Potential Effects of Heliogeophysical Activity on the Dynamics of Sudden Cardiac Death at Earth Middle Latitudes

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Abstract: Limited studies exist on comparing the possible effects of heliogeophysical activity (solar and geomagnetic) on the dynamics of sudden cardiac death (SCD) as a function of latitude on Earth. In this work we continue our earlier studies concerning the changing space environment and SCD dynamics at middle latitudes. The study covered 25 to 80-year old males and females, and used medical data provided by all emergency and first medical aid stations in the Grand Baku Area, Azerbaijan. Data coverage includedthe second peak of Solar Cycle 23 and its descending activity years followed by its long-lasting minimum. Gradation of geomagnetic activity into six levels was introduced to study the effect of space weather on SCD. The ANalysis Of VAriance (ANOVA) test was applied to study the significance of the geomagnetic activity effect, estimated by different geomagnetic indices, on SCD dynamics. Variations inthe number of SCDs occurring on days preceding and following the development of geomagnetic storms were also studied.

Results revealed that the SCD number was largest on days of very low geomagnetic activity and on days proceeding and following geomagnetic storms with different intensities. Vulnerability for males was found to be higher around days of major and severe geomagnetic storms. Females, on the other hand, were more threatened around days of lower intensity storms. It is concluded that heliogeophysical activity could be considered as one of the regulating external/environmental factors in human homeostasis.

Keywords: Solar Activity; Geomagnetic Activity; Human Cardio-Vascular State; Sudden Cardiac Death;Analysis of Variance

Introduction

Effects on space- as well as ground-based technology and human health induced by solar activity (SA) are generally known as space weather. Since the mid-20th century heliobiology, the branch of science that deals with the impact of solar activity on living organisms, has evolved and been pursued on national, regional and international levels. Three main areas of medical research in this field can be distinguished by study type: basic (experimental), clinical, and epidemiological research. Furthermore, clinical and epidemiological studies can be sub-classified as either interventional or non-interventional (Röhrig et al., 2009).Earlier heliobiological studies (Platonova, 1974) were sparse, but in the last 20-25 years or so there has been a significant increase not only in the number but in the quality of such studies as well. The majority of these more recent studies have focused on the association between SA, geomagnetic activity (GMA), cosmic ray activity (CRA) and the functional state of the human cardiovascular system andrelateddiseases (heart and blood vessel diseases), considering both morbidity and mortality. Literature reviews covering studies performed during the last decades on the effects of GMA on human cardiovascular health can be found in Palmer, Rycroft, and Cermack (2006) and Babayev et al. (2012). More specifically, individuals and groups (e.g. Breus et al., 2002; Breus and Rapoport, 2003; Palmer, Rycroft, and Cermack, 2006) have studied how variations on the Sun, solar wind and cosmic ray intensity, can influence the terrestrial magnetosphere and how this may affect the human cardiovascular health state.

The considered problem is very complicated becausealongside medical-biological issues, factors such as meteorological, social, and anthropogenic, as well as disturbances and variations in external factors related to the space environment, can potentially also affect a human organism and its cardio-health state. Specifically, lifestyle factors are considered to be very important in management of heart disease (Chiuve et al., 2011). Therefore great care needs to be taken in order to collate geophysical and physiological-biological-medical data.

Furthering our knowledge and understanding of the relationship between SA and GMA and human health would allow to be better prepared beforehand for any future space weather event and its impacts at any location, on Earth or in space, including current and future space missions. Such measures will be successful only if we better understand the basic processes of space weather impacts on the Earth and humans. Chizhevskiy(Chizhevskiy, 1973) suggested almost a century ago that abrupt changes in the helio-geophysical environment could be a destructive factor in respect to the vital activity of biological systems and this speculation has been studied in different investigations, particularly concerningthe human cardio-health state(Stoupel, 1999; Cornelissen et al, 2002; Vladimirskii, Timurants and Martynuk, 2004; Stoupel et al., 2004; Palmer, Rycroft, and Cermack, 2006).The individual cardio-health state is very important to the physiological stability of the organism.Sudden cardiac death (SCD)is the largest cause of natural death and responsible for half of all heart disease deaths (Chugh et al., 2008; Chiuve et al., 2011).It is described as death of cardiac origin occurring inan one hour time limit, without prodromes (preliminary symptoms) (Myerburg and Castellanos, 1997; Priori and Zipes, 2006). The incidence of SCD increases with age in both men and women(Zipes and Wellens, 1998;Brugada, 2010).

