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ДВЕ ГРУППЫ ОСТРЫХ СЕРДЕЧНЫХ СОСТОЯНИЙ И ФИЗИЧЕСКАЯ АКТИВНОСТЬ ОКРУЖАЮЩЕЙ СРЕДЫ

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TWO GROUPS OF ACUTE CARDIAC EVENTS AND ENVIRONMENTAL PHYSICAL ACTIVITY

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Недавние исследования показали связь между физической активностью окружающей среды и числом сердечно-сосудистых заболеваний и факторов риска. Целью настоящей работы является исследование возможных связей между течением двух групп острых сердечных состояний – внезапной сердечной смерти (ВСС) и острого инфаркта миокарда (ОИМ), и солнечной (СА), геомагнитной (ГМА) активностью и активностью космических лучей (АКЛ). Ежедневные медицинские данные (1096 дней в 2003–2005 г.) были взяты из станций скорой и первой неотложной медицинской помощи, охватывающих все районы и пригороды г. Баку. Были исследованы 788 случаев ВСС, 4919% с диагнозом ОИМ и 440 фатальных случаев от ОИМ до их поступления в медицинские учреждения. Исследования показали повышение числа случаев ВСС и ОИМ в дни экстремальных (высоких и низких) значений ГМА. Из-за редкости геомагнитных бурь в средних широтах, большинство рассматриваемых кардиологических событий приходятся на дни с самыми низкими уровнями ГМА, сопровождаемым высоким уровнем АКЛ (нейтронная активность). Связи с геомагнитной и нейтронной активностью были более значительно выражены для ежемесячных значений ВСС, фатальных ОИМ, и для всех случаев ОИМ. Несмотря на рост смертности от ОИМ на самых высоких уровнях ГМА, дни с самыми низкими значениями ГМА и сопровождаемой повышенной АКЛ являются значительно преобладающими для случаев ОИМ и острой смертности от ОИМ до поступления пациентов в медицинские учреждения. Исследование ежемесячных значений показало обратную корреляцию рассматриваемых острых сердечных состояний с СА и ГМА. Сделано заключение о том что, смертность от ВСС и случаи возникновения ОИМ растут при низких значениях ГМА и высоких уровнях АКЛ, и ГМА и АКЛ могут быть рассмотрены как одни из существенных факторов в регулировании человеческого гомеостаза. Не только высокие, но и низкие уровни ГМА влияют на число рассматриваемых острых сердечных состояний.

Recent studies have shown correlation between environmental physical activity and the number of cardiovascular risk events and factors. The aim of this study was to check possible links between the courses of two groups of acute cardiac events – sudden cardiac death (SCD) and occurrence of acute myocardial infarction (AMI), and solar (SA), geomagnetic (GMA) and cosmic ray (CRA) activities. Daily medical data (1096 days in 2003–2005) were taken from the Grand Baku Area's Ambulance Stations. We studied 788 SCD, 4919 AMI patients and 440 AMI fatal events before their admission to hospital. The studies have revealed a rise in both SCD and AMI numbers on days of the extreme (high and low) GMA levels. Due to rare GMA storms in the considered middle latitudes the most cardiac events are concentrated at the GMA lowest levels accompanied by comparatively high levels of CRA (neutron activity at the Earth surface). The correlation between GMA and relevant CRA was more significantly expressed for monthly SCD, fatal AMIs, and for all the AMIs. Despite the daily raise of AMI mortality at highest GMA levels, the days of lowest GMA and accompanied high CRA levels are much more predominant for AMI occurrence and acute (prehospital) mortality. In monthly comparison it was also an inverse correlation of both acute cardiac events with SA and GMA. We have concluded that both SCD mortality and AMI occurrence increase in low GMA and accompanied high CRA (neutron) levels and, GMA and CRA may be considered as one of the significant regulating factors in human homeostasis. Not only high, but also low levels of GMA affect the number of the considered acute cardiac events.

