances and human physiological parameters is suggested by several published studies. In this work the examination of the potential association between heart rate variations and specific space weather activities was performed. A total of 482 individuals treated at Hippocratio General Hospital in Athens, the Cardiology clinics of Nikaia General Hospital in Piraeus and the Heraklion University Hospital in Crete, Greece, were assessed from July 2011 to April 2013. The heart rate of the individuals was recorded by a Holter monitor on a n hourly basis, while the hourly variations of the cosmic ray intensity measured by the Neutron Monitor Station of the Athens University and of the geomagnetic index Dst provided by the Kyoto Observatory were used. The ANalysis Of VAriance (ANOVA) and the Multiple Linear Regression analysis were used for analysis of these data. A statistically significant effect of both cosmic rays and geomagnetic activity on heart rate was observed, which may indicate that changes in space weather could be linked to heart rate variations.

Keywords Space weather · Cosmic ray intensity · Geomagnetic activity · Heart rate

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1 Introduction

It is known that there is a probable relationship between space weather and human physiological conditions, as it has been studied extensively. Cosmic Ray Intensity (CRI) and GeoMagnetic Activity (GMA) are considered effective indicators of space weather. The first one is expressed very well by different effects caused by the solar activity such as the Forbush decrease, which characterized by a sharp decrease of the CRI values, may be connected to human's health state (Dorman et al. 2001). On the other hand, the most common quantifying factor of GMA is the Dst index and low values of this index (< -50 nT) indicate a geomagnetic storm that can have effects on human health (Papailiou et al. 2011).

During the last decades many researchers have dealt with the potential relationship between geophysical parameters and cardiovascular homeostasis. Many studies have demonstrated that CRI and GMA are associated with variations in human physiological parameters such as heart rate (HR) and arterial blood pressure (Watanabe et al. 1994; Villoresi et al. 1998; Dimitrova 2008; Dimitrova et al. 2004; Mavromichalaki et al. 2008; Papailiou et al. 2011, 2012). Also, a link between the above indicators (GMA, CRI) with cardiovascular disease, including arrhythmias, ischemic heart disease and myocardial infarction, seems to be existed (Baevsky et al. 1997; Dorman et al. 2001; Cornelissen et al. 2002; Stoupel 2002; Stoupel et al. 2007a, 2007b; Palmer et al. 2006; Babayev et al. 2012). It has been indicated that the sudden cardiac death mortality is higher on the highest and lowest daily levels of GMA, while the monthly number of sudden cardiac mortality is inversely related to solar and geomagnetic activity (Stoupel et al. 2006). Furthermore, a decrease in parameters of heart rate variability has been determined in periods, which characterized by high levels of geomagnetic activity (Baevsky et al. 1997; Dimitrova et al. 2009).

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In addition, a temporal relationship has been suggested between the geomagnetic effects of the solar cycle and the cardiovascular incidents (Cornelissen et al. 2005). Moreover, myocardial infarctions and heart arrhythmias have been found to have relation with the 11-year cycle of the solar activity and an increase is noticed during the recovery phase of some intense geomagnetic storms (Katsavrias et al. 2013). Recently, other researchers have observed a relation between polarity reversal of solar magnetic field and various types of arrhythmias (Giannaropoulou et al. 2014; Mavromichalaki et al. 2017).

It is important to note that gender difference in atherogenesis, concomitant pathologies, like diastolic heart failure, hypertension, diabetes, heart rupture, outcomes in coronary revascularization are widely discussed (Stoupel et al. 2005). Women show higher risk in revascularization procedures, more heart failure and higher mortality in acute coronary syndromes. When geomagnetic and cosmic ray activity is correlated with the heart and related failures mentioned above it seems that in women those links are much stronger. In Stoupel et al. (2005) it is mentioned that 'like in many other fields, older women are more susceptible to environmental physical activity compared to younger men with the same pathology'.

A significant difficulty of biogeomagnetics is to determine those characteristics of solar and geomagnetic activity with the greatest effect on human health. Indices of interplanetary disturbances, which are connected to GMA and short-term CRI variations, are used for the research on biological rhythms variations. In Villoresi et al. (1994a, 1994b, 1998), Ptitsyna et al. (1996), Dorman et al. (1999) it is shown that Forbush decreases are the most sensitive indicators of the connection between geomagnetic field disturbances and health parameters, as incidence of ischemic strokes, myocardial infractions and vehicular traffic accidents. The most remarkable and statistically significant effects have been observed during days of geomagnetic perturbations defined by the days of the declining phase of Forbush decreases of cosmic ray intensity.