Perceived and studied in a global manner "space weather – human health" relations have global implications for humans on Earth. However, it is important to investigate and understand how these relations may differ as a function of geomagnetic latitude. Unfortunately, limited studies on comparing the possible effects of SA and GMA on humans at high, middle and low latitudes exist. Space weather effects on human cardio-health state are generally well studied for high latitudes; meanwhile for middle latitudes they are usually conducted either sparsely or cover comparatively short periods of SA. Only during the last 15-20 years or so have collaborative papers started to appear enabling conducting simultaneous/coordinated researches and comparison of results for different latitudes. Such so called collaborating "clusters" exist in Russia, Israel, USA, Bulgaria, Belgium, Azerbaijan, Greece, Japan, Italy, Ukraine, so on (for details, we refer the reader to: Breus et al., 2002; Breus and Rapoport, 2003; Palmer, Rycroft, and Cermack, 2006; Babayev et al., 2012). There are reports on researches conducted even at low latitudes (most lacking zones), such as Saudi Arabia (Alexander et al., 2016). The majority of these studies conducted at all three latitudes reveal a significant relation between space weather changes and dynamics of cardio-vascular morbidity and mortality.

Furthermore, research studies indicate different effects of SA cycle stages on human cardio-health. Influence of space weather on the cardiovascular system of a human being during various solar cycle phases was recently studied within the Russian-Ukrainian "Geliomed" project (Samsonov et al, 2014a).Daily continuous data are very important in epidemiological studies increasing the reliability of the obtained results. The declining phase of the solar cycle differs (Kane, 2009)from the ascending one by its phase length and the intensity of solar extreme events (e.g. coronal mass ejections (CMEs)) and related phenomena such as geomagnetic storms.

Our previous studies (Dimitrova, Babayev and Crosby, 2009; Dimitrova et al., 2009a) investigated the influence of the geomagnetic field (GMF) intensity, estimated by different geomagnetic indices, and the effects of solar drivers (e.g. CMEs) of geomagnetic storms on SCD mortality on the basis of three years (01/01/2003 – 31/12/2005) using daily medical data (788 in total SCD incidences) taken from a middle-latitude geographical location. In the work presented in this paper we further our studies by expanding the period under consideration. SCD dynamics, on the basis of almost seven years (15/11/2002 – 30/06/2009) of daily data (2110 in total SCD incidences),is analyzed.The data are continuous, which allows referring the obtained results mainly to the effects of the declining phase of Solar Cycle 23. Additionally, the selected time period corresponds to one of socio-economic stability in Azerbaijan.The data and methods used in our current study are described in Section 2. Results are presented in Section 3 followed by a section where they are discussed. The paper ends with a conclusion section.

Material and Methods

For this work a daily medical database was created jointly by the Department of the Sun and Physics of Solar-Terrestrial Relations of the Shamakhy Astrophysical Observatory and the Statistical Department of the Baku Central Emergency and First Medical Aid Station (EFMAS) with participation of cardiologists from the Research Institute for Cardiology (RIC) under the Ministry of Public Health of the Republic of Azerbaijan. The database includesdeaths from all causes registered according to World Health Organization (WHO) standards in 21 EFMASs spread over a big urban area (the Absheron Peninsula located at middle latitudes (40023' N, 49052' E), including Baku, the capital city of Azerbaijan, with more than 3 million inhabitants), as well as in the Baku Central EFMAS. The Baku city railway polyclinic No2 and the RIC were partially involved in these studiesand based on joint work provided monitoring results.

More than 1,500,000 emergency calls were subjected to "cleaning" from deaths due to non-cardiovascular reasons (cancer, traffic/road and other accidents, suicide, stroke, etc.), and the remaining relevant data (2110 in total SCD incidences) were analyzed. EFMAS services register all cases of sudden deaths as accurately as possible, including un-witnessed ones. This work is very difficult and sometimes impossible due to lack of information. Even classifications based on clinical circumstances can be misleading and often impossible, because 40% of sudden deaths can be un-witnessed (Priori and Zipes, 2006). We relied on the final diagnosis established by EFMAS and relevant hospital services applying commonly-used relevant SCD post-mortem examinationssuch as determination of ventricular fibrillation (brought on by acute coronary ischemia) and chronic high-grade stenosis of segments of a major coronary artery (supplies the heart muscle with its blood supply), as well as pre-mortem medical methods such as left ventricular hypertrophy (leading cause of sudden cardiac death in the adult population) and other methods of examination (e.g. lifestyle, longstanding high blood pressure which has caused secondary damage to the wall of the main pumping chamber of the heart (the left ventricle), as well as genetic syndromes). A generally accepted definition of SCD is natural death due to cardiac causes, heralded by abrupt loss of consciousness within an hour of the onset of acute symptoms. Time and mode of death are unexpected; the term

Table 1. Gradation of GMA levels characterized by Dst and Ap-index.