1. Introduction

The Sun is the ultimate source of heat and light that maintain Earth's habitable environment, but it is also the origin of visible and invisible influences that affect the Earth, its space environment, and poses also a health and safety threat to human beings and all kinds of human activities either in space or at the Earth's surface through changes in the solar activity and related effects [1–4]. The state of near-Earth space environment is driven by the Sun and is very dynamic on all spatial and temporal scales [5]. The geomagnetic field which protects the Earth from solar wind and cosmic rays is also essential to the evolution of life. When the geomagnetic environment is disturbed, it can have either direct or indirect effect on living beings, including human physiology, even the magnitude of the disturbance is small. Furthermore, the continuous, but always varying, cosmic ray background is also a contributor to the global picture.

There are series of studies in the field named «clinical cosmobiology» [6], considering relationship between the number of total deaths, deaths from cardiovascular diseases, occurrence of acute myocardial infarction (AMI), risk-related cardiovascular parameters, temporal distribution of sudden cardiac death (SCD), stroke, life threatening cardiac arrhythmias, homicide, suicide, etc., and the level of major environmental physical activity factors [7–15].

Despite substantial progress in modern preventive and clinical cardiology, SCD and AMI remain one of the central acute cardiac events. SCD and AMI, depending mainly on physiological/biological and social factors (see: below), are also influenced remarkably by seasonal and terrestrial weather changes – by variations in temperature, atmospheric pressure and other meteorological parameters [16]. But, alongside with aforementioned affecting factors, disturbances and variations in the environmental physical activity can play a significant role in SCD incidence and AMI mortality and morbidity as a trigger factor [7, 8, 10–12, 14]. Sporadic and impulsive manifestations of solar (SA) and geomagnetic

activity (GMA) can be considered as some "failures" of relatively regular rhythms of heliogeophysical factors, affecting, in turn, the dynamics of the considered acute cardiac events [3].

The aim of our study was to check the possible interrelationship between environmental physical activity factors (i.e., effects of SA, GMA and cosmic ray activity (CRA)) and monthly and daily numbers of SCD, incidence of AMI and acute, preadmission mortality from AMI in the middle-latitude located big borderline Eurasian industrial city – Baku (capital of the Republic of Azerbaijan), at the declining phase of the solar activity cycle 23.

2. Material and methods

2.1. Medical data

Potential effects of environmental physical activity changes on the incidence of SCD, and AMI morbidity and mortality were studied using available daily (continuous) medical data created for deaths from all causes registered according to the World Health Organization (WHO) standards in 21 Emergency and First Medical Aid Stations (EFMAS) as well as in the Central EFMAS covering the big urban area, namely Grand Baku Area with more than 3 millions inhabitants (Baku + the Absheron Economic Region) located at the middle latitudes (40°23' N, 49°51' E).

More than 1000000 emergency calls were subjected to the "cleaning" from deaths and incidences due to non-cardiovascular reasons, sudden death of unknown or unspecified cause, cancer, traffic and industrial accidents, suicide, homicide, stroke, etc., and remaining data (cardiovascular-related deaths) were analyzed.

The daily SCD mortality (Fig. 1.), AMI morbidity (Fig. 2.) and AMI mortality data (Fig. 3.) were created in accordance to the WHO's International Classification of Diseases, 10-th revision (ICD-10, version 2007, Chapter IX, Diseases of the Circulatory System), Codes I46.1 and I21, respectively (http://www.who.int/classifications/apps/icd/icd10online/): length of data series: T = 1096 days (January 2003 - December 2005); sampling interval: d = 1 day; months: m = 36 months; total cases: SCD: 788 (84.5% male), AMI: 4919; number of fatal AMI cases at the pre-admission stage: 440, number of persons with AMI, treated in hospitals: 4479; age limitation of the study: 25–80 years old.

SCD was considered as a death of cardiac origin occurring in one hour time limit, without prodromes (preliminary symptoms). The AMI data were specified as acute or with a stated duration of 4 weeks or less from onset (for successful hospital treatment of AMI medical teams and patient education efforts are made to bring the AMI patients to the hospital within 1–6 hours from the beginning of symptoms). Both acute cardiac events' data contained also statistical information about the gender and age of patients/victims, exact time of death, etc., enabling to conduct more detailed analysis. AMI mortality data revealed a maximum for male around the age of 55 while for female it was around 68. The incidence of atherosclerotic vascular disease and myocardial infarction is higher in men than women in all age groups; it is displayed in our medical data as well. This gender difference in myocardial infarction incidence, however, narrows with age increase.