Forbush decreases of the cosmic ray intensity, which are connected to interplanetary disturbances, can be used as indicators of the relationship between the geomagnetic field fluctuations and health parameters (Dorman et al. 2001). The most important results are those concerning cardiovascular diseases and diseases of the nervous system, especially strokes, myocardial infarctions and traffic accidents as well (Villoresi et al. 1994a, 1994b; Ptitsyna et al. 1996; Dorman et al. 1999; Stoupel et al. 2009). It is obtained that the monthly number of acute myocardial infraction is significantly related to solar, geomagnetic and cosmic ray activity (Stoupel et al. 2005, 2007a, 2007b).

Moreover, the cosmic ray diurnal variation of CRI that has been found to be the variation of the CRI during the course of each day (Nagashima and Ueno 1971), following a sinusoidal wave and reaching its peak early in the evening (Mavromichalaki 1989). It is believed that it is caused by spatial anisotropies, outside of the Earth's atmosphere and geomagnetic field. The spiral magnetic field is rotated around the Sun hence the gas of the isotropic CR is shaken by the geomagnetic field, consequently acquiring a speed of several hundred km/s. In more detail this speed is greater than the speed of the Earth's orbit, so the intensity coming from the direction of 90°E of the Earth-Sun line is increased, while the intensity of the opposite direction is reduced. Aside from, several human physiological parameters display an entrain able oscillation of about 24 hours, known as the circadian rhythm. Additionally, heart rate has also been found to follow a circadian rhythm (Hsu et al. 1977; Deagute et al. 1991; Massin et al. 2000). Plasma catecholamine levels, and subsequently the heart rate, have been observed to be higher early in the morning (White 2001). An increased risk of adverse cardiovascular events is also associated with the morning hours. According to recent evidence, this connection might stem from the combination of the sleep-wake cycle and endogenous circadian rhythm, which modulate the cardiac function in humans, leading to increased cardiac vulnerability (Boudreau et al. 2012). Disturbances in cosmophysical parameters may also play a role in the observed variations on human heart rate, in addition to many intrinsic and extrinsic factors (Stoupel et al. 2005).

Despite the accumulating evidence regarding the impact of space weather on human's cardio-health state, there is a luck of plausible mechanisms explaining these conclusions and results yet. Taking into account that heart disease is the leading cause of mortality (Thom 1989; Murphy et al. 2012; http://www.cdc.gov/nchs/data/nvsr/nvsr60/nvsr60_04.pdf), the study of factors that may adversely affect cardiac functionality is of great importance. In this context, we tried to examine the possible association of the CRI variations and of the GMA disturbances with the human heart rate.

In this regard, we examined the potential relationship between the diurnal variation of CRI recorded at the ground based neutron monitors and heart rate obtained by the Holter monitors during the period 2011–2013. For this purpose, the hourly heart rate data of 482 individuals from three greek hospitals were assessed in respect with the respective CRI values recorded at the Athens Neutron Monitor Station. The geomagnetic disturbances and the occurred storms during the examined period were also examined.

2 Data and method of analysis

2.1 Medical data

A sample of 482 persons was assessed during the time period from July 2011 to April 2013. Hourly values of the heart rate were gathered during their treatment in the Cardiology clinics of the Hipokrateio General Hospital in Athens, the Nikaia General Hospital in Piraeus and the Heraklion University Hospital in Crete, Greece. The heart rate was monitored by using a Holter, which is an ambulatory electrocardiography device. The Holter records the heart rate on a 24-hour basis, when the patient conducts everyday life activities. Each one of these devices was placed on each patient for 24 hours independent if there were or not disturbances.

2.2 Cosmic ray intensity data

Hourly corrected for pressure values of the hadronic component of the CRI, recorded at the Athens Neutron Monitor Station (A.Ne.Mo.S.) of the Faculty of Physics of the National and Kapodistrian University of Athens were used. The Athens Neutron Monitor Station is a modern one offering high resolution real-time cosmic ray data to the Internet (http://cosray.phys.uoa.gr), while those are transferred every 1-min to the European High resolution Neutron Monitor Database—NMDB (http://www.nmdb.eu). This station is placed at the University Campus at 260 m above the sea level and detects particles with cut-off rigidity of 8.53 GV. The cosmic ray intensity data were normalized according to the relation

$$CRI = [CRI_{\text{obs}} - CRI_{\text{aver}}]/CRI_{\text{aver}}$$

CRI_{obs} is the observed CRI value and CRI_{aver} is the average value relating to the examined period. The normalized cosmic ray intensity values (%) regarding the examined period are shown in Fig. 1a. In addition, the Forbush decrease on 8th of March 2013 is presented in Fig. 1a. In this analysis, the total CRI values were distributed into five levels (0, 1, 2, 3, 4) corresponding to selected CRI intervals given in Table 1. The corresponding mean HR values in each level are also given in this table. A similar technique has been also used in previous studies, such as the one by Papailiou et al. (2012).