GMA Index (nT)	I0 very low GMA	I quiet GMA	II weak storm	III moderate storm	IV major storm	V severe storm
Dst	Dst≥0	(0÷-20)	[-20÷-50)	[-50 ÷-100)	[-100÷-50)	Dst≤-150
Ap	Ap<8	[8÷15)	[15 ÷30)	[30 ÷50)	[50 ÷ 100)	Ap ≥ 100

Table 2. Number of SCDs as a function of GMA level defined by Ap- and Dst-index values for the studied time period.

Parameters / **GMA Levels**	**Ap**		**Dst**	
	Days	**SCD**	**Days**	**SCD**
I0 very low GMA	1238	1163	517	445
I quiet GMA	612	494	1307	1160
II weak storm	368	295	500	448
III moderate storm	135	111	82	47
IV major storm	50	33	10	8
V severe storm	22	14	9	2

"unexpected" is the hallmark of the definition of SCD and four consecutivetime elements must be considered to satisfy clinical, scientific, legal and social considerations: prodromes, onset, cardiac arrest, and progression to biological death.This permits one to include a broad range of preceding clinical states, having different levels of risk as well as external factors such as space weather variations, when identifying the cause of death.

SCD data were separated from the initial data on cardiovascular-related deaths in accordance to the International Classification of Diseases and Related Health Problems, 10th revision (ICD-10, 2006, ISBN 978 92 4 154834 2), Code I46.1 (http://apps.who.int/classifications/icd10/browse/2016/en#/I46.1). Deaths due to diagnosed acute myocardial infarction are not considered in this paper. Data used included only reliably established cases of SCD within obvious limits, excluding cases of victims having non-favorable living and/or working conditions and non-healthy physical environments, and so on. The 1-hour definition was used for the majority of SCD cases, while a 24-hour definition was applied for unwitnessed deaths of victims known to be alive and functioning normally prior to being found.

To quantify different effects of GMA,geomagnetic indices (daily disturbance storm time (*Dst)*-index and planetary *Ap*-index) were extracted from OMNIWeb, NASA (http://omniweb.gsfc.nasa.gov/form/dx1.html). The effect of geomagnetic storm intensity on SCD was studied by dividing both indices into six intervals to represent the level of GMA (see Table 1).

Data (medical and space environment) were subjected to medical and mathematical/statistical analysis:

- Relevant correlation coefficients were calculated;
- Analysis of variance (ANOVA) was applied to check the significance of the GMF intensity effect on SCD dynamics;
- The effect of geomagnetic storms before and after their development on SCD dynamics was also investigated by ANOVA and by using the superposed epoch method;
- GMA impact up to 3 days before (-3rd) and 3 days after (+3rd) sharp changes in geomagnetic conditions was studied;
- Factorial ANOVA (2-way) was applied to study gender effects;
- The chosen level for statistical significance was $p \leq 0.05$;
- Statistical package STATISTICA (StatSoft Inc., version 6, 2001) was used for data visualization and statistical analyses.

Results

The number of days with different GMA levels according to Ap- and Dst-index values as defined in Table 1 and the respective number of SCD cases for the period under consideration are listed in Table 2. Fig. 1 shows geomagnetic indices (Dst and Ap) dynamics and the distribution of SCDs for average monthly data.

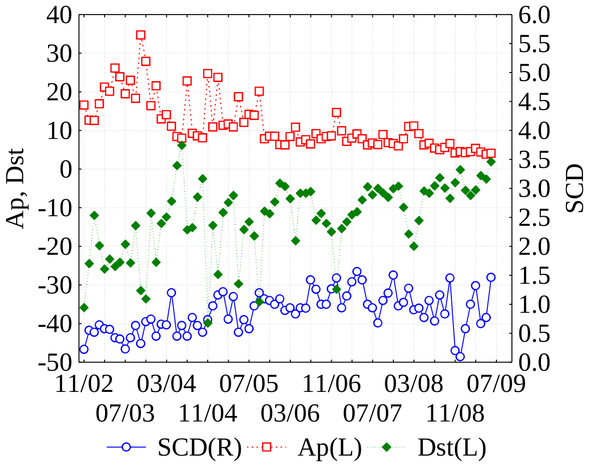

Fig. 1. Monthly averaged geomagnetic indices (Ap and Dst) and SCD numberas a function of time (15/11/2002 - 30/06/2009); L: left axis,R:right axis.

