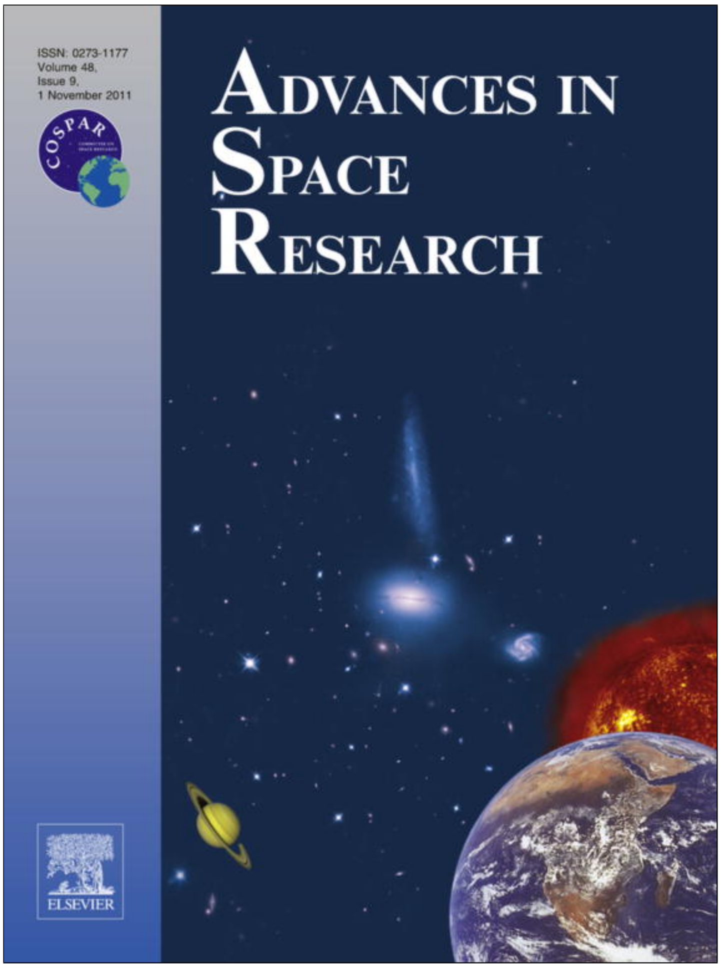
ISSN: 0273-1177
Volume 48,
Issue 9,
1 November 2011
COSPAR
ADVANCES IN SPACE RESEARCH
ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect
Advances in Space Research 48 (2011) 1545–1550
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Effect of geomagnetic disturbances on physiological parameters: An investigation on aviators

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Received 26 May 2011; received in revised form 9 July 2011; accepted 11 July 2011
Available online 20 July 2011

Abstract

Over the last years the potential effect that the geomagnetic activity may have on human physiological parameters (such as heart rate, arterial diastolic and systolic pressure) is being widely investigated with irrefutable results. As it is suggested, human health can be affected by solar activity and related geophysical changes. In this study a group of 4018 Slovak aviators was examined from January 1, 1994 to December 31, 2002, covering periods with high solar and geomagnetic activity. Specifically, medical data of mean values of arterial diastolic and systolic blood pressure, which were registered during the medical examinations of the Slovak aviators, were related to daily variations of Dst and Ap geomagnetic indices. All subjects were men (from 18 to 60 years old) in good health. Statistical significance levels (*p*-values) of the effect of geomagnetic activity on the aforementioned parameters up to three days before and three days after the geomagnetic event were established using the statistical method ANalysis Of VAriance (ANOVA). Statistical analysis of the arterial blood pressure variations for different levels of geomagnetic activity revealed that geomagnetic changes are connected to variations of the human physiological parameters.

Keywords: Geomagnetic activity; Geomagnetic storms; Heart rate; Blood pressure

1. Introduction

Many attempts have been made in order to define and analyse the relationship between geomagnetic activity (GMA) and space weather changes and human health. This new scientific field, which in the last few years is being enriched with more results, is called Clinical Cosmobiology (Stoupel, 2006a). Because this kind of research is complicated, since the responses of the human organism and the state of human health can be affected and influenced by many factors, relevant investigations were conducted in different ways. Some studies used data collected from stations all over the world in a period of many years whereas others gathered data concerning specific time periods of high solar and geomagnetic activity. These data were correlated to medical data of either a specific group of people under examination or random samples of the population.