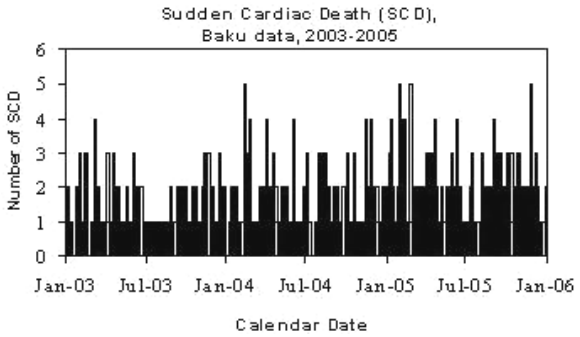

Fig. 1. Temporal distribution of number of the sudden cardiac deaths.

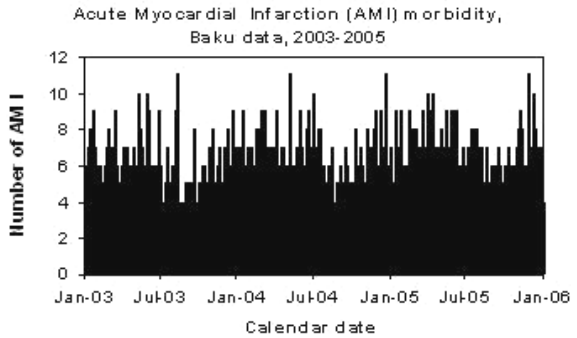

Fig. 2. Acute myocardial infarction morbidity data.

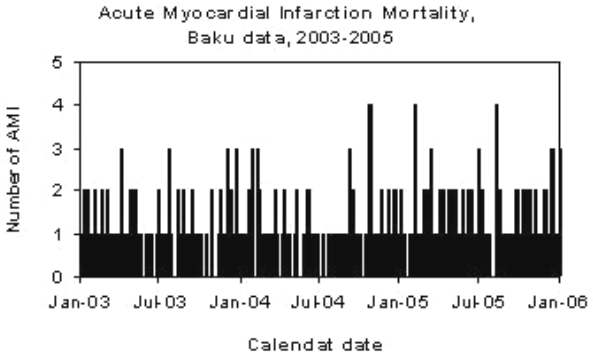

Fig. 3. Acute myocardial infarction mortality data.

2.2. Space weather data

The following space weather parameters (daily and monthly values), taken mainly from US NOAA National Geophysical Data Center (www.ngdc.noaa.gov), NOAA Space Environment Center, Boulder, Colorado (www.sec.noaa.gov), the Moscow Cosmic Ray Station (Neutron Monitor), IZMIRAN, Russian Academy of Sciences (http://helios.izmiran.rssi.ru/cosray), Oulu University, Finland (http://cosmicrays.oulu.fi), etc., were used in our studies for the same time period: sunspot number (SNN) and solar radio flux at 10.7 cm wavelength (F10.7); Ap, Cp, and Am geomagnetic indices; the neutron monitoring data at the Earth's surface (imp/min).

Studies were performed for aforementioned SA, GMA and CRA indices and included comparative analysis for both genders (female and male).

In order to study effects of different levels of GMA, there was introduced so called gradation of GMA (Table 1). According to this gradation, GMA levels were determined as Quiet (I^0-level), Unsettled (II^0), Active (III^0), Minor Storm (IV^0), Major (IV^0) and Severe Storms (IV^0).

Table 1

Geomagnetic activity gradation

Category	«Ap» index range	Amplitude (nano-Tesla)
Quiet (I^0)	0 < Ap < 8	0÷20
Unsettled (II^0)	8 < Ap < 16	21÷40
Active (III^0)	16 < Ap < 30	41÷70
Minor storm (IV^0)	30 < Ap < 50	71÷120
Major storm (IV^0)	50 < Ap < 100	121÷200
Severe storm (IV^0)	100 < Ap	201÷ > 550

Considered time interval (2003–2005) corresponds to the declining phase (which differs from ascending phase by the length of phase and intensity of solar extreme events and related geomagnetic storms) of the 11-year solar activity cycle 23 and period of relative economical and social stability in Azerbaijan and therefore considered data could be considered as a reliable and interesting one.