Table 3. Significant correlation coefficients (r) and their significance levels (p) for monthly averaged data.

GMA index	Correlation coefficient (*r*)	Significance level (*p*-value)
Ap	-0.42	0.000
Dst	0.22	0.045

Table 4. Significance levels (p-values) of the GMA (Ap and Dst-indices) effect on the SCD number in Baku for days before (-3,-2,-1), during (0) and after (+1,+2,+3) geomagnetic storms for the period Nov.2002-mid-2009.

Day	Significance level (*p*-value)	
	Ap	Dst
-3	0.03*	0.05*
-2	0.001*	0.02*
-1	0.02*	0.03*
0	0.03*	0.05
+1	0.002*	0.12
+2	0.007*	0.002*
+3	0.007*	0.0001*

* - *statistically significant result*

Negative statistically significant correlations between the average monthly GMA and average monthly SCD number were established (Table 3). The correlation coefficient for Ap-index is negative and for Dst-index it is positive (Dst decrease is related to GMA increase), which indicates that irrespectively of the GMA index being used, the SCD number is higher for lower GMA activity.

Table 4 shows significance levels (*p*-values) obtained by ANOVA that was used to study the GMA effect, estimated by the geomagnetic indices under consideration (Ap and Dst) on the SCD number for days before ("-3, -2, -1"), during ("0") and after ("+1, +2, +3") geomagnetic storm development. It reveals statistically significant effects for almost all of the obtained results.

ANOVA revealed that SCD mortality was highest at very low GMA and that the SCD number decreased with the increase of GMA according to Ap-index values (Fig. 2). The vertical bars in the figure denote 0.95 confidence interval (CI). Similar SCD dynamics was revealed when using Dst-index variations, Fig. 3.

2-way ANOVA revealed that males in general are more predisposed to SCD. However both genders have similar trends in SCD dynamics under GMA intensity variations. For both males and females SCD incidences decrease with GMA increment irrespectively of GMA index: Ap-index (Fig. 4) or Dst-index (Fig.5).

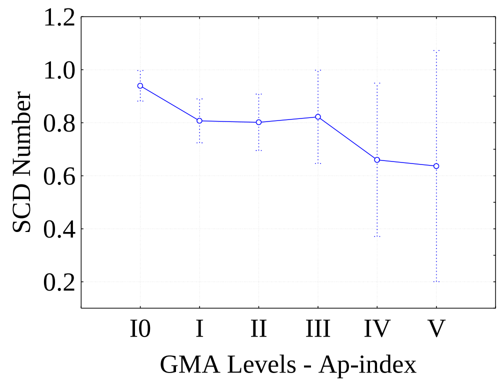

Fig. 2. GMA effect, estimated by Ap-index, on SCD number (±95% CI), where CI is confidence interval.

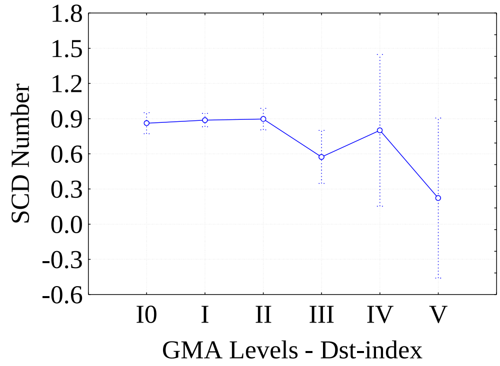

Fig. 3. GMA effect, estimated by Dst-index, on SCD number (±95% CI).

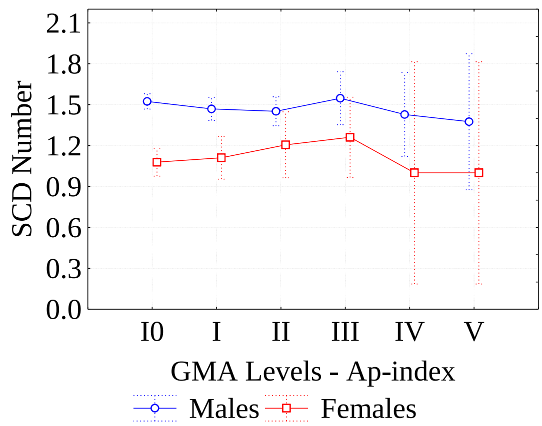

Fig. 4. GMA effect, estimated by Ap-index, on SCD number regarding gender (±95% CI).