2.3 Geomagnetic activity data

The GMA during the examined period was analyzed by the use of the geomagnetic index Dst. These data were obtained from the World Data Centre for Geomagnetism, Kyoto, which provides online real-time data (http://wdc.kugi.kyoto-u.ac.jp/dst_realtime/index.html). Furthermore, the Dst index variations during the period from July 2011 to April 2013 are displayed in Fig. 1b. In this analysis, when Dst index is less than −100 nT it is reflected to be a geomagnetic storm (Papailiou et al. 2011). The geomagnetic storm of March 2013 that is resembled to the Forbush decrease of cosmic ray intensity is indicated in this Figure. For the purpose of investigation and examination, the GMA data were divided

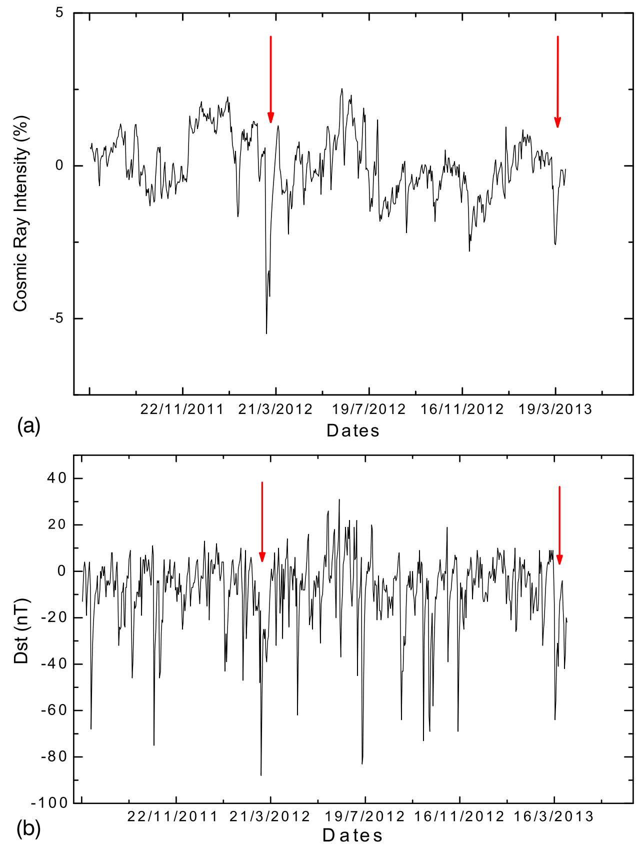

Fig. 1 **(a)** Time profile of the normalized daily CRI (%) recorded at the Athens Neutron Monitor Station during the examined period. Great Forbush decreases are indicated by *arrows*. **(b)** Time profile of the daily average Dst index values during the examined period. Geomagnetic storms are indicated by *arrows*

Table 1 The CRI and the Dst levels used in the ANOVA analysis are indicated. The respective number of measurements and the mean HR values are given

Levels	Intervals	Number of measurements	Mean HR (bpm)	CI 95%
Cosmic ray intensity				
0	$CRI \le -3\%$	285	75.38	73.57–77.19
1	$-3\% < CRI \le -1\%$	1571	71.84	71.06–72.61
2	$-1\% < CRI \le 0\%$	3381	70.10	69.61–70.60
3	$0\% < CRI \le 1\%$	3058	69.73	69.22–70.24
4	$CRI > 1\%$	2366	70.40	70.12–70.69
Dst index				
0	$Dst \ge 0$ nT	3813	70.83	70.36–71.31
1	-20 nT $< Dst < 0$ nT	4844	69.58	69.15–70.00
2	-50 nT $< Dst \le -20$ nT	1757	71.44	70.77–72.11
3	-100 nT $< Dst \le -50$ nT	272	71.67	69.91–73.42
4	$Dst \le -100$ nT	41	72.66	69.83–76.48

into five levels (0, 1, 2, 3, 4), as in the CRI data, according to Dst index values, given in Table 1. Finally, the corresponding HR values are also shown in this Table and the stratification technique has been also used by Mavromichalaki et al. (2012).