2.3. Applied methods.

Correlation and cross-correlation analyses were applied to the considered data. Parametric (Pearson) statistical method and Chi-square statistical analyses method, as well as Student's t-test were used for the comparative study. Correlation coefficients r and their probabilities p were calculated. Probabilities of 95 % and higher were considered as significant ones meanwhile those of 90–94% – as strong trends towards a significance.

2.4. Limitations of the study.

This comparatively limited study used EFMAS's pre-admission data, which did not allow including or excluding cases and/or inaccuracies confirmed or excluded at the admission phase of the illness, but allowed more precisely to deal with the time of the beginning of the clinical symptoms of the acute AMI disease. The outpatients' data predispose to the loss of such forms of the disease as Non-STE AMI. Troponin and other enzymatic markers that are part of the hospital phase of diagnostics in AMI were also not included in this study.

The high number of unwitnessed deaths can in some cases affect the accepted time limits of SCD description. Some SCD could not be reported to EFMAS and medical institutions.

3. Results of study and discussions

3.1. Sudden cardiac death.

Sudden cardiac death is an unexpected death due to cardiac causes, an abrupt loss of heart function, occurring in a short time period (generally within 1 hour after the onset of the disease; it is the presently accepted time limit), in a person with known or unknown cardiac disease in whom no previously diagnosed fatal condition is apparent [17, 18]. Approximately half of all cardiac deaths can be classified as SCDs. Several millions of people a year die because of SCD without being admitted to a hospital or an emergency room. The time and mode of death are unexpected. There are many endogenous factors that can place a person at risk of SCD, including: coronary artery disease resulting in ventricular tachycardia, ventricular fibrillation, asystolia, pulseless electrical activity, dilated and hypertrophic cardiomyopathy, smoking, etc. SCD has a much higher incidence in men than women. SCD in females less than sixty five years old is relatively rare. The incidence of SCD increases with age in both men and women.

In our study in total 788 SCD occurred; women (15.5 %) were less affected by high GMA than men (84.5 %). The daily CRA (neutron activity at the Earth's surface, Moscow data, imp/min) was 8475.35 ± 339.7 for the whole considered 3-year period while 8538.08 ± 322.5 in 523 days with SCD incidence (probability of difference: p = 0.0003).

The daily number of SCD was between 1 and 5. At days with 4–5 SCDs (n = 16) the CRA was 8657.5 ± 189 (compared with all 1096 days, p = 0.00018, with 523 days with SCD (from 1 to 5) – p = 0.016). Application of parametric (Pearson) statistical method to the monthly SCD data revealed a significant and inverse correlation with SA indices (SSN: r = – 0.76, p < 0.0001, Smoothed SSN: r = – 0625, p < 0.0001, F10.7: r = – 0.7, p < 0.0001, Adjusted F10.7: r = – 0.75, p < 0.0001) and with GMA indices (Ap: r = – 0.43, p = 0.008, Cp: r = – 0.47, p = 0.0084, Am: r = – 0.44, p = 0.007). A positive correlation was found for CRA (r = 0.511, p= 0.0014). Table 2 includes results of comparative analysis for both genders (female and male) on a daily GMA basis.

Table 2

Daily Geomagnetic Activity (GMA) and Sudden Cardiac Deaths (SCD), Baku data, 2003–2005

Parameters	GMA levels (see: Table 1)				Total number or per cents for parameters
	I^0	II^0	III^0	IV^0	
Number of SCD	369	267	118	34	788
Number of SCD, %	46.83	33.88	14.97	4.32	100
Males in total number of SCD	305	230	101	30	666
Males in total number of SCD, %	45.8	34.5	15.2	4.5	100
Females in total number of SCD	64	37	17	4	122
Females in total number of SCD, %	52.46	30.33	13.93	3.28	100
Number of all considered days in 2003–2005, %	473	401	185	37	1096
Number of all considered days in 2003–2005, %	43.16	36.59	16.87	3.38	100
SCD/daily	0.78	0.66	0.64	0.92	–

Table 2 shows distribution (either in figures or per cents (%)) of number of SCD victims, number of males and females in total number of SCD for different levels of GMA as defined in Table 1 (i.e., 369 from 788 (or 46.8% from 100%) SCD happened in the days with GMA level of I^0, meanwhile only 34 (or 4.31%) SCD were registered for GMA level of IV^0, so on). This table also displays how many days from total 1096 ones were geomagnetically quiet (or less disturbed) (473 days at I^0 level) or highly disturbed (37 days at IV^0 level). Daily occurrence of SCD corresponding to different levels of geomagnetic disturbance is included in Table 2 as well.