Fig. 6 shows SCD number variations before, during and after geomagnetic storms with different intensities according to Ap-index from -3rd to +3rd day of their development. Results from the superposed epoch analysis indicate that the largest number of SCD incidences was around days of very low and quiet GMA. Furthermore, the SCD number had peak variations on days preceding and following geomagnetic storms. SCD dynamics under GMA changes, estimated by Dst-index was found to be very similar (Fig. 7).

Further analyses were performed to study reactions of both genders to geomagnetic storms on days preceding and following different geophysical variations.

Fig. 8. and Fig. 9 show the dynamicsin SCD incidence for males on days before, during and after GMA variations considering respectively the Ap- and Dst-index. Results revealed peak increases in incidences of SCDsin males on days immediately before and after major and severe geomagnetic storms.

The dynamics of SCD incidences in females on days around geomagnetic storms (also defined by Ap- and Dst-index levels) is shown on Fig. 10 and Fig. 11. Results show that females had also peak increases around days of geomagnetic storms. Females were found to be most vulnerable on days after moderate geomagnetic storms.

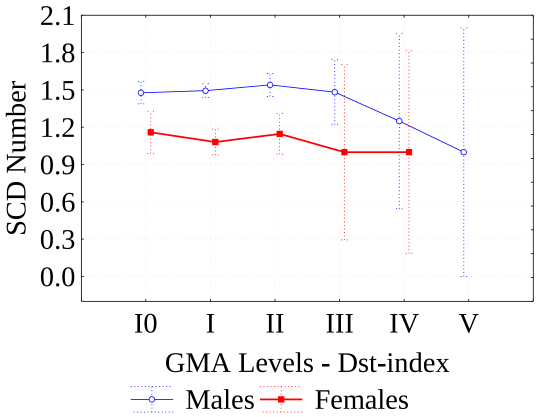

Fig. 5. GMA effect, estimated by Dst-index, on SCD number regarding gender (±95% CI).

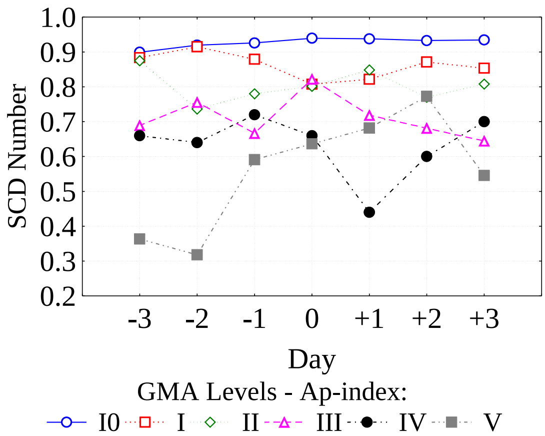

Fig. 6. GMA effect, estimated by Ap-index, on SCD number before, during and after geomagnetic storms.

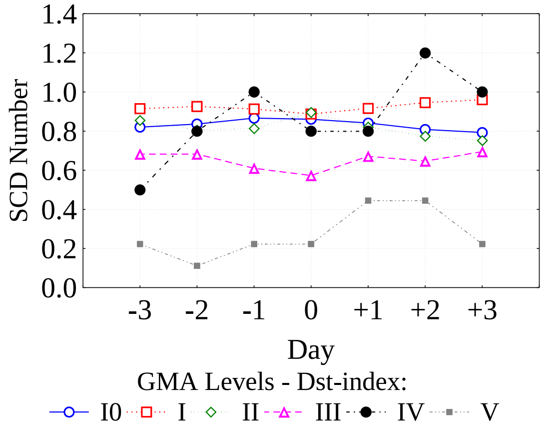

Fig. 7. GMA effect, estimated by Dst-index, on SCD number before, during and after geomagnetic storms.

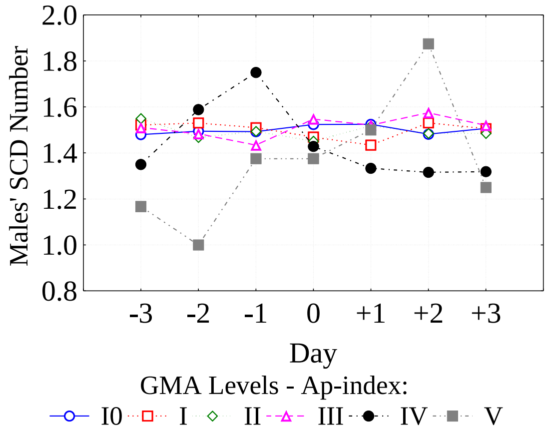

Fig. 8. GMA effect, estimated by Ap-index, on SCD number in males before, during and after geomagnetic storms.