2.4 Statistical methods

At first, a univariate analysis was applied to evaluate the importance of our negative confounding factors alongside with the statistical methods of Analysis Of VAriance (ANOVA, http://www.statisticssolutions.com/manova-analysis-anova/) (Papailiou et al. 2012; Dimitrova et al. 2013) and of Multiple Linear Regression analysis (www.stat.yale.edu/Courses/.../linmult.htm) were applied to evaluate the effect of both cosmic ray intensity variations and geomagnetic activity on the heart rate variations. The respective levels of significance (p-values) were calculated and discussed.

In the applied regression models, the heart rate was taken as dependent variable, while the independent variables included CRI, Dst index, the time of data recording, and a unique patient identifier (to control for inter-patient variability).

What is more, the statistical packages SPSS (IBM SPSS Statistics 20) and STATISTICA (ver. 10, Stat-Soft INC., 2011), were used for the purpose of statistical analysis. The chosen level for statistical significance was set to $p < 0.05$, and the same value was used for interpreting the results. In more detail, different significant levels have several advantages and disadvantages; smaller p gives greater confidence in the determination of significance, however it causes greater risks of failing to reject a false null hypothesis.

3 Results

In this study, a total of 482 individuals was examined, among which 275 (57%) men, 198 (41%) women and 8 (2%) without information. There was no significant difference between men and women regarding the heart rate mean values. The mean heart rate value for the men during this period was found to be 69 ± 12 bpm, while for the women it was found 71 ± 12 bpm with a statistically significant p-value equal to 0.043. In spite of this evidence, it is significant to mention that from previous studies (Papailiou et al. 2009) it is outlined that there is a different behavior of the heart rate of men and women in connection with the cosmic ray intensity and the geomagnetic activity. Moreover, the correlation of the heart rate of individuals with the geomagnetic activity together with the cosmic ray intensity seems to be much stronger in women than in men. Also, it was found that for the examined group of people the 40% of women and only the 20% of men had a correlation coefficient over 0.25.

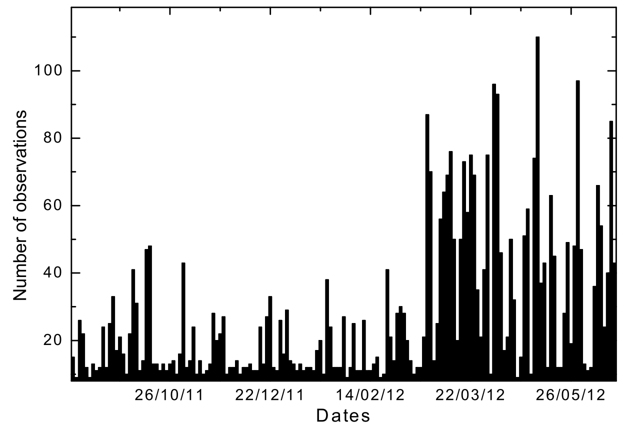

Fig. 2 Number of daily selected HR measurements from all the patients' observations during the period July 2011 to April 2013

In total, 10720 measurements of CRI, Dst index and heart rate for the time interval from the year 2011 to 2013 were recorded and analyzed. It is characteristic that the examined time period covers the ascending phase of the current solar cycle 24 reaching to its maximum in the year 2014. The time profiles of the CRI and the Dst index are presented in Figs. 1a and 1b, respectively. A Forbush decrease of cosmic ray intensity is recorded at neutron monitors started at the 8th of March 2013 and it is indicated by an arrow in this figure, the corresponding geomagnetic storm in the Dst index values is also indicated in Fig. 1b. The frequency of the heart rate observations used in this study is illustrated in Fig. 2. It seems that the number of data during the last year was higher than the first one.

Additionally, in a bivariate analysis approach, cosmic ray intensity was correlated to the heart rate with a correlation coefficient −0.024 and p-value equal to 0.011. Dst index was correlated with the heart rate as well, getting a correlation coefficient −0.024 and p-value equal to 0.012. According to the multiple linear regression model, after adjusting for day time and individual patient, both CRI and Dst index were found to be independently associated with HR. The cosmic ray intensity was negatively correlated to the heart rate with a regression coefficient: −0.025 (95% CI: −0.179, −0.025) and p-value 0.009, also Dst index was negatively correlated with HR with a coefficient: −0.022 (95% CI: −0.035, −0.003) and p-value 0.023.