3.1. Acute myocardial infarction.

AMI is usually a consequence of coronary artery atherothrombosis [19]. Rare AMI are related to other etiology and pathogenesis. Three components of atherothrom-

Table 3

Outpatients' data about Acute Myocardial Infarction (AMI) morbidity / mortality on I^0-IV^0 daily levels of geomagnetic activity (GMA), Baku data, 2003–2005

Parameters	GMA levels (see: Table 1)				Total number or per cents for parameters
	I^0	II^0	III^0	IV^0	
Number of all considered days in 2003–2005	473	401	185	37	1096
Number of all considered days in 2003–2005, %	43.1	36.6	16.9	3.4	100
Number of days without AMI	11	9	2	0	22
Number of days with AMI	462	392	183	37	1074
Number of all patients – AMI morbidity	1947	1606	754	172	4479
Number of all patients – AMI morbidity, %	43.5	35.9	16.8	3.8	100
Patients (AMI morbidity)/daily	4.21	4.10	4.12	4.65	–
Days with pre-hospital AMI deaths (mortality)	267	62	11	4	344
Days with pre-hospital AMI deaths (mortality), %	77.6	18	3.2	1.2	100
Fatal AMI distribution	267	124	33	16	440
Fatal AMI distribution, %	60.7	28.2	7.5	3.6	100
Deaths (AMI mortality)/daily	1	2	3	4	–
Days without deaths	206	339	174	33	752
Days without deaths, %	27.4	45.1	23.1	4.4	100

bosis, i.e. blood hypercoagulability, increased inflammation markers and unstable atherosclerotic plaque in the coronaries with an increased possibility of atheroma rupture, fissuring are involved in the beginning of acute closure of a culprit coronary artery, resulting in an AMI. For AMI the presence of clinical, electrocardiogram (ECG) and enzymatic markers are obligatory. Understanding of plaque rupture-thrombosis is also important. According to the recently published paper [20], acute major coronary artery thromboses plaque rupture represents the beginning of the event in 75 % of cases. Each of these mentioned predisposing factors has links with elements of environmental physical activity (see: [10]).

Table 3 presents the comparative data in percentages of daily GMA levels on all considered 1096 days in the years 2003–2005 and days with AMI occurrence (morbidity and mortality) at this time in Grand Baku Area. One can see that distributions are very similar. A daily comparison of AMI morbidity and pre-admission mortality from AMI at GMA levels I^0 – IV^0 was also carried out. Comparing days without AMI on quiet (I^0) GMA-level and at the three higher levels, Ch-square study (probability: $p < 0.0001$) reveals that fewer days are free from AMI at the lowest level of daily GMA and, as a consequence, higher neutron activity is concomitant with the period of higher occurrence of AMI.

Again, as in the Table 2, the Table 3 displays how many days from total 1096 ones were geomagnetically quiet (or less disturbed) (473 days at I^0 level) or highly disturbed (37 days at IV^0 level). Distribution of days with and without AMI (both cases), as well as days with out-of-hospital AMI mortality corresponding to the different GMA levels is shown in this table. There are distributions (either in figures or per cents (%)) of numbers of AMI victims (fatality and incidence) for different levels of GMA as they are defined in Table 1 (i.e., 1947 from 4479 (or 43.5% from 100%) AMI incidence (morbidity) in the days with quiet GMA level of I^0, meanwhile only 172 (or 3.8%) AMI morbidity was registered for high GMA level of IV^0, so on). Daily occurrence of AMI morbidity and mortality corresponding to different levels of geomagnetic disturbance is included in Table 3 as well.