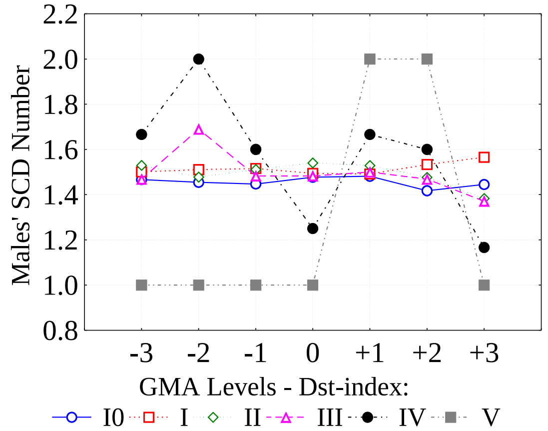

Fig. 9. GMA effect, estimated by Dst-index, on SCD number in males before, during and after geomagnetic storms.

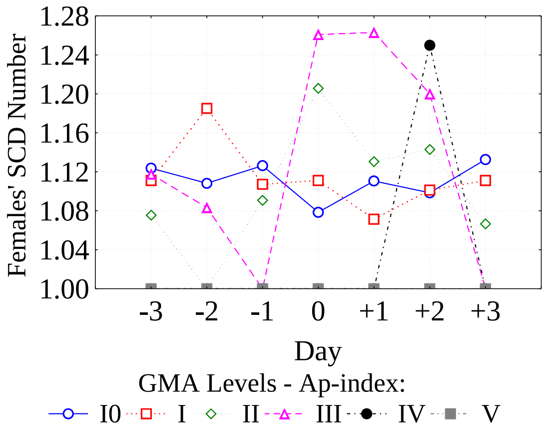

Fig. 10. GMA effect, estimated by Ap-index, on SCD number in females before, during and after geomagnetic storms.

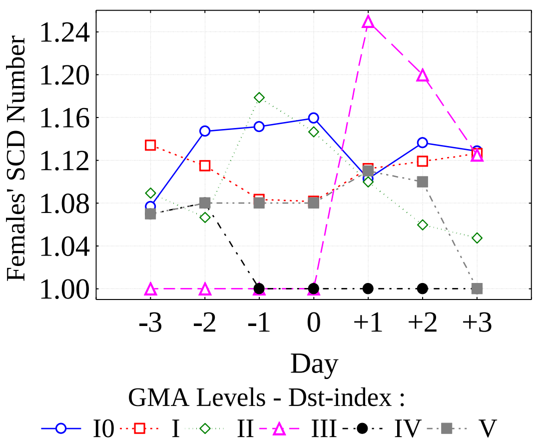

Fig. 11. GMA effect, estimated by Dst-index, on SCD number in females before, during and after geomagnetic storms.

Discussions

The findings presented above indicate that GMF variations could affect the human cardio-health state potentially resulting in SCD.It was found that both very low GMA and geomagnetic storms are related to an increase of fatal cardiac incidencessuch as SCD. Differences in gender reaction were observed: bothmales and females react but have different vulnerability to geomagnetic storms of various intensities. Males were highly vulnerable to SCD around days of major and severe geomagnetic storms. Females were more vulnerable around periods of geomagnetic storms with lower intensity. These results indicate that probably different biophysical and/or pathophysiological mechanisms in both genders are activated in relation to adaptation processes to environmental variations. Gender differences have been revealed in other studies (Stoupel et al., 2004; 2006) suggesting women are less threatened to suffer SCD incidences by high GMA.Partially, on one hand, it is probably related to the fact that in general SCD has a much higher incidence in men than women, reflecting gender differences in the occurrence of coronary heart disease as well (Zipes and Wellens, 1998).On the other hand, studies show that females' physiological parameters such as arterial blood pressure (ABP) and pulse pressure react more expressively to the degree of GMA change while males need a longertime period to return to normal ABP values (Dimitrova 2004; 2006; 2008).Simultaneously females report subjective psycho-physiological complaints for a longer period of time (Dimitrova 2004; 2006; 2008). Established variations in physiological reactions are within normal limits and reflect adaptation processes to environmental variations. It seems that females possess more wide-ranging adaptation capabilities which help them to overcome unfavorable sharp environment variations.