Finally, applying the ANOVA analysis approach, it was indicated a statistically significant negative correlation between HR and CRI ($p < 0.01$). The mean heart rate values in the different cosmic ray intensity levels are presented in Fig. 3. It was noticed that when approaching from the lowest levels to higher ones that means that the mean cosmic ray intensity is increased, the heart rate was decreased. Also, a significant association between HR and Dst index variations was observed ($p = 0.05$) as it is shown in Fig. 4. Also, the

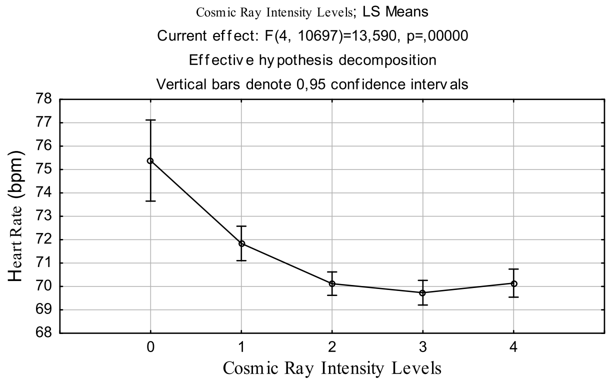

Fig. 3 Distribution of the mean HR values for the different CRI levels

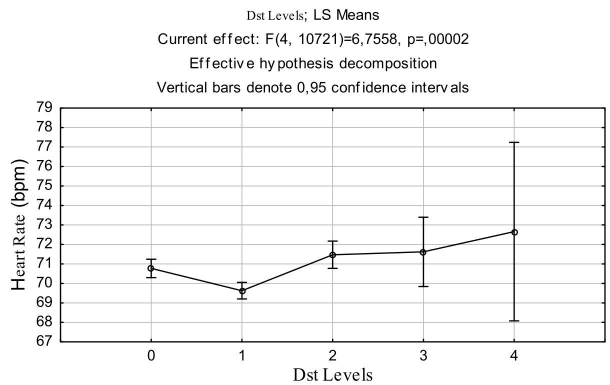

Fig. 4 Distribution of the mean HR values for the different Dst index levels

analysis pins that in the lowest levels of Dst index that correspond to low geomagnetic activity, the variations of the heart rate were minor.

Disturbed periods: Data were also categorized according to the intensity of space weather events. This period is characterized by a number of Forbush decreases (Fd) of cosmic ray intensity, but not strong events. These events were caused by flares with importance ≤ M-flare and only three of them were caused by X-flares (18/2/2011, 8/3/2012, 8/3/2013). The amplitude of the effects ranges from 2% to 12%. The greatest one is that one of March 2012 presented in Fig. 5. This Forbush decrease was due to an X-ray flare (X5.4) occurred on 07/03/2012 at 00:02UT in AR 1429. It was followed by a halo coronal mass ejection (CME) that was recorded by SOHO/LASCO (cdaw.gsfc.nasa.gov) on 07/03/2012 at 00:24UT with a linear speed of 2684 km/s. A sudden storm commencement took place, when the shock arrived on Earth on 08/03/2012 at 11:05UT. It was recorded at the neutron monitors with an amplitude of 11.7 % during the time period from March 5 to March 21, 2012 and therefore that period was isolated and analyzed separately (Fig. 5). The Dst index reached the value of −131 nT on 09/03/2012 that means a geomagnetic storm was occurred. During that time period, a total of 38 patients were examined, corresponding to 912 HR observations using a Holter ambulatory device. In the performed multiple linear regression analysis, a statistically significant negative correlation (regression coefficient: −0.138, $p < 0.01$) between HR and the respective CRI values was observed. The case of this Forbush decrease is presented in Fig. 5.

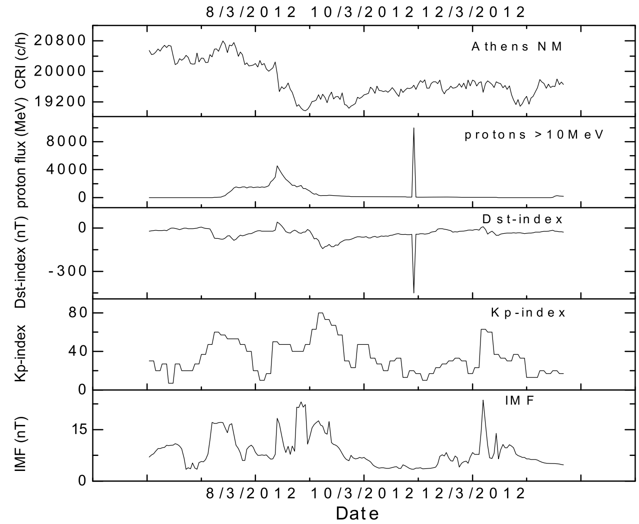

Fig. 5 Cosmic ray intensity, proton flux, Dst-index, Kp-index and IMF during the Forbush decrease of March 2012, are presented