Monthly AMI morbidity and pre-admission mortality from AMI and SA, GMA and CRA parameters were compared. These interrelationships were expressed by Pearson correlation coefficients r and their probabilities p. Both monthly AMI morbidity (n = 4479) and mortality (n = 440) numbers show significant links with CRA (morbidity: $r = 0.35$, $p = 0.0377$; mortality: $r = 0.494$, $p = 0.002$) and inverse relationship with SA («morbidity-SSN»: $r = –0.37$, $p = 0.02$ and «mortality–SSN»: $r = –0.36$, $p = 0.029$; «morbidity-F10.7»: $r = – 0.436$, $p = 0.0078$ and «mortality–F10.7»: $r = –0.46$, $p = 0.0047$; so on). For GMA a significant inverse correlation was found only for fatal cases of AMI (440 in 344 days): «morbidity–A_p»: $r = – 0.455$, $p = 0.005$; «morbidity-Am»: $r = – 0.43$, $p = 0.0075$; «morbidity–Cp»: $r = – 0.47$, $p = 0.0038$.

On lowest GMA-levels, most of days were with fatal AMIs; on the three higher daily levels of GMA there were significantly fewer AMIs. Days without fatal AMIs show an inverse result. Chi-square study between days free of AMI on quiet and the three higher GMA days was 248.05, $p < 0.0001$.

The daily CRA (neutron activity at the Earth's surface, Moscow data, imp/min) was 8475.35 ± 339.7 for the whole considered 3-year period (1096 days) and 8275 – for days without any AMI meanwhile 8545 – in 10 days with maximal AMI morbidity (10–11 per day) incidence, 8539 – in 344 days with fatal AMI and 8609 – in 12 days with maximal (3–4 per day) pre-admission AMI mortality.

The obtained results are in accordance with results of some papers, concerning the influence not only high but also low levels of geomagnetic disturbances. For example, one of the three definite conclusions of review paper [4] is that extremely high as well as extremely low values of GMA seem to have adverse health effects. Significant correlation, as in our case, was also found between monthly incidence

of AMI and month-to-month variations of cosmic ray index in the Indian study [16].

Solar activity modulates the cosmic ray flux [21], where the primary driver is the solar wind. The changing solar activity is responsible for varying solar wind strength. A stronger wind will reduce the flux of cosmic ray reaching Earth, since a larger amount of energy is lost as they propagate up the solar wind. When the solar wind blows heavily, cosmic rays are weak, and when the solar wind is in a lull, cosmic rays become strong. There is a close correlation between the velocity of the solar wind and the K_p index of geomagnetic activity. Geomagnetic storms, on the other hand, are closely related to solar eruptions [5]. The highest velocities in the solar wind are caused by energetic solar eruptions and coronal holes. Strong eruptions (flares and eruptive prominences) avoid sunspot maxima and even occur close to sunspot minima.

Therefore cosmic rays could be considered as reliable indicators of solar and/or geomagnetic activity. Cosmic ray flux varies inversely with solar activity. Low solar activity and related-decreased geomagnetic activity are accompanied by intensification of the cosmic ray activity in the near-Earth space.

Ptitsyna et al. [22] found that among all characteristics of geomagnetic activity, Forbush-decreases are better related to hazardous effects of solar variability-driven disturbances of the geomagnetic field. On the basis of statistical data on several millions medical events in Moscow and in St. Petersburg, Villoresi et al. [23, 24] found an sufficient influence of geomagnetic storms accompanied with comic ray Forbush-decreases on the frequency of myocardial infarcts, brain strokes and car accident road traumas. The most remarkable and statistically significant effects on myocardial infarctions (increase by 10.5±1.2%) have been observed [25] during days of geomagnetic perturbations defined by the days of the declining phase of Forbush-decreases in cosmic ray intensity.

The possible biological mechanisms of the multidirectional effects of the considered environmental physical factors on humans have not been yet established but they show correlation with many medical events, having behavioral, laboratory, pathological and other aspects.

The occurrence of all forms of AMI and SCD rise during stormy levels of GMA. But stormy GMA is a relatively rare event in the middle latitudes (3–6 % of days yearly), where Baku city is located. As a consequence, most AMIs and SCDs occur on days (or months) of low GMA accompanied by comparatively high levels of CRA.