According to the General Adaptation Syndrome theory by Hans Selye (1956) the typical reaction of the human organism to any lasting stress-factor (the non-specific stress-response) consists of three stages: 1) alarm (the body's physiological system drops below optimal functioning), 2) resistance (peak-capacity load of the physiological compensatory systems at levels above homeostatic) and 3) exhaustion (physiological parameters drop after the organism's energy depletion). The exhaustion stage is the most dangerous for the organism, as it cannot continuously resist to environmental stressors and may at some stage become vulnerable to diseases.

Though several interpretations can be found in the literature, (Breus and Rapoport, 2003; Palmer, Rycroft, and Cermack,2006; Babayev et al, 2012), the biophysical mechanisms through which space weather factors affect the human physiological and cardio-vascular state have yet to be definitely identified.Based on the theory of phase transition induced by the noise and applied in biology, one can consider the human being as a biological object acting as an open non-linear system being in the state of non-stable dynamic balance (Breus and Rapoport, 2003). Transition of this systeminto another state can happen even in the case of a very weak external influence at noise level. Any changes in the natural electromagnetic field (geomagnetic field) caused by solar sources can play a role of one of these external factors. There have been a number of scientists who have studied theoretically and experimentally the physical mechanisms of magnetic parametric resonance in bio-systems (Lednev, 1991, 1996; Vincze, Szasz, and Liboff, 2008; Belova and Panchelyuga, 2010; Belova, Ermakov and Lednev, 2013). Experimental studies (Babayev and Allahverdiyeva, 2007) of the influence of periodical and aperiodical changes of GMA upon the human brain, health and psycho-emotional state show that weak and moderate geomagnetic storms do not cause significant changes in the brain's bioelectrical activity and exert only stimulating influences, while severe geomagnetic disturbances cause negative influences, as they seriously disintegrate brain functionality, activate braking processes and amplify the negative emotional background of an individual. It has also been shown that geomagnetic disturbances affect mainly the emotional and vegetative spheres of the human nervous system. In our opinion, a human being's physiological state and the brain's bioelectrical activity, affected by major and severe geomagnetic storms, may influence the behavior of the human cardiovascular system alongside other medical-physiological factors.

SA is the main driver of space weather and one of its manifestations is GMA variations. The results showing variations in physiological parameters and cardio-vascular incidences on the days preceding and following geomagnetic storms indicate that GMA as an indirect indicator of geo-effective solar events and is just one of the space weather factors (alongside with conditions and events on the Sun, in the solar wind, in near-Earth space and in terrestrial upper atmosphere) affecting human homeostasis.

Our previous studies (Dimitrova et al., 2008; Dimitrova, Babayev and Crosby, 2009; Dimitrova et al., 2009a-b) revealed that the various types of geomagnetic storms, depending on their solar driver (magnetic clouds or high speed solar wind streams), affect the human cardio-vascular health state in different ways. It seems that it is therefore not geomagnetic storm intensity but rather the solar driver that is the determining factor for the physiological reactions. At the same time the possible adverse effect of very low GMA on cardio-vascular diseases should not be neglected. Stoupel et al. (2004, 2006, 2007, 2013) suggested that the role of environmental physical factorssuch as galactic cosmic ray (neutron) activity that becomes more active during low GMAshould be the object of further studies.

As it was mentioned above, the majority of the studies conducted at high, middle and low latitudes reveal significant relations between space weather changes and dynamics of cardio-vascular morbidity and mortality. Although the effects are more remarkable at high latitudes, mid-latitude studies also show the existence of an influence that should not be neglected. Here we describe results of some recent studies.

Botoeva, Khetagurova and Rapoport (2013) conducted a comprehensive analysis of incidence of myocardial infarction morbidity (2007-2010) in the mid-latitude city Vladikavkaz (Russia) as a function of SA and GMA. It was found that the number of myocardial infarctions increases on days with enhanced GMA especially among subjects aged 50-69 years. Regression analysis of the relationship between the number of sunspots and myocardial infarctions showed that 42% of the cases were due to changes in the number of sunspots. The authors conclude that their results suggest that the chaotic dynamics of external factors has an important role in the development of myocardial infarction.

Samsonov et al. (2014a) studied the influence of space weather on the cardiovascular system during various solar cycles. It was revealed that during a phase of minimum (2009) and growth phase (2011) of the 11-year SA a distinction in the response of the cardiovascular system of a human being was connected with the level of GMA, latitude of residing and the human being's age.