Evidently, a small Forbush decrease was detected from September 21st to October 1st, 2011 with amplitude of 4.4% recorded at neutron monitors was isolated and analyzed, as well. Moreover, the decrease was due to an M7.1 flare that happened on 25/09/2011 and was followed by a halo CME with a linear speed of 704 km/s. Also, the Dst index touched the value of −101 nT on 26/09/2011, which means that a geomagnetic storm was occurred. During this period, a total of eight patients were examined, corresponding to 192 HR measurements. Using the multiple linear regression analysis there was found no statistically significant correlation ($p = 0.167$) between HR and the relevant CRI values. This result indicates that we cannot give yet a certain conclusion concerning these studies.

Diurnal variation: The whole sample of our medical data was examined also on a daily basis independently for each case. In this study, it is observed that there are cases that show hourly values of the heart rate with a daily variation as well as the CRI and others that seem to have opposite behavior. Some remarkable instances both of these cases are showed in Figs. 6 and 7. In Fig. 6a an example of a man on 7th of March 2012 with a similar behavior of CRI and heart rate is illustrated. In contrast, in Fig. 7a a case of a woman on 2nd of October 2012 that appears opposite behavior of CRI and heart rate is illustrated. The corresponding correlation diagrams are presented in Figs. 6b and 7b giving a significant correlation coefficient, respectively.

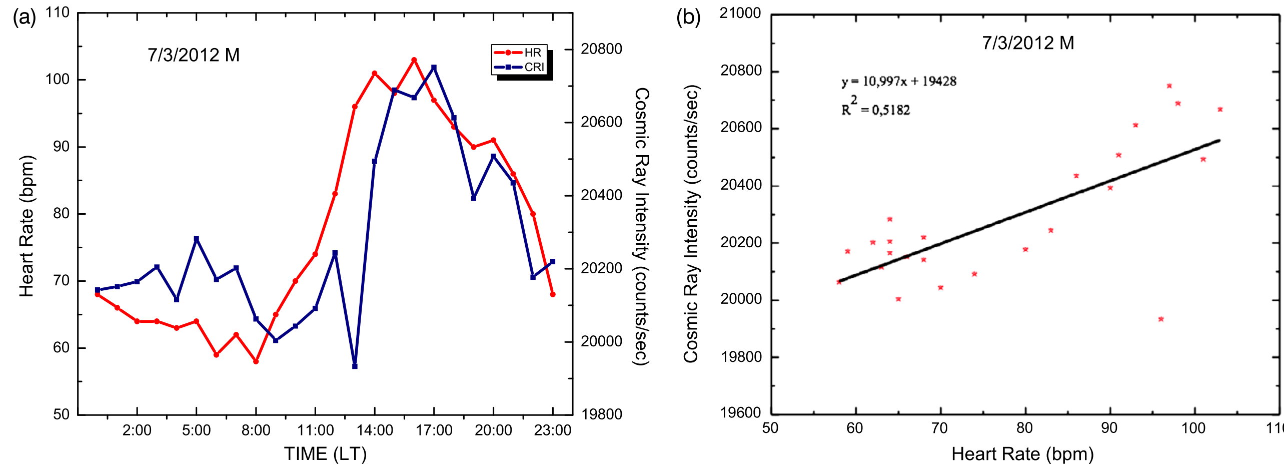

Fig. 6 **(a)** Hourly values of CRI and HR of a man on 7th of March 2012 are presented. **(b)** Correlation diagram of the CRI and HR values for the individual of the Fig. 6(a)