A similar study conducted in a different geographic location also based on first cardiology aid data found that acute coronary events and arrhythmia were linked with high energy (> 90–100 MeV) space proton flux [26], a part of space energy very closely connected with CRA [27, 28]. Periods of high GMA predispose to the development of vascular lesions where the primary thrombotic-inflammatory processes are predominant and the plaque primary lesion process less. This is an additional example of the multidirectional involvement of the physical environment in the regulation of human homeostasis, described as the equilibrium paradigm in clinical cosmobiology [9].

4. Conclusions

Significant part of cardiovascular diseases and related deaths can not be explained only by known medical/physiological risk factors. In this paper we have studied possible environmental physical activity (such space weather changes as variations in SA, GMA and CRA) influence on SCD incidence and occurrence of AMI mortality and morbidity. Obtained results are classified:

1. The timing of SCD and AMI (both morbidity and mortality) shows remarkable relationship to variations in environmental physical activity.
2. The number of SCD rises on the highest and lowest daily levels of GMA. The relatively rare GMA storms concentrate most of SCDs at days of lowest levels of GMA. Monthly number of SCD is inversely related to SA and GMA and is accompanied by high levels of CRA. Gender difference in «SCD – GMA» interrelationship was found: men were more sensitive and apparently affected more. These results are in agreement with observations in some other parts of the world [11, 29].
3. Despite the daily raise of AMI mortality at highest GMA levels, the days of lowest GMA, accompanied by comparatively high levels of CRA, are much more predominant for AMI occurrence (morbidity) and acute (pre-hospital) mortality. Monthly number of AMI is significantly and inversely related to the monthly solar and geomagnetic activity, accompanied by increased CRA. This relationship is stronger for fatal AMI at the pre-admission stage of the illness. One of possible predisposing factors can be life threatening arrhythmia related to changes in environmental physical activity.
4. Obtained results are in accordance with results of some papers (see: [4] and references herein), concerning the influence not only high but also low levels of geomagnetic disturbances on the dynamics of considered acute cardiac events.
5. The clinical course of SCD and AMI seems to be linked to changes in GMA and CRA levels alongside other affecting factors. Geomagnetic and cosmic ray activities could be considered as one of the regulating factors in the human homeostasis.

REFERENCES

1. Jansen F., Pirjola R., Favre R. Space weather hazard to the Earth? Zurich: Swiss Re Publishing. 2000. P. 40.
2. Space Storms and Space Weather Hazards, I. A. Daglis (ed.), NATO Science Series, II. Mathematics, Physics and Chemistry, Kluwer Academic Publishers. 2001. V. 38. 492 p.
3. Breus T.K., Rapoport S.I. Magnetic Storms: Medical-Biological and Geophysical Aspects. Moscow: «Sovetskii Sport» Press. 2003. 192 P. (In Russian).
4. Palmer S.J., Rycroft M.J., Cermack M. Solar and geomagnetic activity, extremely low frequency magnetic and electric fields and human health at the Earth's surface // Surv. Geophys. 2006. V. 27. P. 557–595.
5. Bothmer V., Daglis I.A. Space Weather: Physics and Effects. Springer Praxis Books, Environmental Sciences. 2006. 476 p.
6. Stoupel E. Clinical Cosmobiology // Canadian Medical Meteorology Network. Bio-Electro-Magnetics Institute. 1989. V. 1.
7. Stoupel E. Sudden cardiac deaths and ventricular extrasystoles on days with four levels of geomagnetic activity // J. Basic Clin. Physiol. Pharmacology. 1993. V. 4. P. 357–366.

8. Stoupel E., Domarkiene S., Radishauskas R., Abramson E. Sudden cardiac death and geomagnetic activity: links to age, gender and agony time // J. Basic Clin. Physiol. Pharmacol. 2002. V. 13(1). P. 11–21.

9. Stoupel E. The equilibrium paradigm in clinical cosmobiology // J. Basic Clin. Physiol. Pharmacol. 2002. V. 13(3). P. 255–261.

10. Stoupel E. The effect of geomagnetic activity on cardiovascular parameters (Editorial) // Biomed. Pharmacoter. 2002. V. 56 (Suppl.2). P. 247s–256s.