Samsonov et al. (2014b, 2014c) studied the relationship between emergency medical calls for myocardial infarction in Yakutsk, Russia (subauroral geomagnetic latitudes) and parameters of the space weather near maximum (1992) and minimum (1998) GMA years. The comparison of the seasonal behavior in the number of calls with the simultaneous seasonal behavior of deaths from myocardial infarctions in Bulgaria (middle latitudes) exhibited significant differences that could be connected with Pc1 type (0.2-5 Hz) geomagnetic pulsations in Bulgaria. In Yakutsk, several observed maximums of the number of infarctions coincided with the sharp and considerable increase in planetary GMA. It is supposed that night magnetospheric substorms, which are also observed in subauroral latitudes at magnetically disturbed times, could be responsible for maximums. Substorms are always accompanied by irregular geomagnetic Pi1 pulsations in the frequency range from 0.02 to 3-4 Hz. These pulsations could be considered a biotropic factor, similar to stable quasi-sinusoidal geomagnetic Pc1 pulsations at middle and low latitudes, that could potentially influence the development of myocardial infarctions at middle latitudes. The Pi1 irregular geomagnetic pulsations, which do not propagate to the lower latitudes, could be a biotropic factor at subauroral latitudes.The frequency range of both pulsation types falls in the range of human cardiac contractions.

Shadrina et al. (2016) studied differences in cardiogram changes for arctic and mid-latitude zone inhabitants during geomagnetic storms. Analyses of changes in parameters characterizing the state of the human cardiovascular system – a symmetry coefficient of a T-wave of the electrocardiogram (parameter T) – for the inhabitants of Tixie and Yakutsk during geomagnetic storms were conducted. It was shown that the growth of parameter T for Arctic zone inhabitants often was observed two days before the beginning of a storm, but maximum values of the parameter was achieved the second or third day after the beginning of a storm – during the recovery phase. For the mid-latitude city inhabitants,the increase of parameter T two days before the beginning of the storm is not always shown, but appears more clearly as maximum on the first day, i.e. during the main phase of a storm.

Alexander et al. (2016) investigated space weather effects on humans in the low latitude city Tabuk, Saudi Arabia. They studied the relation between emergency hospital admissions (data from King Khalid hospital) and space weather indices (geomagnetic index Kp, flare index FI) andphenomena (CMEs and solar proton events). The impact ofgeomagnetic storms up to 5 days before and 5 days after sharp geomagnetic changes was investigated. The number of admissions was found to increase on days following geomagnetic storms. Statistically significant effect of GMA levels on the hospital admissions was established.

These aforementioned studies, alongside with others, reveal that the "space weather – human cardiovascular health" relationship isobserved as a common effect at all three latitudes on the Earth. Our results at middle latitude support this observation and highlight also the importance of understanding how this effect changes during the SA cycle at various latitudes as a function of age and gender.

Conclusions

In this paper results of collaborative studies on revealing the possible effects of solar and geomagnetic activity on the dynamics of SCDat middle latitudes are described. The study covers the years of the second peak of Solar Cycle 23 followed by its descending activity and long-lasting minimum years (end of 2002 to mid-2009), a period of time of relative socio-economic stability in Azerbaijan. Daily SCD data (with important details such as gender, age anddate) were used. ANOVA was applied to study the significance of the effect of geomagnetic activity variations, estimated by two geomagnetic indices(daily Dst-index and planetary Ap-index). SCD dynamic on the days preceding and following geomagnetic storms was investigated. The reaction of both genders to geomagnetic activity was especially studiedand the following observations were made:

- The number ofSCDs increased on days of very low GMA and on days preceding and following the development of geomagnetic storms;
- There were differences in male and female vulnerability to GMF intensity;
- Vulnerability of males was higher around days of major and severe geomagnetic storms;
- Females were more threatened around days of lower intensity storms.
- Irrespective of the geomagnetic index used, similar results are found.

Evaluation of the above results has revealed that GMF variations can potentially trigger the incidence rate of SCDs and that heliogeophysical activity could be considered as one of the regulating external/environmental factors in human homeostasis. However, a better understanding of how the GMF and the human organism interact on cellular level is needed.

In summary, our results suggest that further studies in this direction should be pursued.A limitation of the current study is that data cover a relatively short time period of 7 years, not spanning a whole phase of the 11-year SA cycle. To confirm and clarify the results presented in this paper the authors intend to perform studies for at least one solar cycle covering the effects of solar drivers and galactic cosmic rays intensity variations on SCD as a function of solar cycle phase and geomagnetic latitude.

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