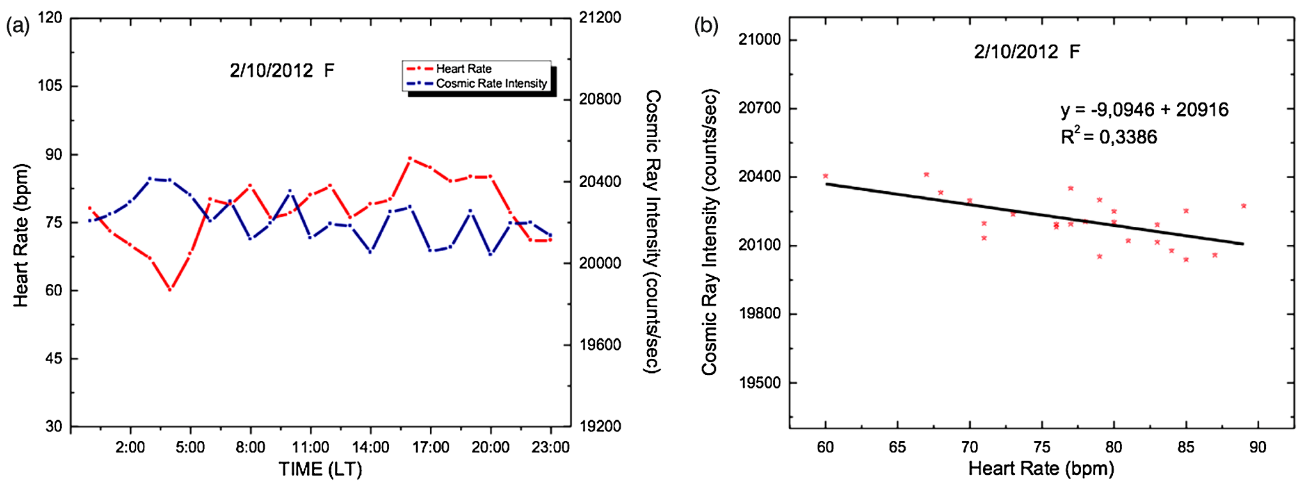

Fig. 7 **(a)** Hourly values of CRI and HR of a woman on 2nd October 2012, are given. **(b)** Correlation diagram of the CRI and HR values for the individual of the Fig. 7(a)

Furthermore, Fig. 8 illustrates the mean heart rate of our cases 24-hour measurements of the Holter device as well as of the corresponding cosmic ray intensity all over the examined period. The expected diurnal variation of cosmic ray intensity is indicated. It is noteworthy to note that the same behavior is appeared in the heart rate values. This is in accordance with the above described model of the diurnal variation (Mavromichalaki 1989). The statistical results of this study are summarized in Table 2.

4 Discussion

An increasing number of studies have concluded a link between human health state and space weather parameters (Cornelissen et al. 2002; Stoupel 2006; Babayev and Allahverdiyeva 2007; Dimitrova et al. 2009). Moreover, a significant number of these researches focuses on the impact of cosmic ray activity on human physiological state (Stoupel et al. 2007a, 2007b; Papailiou et al. 2009, 2011) since cosmic ray activity could be considered as one of the regulating external/environmental factor in human homeostasis (Stoupel et al. 2006).

Likewise, the findings of this study are in line with previous studies (Mavromichalaki et al. 2008, 2012). The researchers observed that the effects on HR were stronger in the low levels of Dst (when geomagnetic storms exist) and in high cosmic ray intensity decreases, such as Forbush decreases. Furthermore, it was observed that heart rate increased on the days before, during and after geomagnetic storms and on the days before and following the cosmic ray intensity decreases.

Papailiou et al. (2011) examined the variations of heart rate, geomagnetic activity and cosmic ray intensity in a

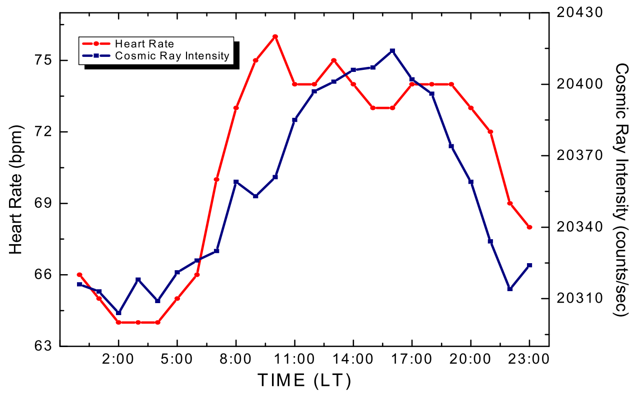

Fig. 8 The distribution of the average hourly values of HR and CRI over the day during the period from July 2011 to April 2013 is presented

Table 2 Statistical results of our study

A. Bivariate analysis

	Correlation coefficient *r*	*p*-value
CRI–HR	−0.024	0.011
Dst–HR	−0.024	0.012

B. Multiple linear regression

(a) Quiet period

	Correlation coefficient *r*	*p*-value
CRI–HR	−0.025	0.009
Dst–HR	−0.022	0.023

(b) Disturbed period

	Regression coefficient	*p*
03/2012	−0.138	<0.01
09–10/2011	no significant correlation	0.167

group of aviators (healthy volunteers). The authors determined that the cardiovascular function of the subjects was affected by both geomagnetic activity and cosmic ray intensity variations. Moreover, morbidity and mortality caused by cardiovascular disease has been studied widely by many investigators. 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 solar activity cycle. It was shown that the frequency of mortality due to myocardial infarction increased in Minnesota by 5% during years of maximum solar activity compared to years of minimum solar activity. Another study conducted in the Republic of Lithuania, examined potential connections between space weather parameters including solar, geomagnetic and cosmic ray activity and monthly deaths number (Stoupel et al. 2011). Conclusively, the study together with the examiners determined that there is a relationship between cosmophysical activity and timing of death.