11. Stoupel E., Kalediene R., Petrauskiene J., et al. Three kinds of cosmophysical activity: links to temporal distribution of deaths and occurrence of acute myocardial infarction // Med. Sci. Monit. 2004. V. 10(2). P. CR80–CR84.

12. Stoupel E., Domarkiene S., Radiashauskas R., et al. Variants of acute myocardial infarction in relation to cosmophysical parameters // Seminars in Cardiology. 2005. V. 11(2). P. 51–55

13. Stoupel E., Kalediene R., Petrauskiene J., et al. Suicide-homicide temporal interrelationship, links with other fatalities, and environmental physical activity // Crisis. 2005. V. 26(2). P. 85–89 (DOI:10.1027/0227-5910.26.2.83).

14. Stoupel E. Cardiac arrhythmia and geomagnetic activity // Indian Pacing and Electrophysiology Journal. 2006. V. 6(1). P. 49–53.

15. Stoupel E., Kalediene R., Petrauskiene J., et al. Clinical cosmobiology: distribution of deaths during 180 months and cosmophysical activity. The Lithuanian study, 1990–2004. The role of cosmic rays // Medicina (Kaunas). 2007. V. 43(10). P. 824–831.

16. Selvam A.M., Sen D., Mody S.M.S. A study of circadian rhythm and meteorological factors influencing acute myocardial infarction Indian Institute of Tropical Meteorology, Research Report No RR-073 (ISSN 0252-1075), April 1997.

17. Myerburg R.J., Castellanos A. Cardiac arrest and sudden cardiac death / E. Braunwald (Ed.), Heart Disease. 5-th edition, Philadelphia, W.B. Saunders Company. 1997. P. 742–779.

18. Priori S., Zipes D.P. Sudden Cardiac Death: A Handbook for Clinical Practice, Blackwell Publishing. 2005.

19. Atlas of Atherothrombosis // E.J. Topol (Ed.), London: Science Press. 2005. P. 61–86.

20. Antman E.M., Braunwald E. ST-elevation myocardial infarction: Pathology, pathophysiology, and clinical features // Braunwald's Heart Disease, 7th edition. Philadelphia. Elsevier Saunders, 2005. P. 1141–1226.

21. Kristjansson E., Kristiansen J., Kaas E. Solar activity, cosmic rays, clouds and climate – an update // Adv. Space Res. 2004. V. 34 (2). P. 407–415

22. Ptitsyna N.G., Villoresi G., Dorman L.I., et al. Natural and man-made low-frequency magnetic fields as a potential health hazard // Physics – Uspekhi (Uspekhi Physicheskikh Nauk), 1998. V. 41(7). P. 687–709 (DOI: 10.1070/PU1998v041n07ABEH000419. (In Russian).

23. Villoresi G., Breus T.K., Dorman L.I., Rapoport S.I. The influence of geophysical and social effects on the incidences of clinically important pathologies (Moscow 1979–1981) // Physica Medica. 1994. V. 10(3). P. 79–91.

24. Villoresi G., Dorman L.I., Ptitsyna N.G., et al. Forbush-decreases as indicators of health-hazardous geomagnetic storms // Proc. 24th Int. Cosmic Ray Conf., Rome, 1995. V.4. P. 1106–1109.

25. Dorman L.I. Space weather and dangerous phenomena on the Earth: principles of great geomagnetic storms forecasting by online cosmic ray data // Annales Geophysicae. 2005. V. 23, P. 2997–3002.

26. Stoupel E., Abramson E., Drungiliene D., et al. Klaipeda emergency cardiovascular aid services correlate with 10 cosmophysical parameters by time of occurrence // J. Clin. Basic. Cardiol. 2002. V. 5(3). P. 225–227.

27. Amelino-Camelia G. Relativity: Special treatment // Nature. 2002. V. 418, N 6893. P.34–35.

28. Sigl G. Ultrahigh energy cosmic rays: physics and astrophysics at extreme energies // Science. 2001. V.291. P. 73–79.

29. Stoupel E., Israelevich P., Kusniec J., et al. Are neutrons involved in the pathogenesis of life-threatening cardiac arrhythmias? // J. Basic Clin. Physiol. Pharmacol. 2006. V. 17(1). P. 55–62.

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