However, not all studies have identified a statistically significant relationship between geomagnetic activity and heart rate. A study examining the effect of geomagnetic activity on some cardiovascular parameters found that low geomagnetic activity was associated with disturbances in heart functionality such as higher levels of growth hormone and 11-ketosteroids in the peripheral blood, more sudden deaths and higher rate of ventricular tachycardia. On the other hand, other studied parameters, incorporating hemoglobin level, electrolyte level, heart beat and pulse rate, were found not to be linked to the geomagnetic activity (Stoupel 2002). Similarly, another study conducted for about five consecutive years found no such association, although the investigators acknowledged several limitations in the study design (Ghione et al. 1998). An additional study examined the potential effect of geomagnetic activity on heart rate variability during exercise recovery and the conclusion was that there is no linear effect of geomagnetic activity on heart rate variability after the exercise (Weydahl et al. 2002).

Further, the effects of geomagnetic and cosmic ray activity on the heart rate parameters were examined separately since geomagnetic storms and FDs are two phenomena that are connected but could also evolve independently (Kudela and Brenkus 2004; Kane 2010). FDs are created by instabilities in the heliosphere, while Dst variations depend on the local situation in the magnetotail near the Earth (Kane 2010). Usually, high cosmic ray activity (strong decreases in CRI) is related to strong GMA (corresponding Dst depressions); However, as already stated, when CRI decreases it is not always accompanied by strong GMA variations and, respectively, large Dst depressions are not marked by CRI decreases.

It should be noted that, in order to reach definitive conclusions about the association (or not) of geomagnetic activity with heart rate, larger studies with long follow up, which might include more data about geomagnetic activity events, are warranted. Multicausality and multicomplexity should be taken under consideration in the design of such studies, since various approaches focus only on individual parameters (not adjusting for possible cofounders) may mislead research needed to clarify the impact of space weather parameters on health. Therefore, even though cosmic ray activity and geomagnetic activity variations, in some cases, seem not to be the main contributors in causing specific illnesses, further research is necessary to examine their precise role in the development of disease.

From the results of this study it was established and suggested that there is a statistically significant link between space weather parameters and human heart rate. Throughout the examined period it was included the ascending phase and the maximum period of the solar cycle 24 starting in

January 2009 and peaking in April 2014; it is considered to be an active period in the less active cycle in the past 100 years, according to NASA's predictions (Hathaway 2012). In this regard, there were limited observations corresponding to days with strong geomagnetic disturbances (low Dst index values) in the study, and the extrapolation of our findings regarding the relationship between HR and Dst to such a setting may be limited. The same behavior is appeared in the cosmic ray events, although a total of 280 events occurred during this period.

What is more, studying some limited cases of Fds of CRI and their association with HR variations we cannot give a certain conclusion concerning the disturbed periods.

5 Conclusions

In this study the potential association between Space Weather variations, indicating by the cosmic ray intensity and the geomagnetic activity parameters with the human heart rate, was examined. A statistically significant inverse relationship between cosmic ray intensity and heart rate on an average daily basis was observed. Regarding the Dst index values were negatively associated with the heart rate, indicating an impact of the geomagnetic parameters on human heart rate. It should be noted that in all the applied statistical methods the correlation coefficients were comparable.

It is concluded that examining the cases of individuals separately on a diurnal basis a percentage of 30% of our cases were statistically significant. It is noticed that during the examined Forbush decrease periods (March 2012, September 2011 etc.) the correlation coefficients were found to be higher than in the overall approach. This lightly reflects an increased impact of geomagnetic parameters on human heart rate during disturbed periods.

As it is depicted from our results, cosmic ray variations and geomagnetic disturbances could be indicators of Space Weather that might play a role in regulating cosmophysical factors in human cardio-health state. In this regard, the detailed comprehension of the profound mechanisms underlying this association may be helpful in detecting the pathophysiology, prevention, and treatment of cardiovascular disease, which is complex and multifactorial. Further studies with a greater sample of measurements are warranted to precisely determine the role of space weather on human health. What is more, in the last couple of years there is an increasing amount of evidence connecting biological effects to solar and geomagnetic conditions.

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