An analysis in Baku, Azerbaijan showed that the number of sudden cardiac deaths connected to daily levels of GMA and cosmic rays could be one of the regulating factors for human homeostasis (Stoupel et al., 2006b). Moreover after studying the distribution of the monthly death number for 192 months in Lithuania, a correlation between this number and cosmic ray activity and an inverse correlation with solar activity was found. Monthly GMA was significantly correlated with traffic accidents, ischemic heart disease/stroke ratio, and suicide victim number. Deaths from stroke, non cardiovascular causes, suicide, traffic

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doi:10.1016/j.asr.2011.07.004

accidents were related to cosmic ray activity and, inversely, to solar activity (Stoupel et al., 2007a).

Furthermore the potential effects of geomagnetic indices variations on human health lead to a series of studies concerning the influence of local geomagnetic storms on arterial blood pressure (Dimitrova et al., 2004a,b). Arterial diastolic and systolic blood pressure increased significantly during strong local geomagnetic storms. It is interesting to mention that women and men reacted in different ways. Women showed more sensitivity to the geomagnetic fields' variations as did people under drug treatment, mainly hypertensive therapy (Dimitrova, 2008).

Geomagnetic field variations, like geomagnetic storms, can influence the human nervous system and therefore are connected to traffic accidents caused by anxiety and nervous reactions (Aschikaliev et al., 1995). Space weather conditions are not related to train accidents due to technical factors. On the other hand their relation to those due to human error is statistically significant (Dorman et al., 2001). Recently (Mendoza and Sánchez de la Peña, 2010) have indicated that at low latitudes there are biological responses to the solar/geomagnetic activity.

Moreover periodicities were found in the reported cardiovascular incidents and their relation to periodicities of geomagnetic phenomena of the solar cycle is being discussed (Cornelissen et al., 2005). Many studies correlate the myocardial infractions incidents' and heart rhythms variations' to the periodicity of the solar activity (11 year cycle) and geomagnetic storms. An international project, called BIOCOS (BIOsphere and COSmos), is trying to monitor, register and analyse variations of human physiological parameters in different geographical locations and in relation to geomagnetic phenomena and solar activity (Cornelissen et al., 2002).

The influence of geomagnetic activity on the functionality of the human brain, human health and psycho-emotional state was investigated in the region of Baku (Babayev and Allahverdiyeva, 2007). It was confirmed that for middle latitude locations, human physiology and psychology is affected by geomagnetic disturbances. The same study concluded that anxiety, work and concentration ability could be influenced by GMA making it clear that comprehending the connection between space weather and human physiology is of great importance in order to prevent or treat physical or psychological diseases.

The effect of geomagnetic changes, cosmic ray intensity variations and solar activity has not only been studied on cardiological parameters but on other parameters of the human physiology as well. The mental performance or health state of aviation personnel is influenced by space weather conditions (Dzvonik et al., 2006). Values of heart rate in load are lower during periods of maximum solar activity in comparison to those during periods of minimum solar activity. The inverse results apply to arterial diastolic blood pressure. Recently several review papers on space weather effects have been published covering a wide area of subjects including also cosmic ray effects on health (e.g. Singh et al., 2011).

Three different scientific groups from Athens (Greece), Kosice (Slovakia) and Sofia (Bulgaria) have collaborated on the study of the potential effect of GMA on the physiological state of a group of aviators. Human physiological parameters (arterial diastolic and systolic blood pressure) were analyzed in relation to Dst- and Ap-geomagnetic indices variations for a time period of eight years.

2. Data and method

2.1. Medical data

The arterial diastolic (DP) and systolic (SP) blood pressure measurements used in this study refer to a group of 4018 Slovak aviators and were provided during their periodical medical checks at ground level. The group consisted only of men (from 18 to 60 years old), all in good health. Daily mean values of DP and SP (mmHg) in rest (without load) (DPR, SPR), DP and SP in 1st degree of load (DPFDL, SPFDL – sitting on a stationary bike and pedaling at a power of 50–100 W), DP and SP in 2nd degree of load (DPSDL, SPSDL – sitting on a stationary bike and pedaling at a power of 100–150 W), maximum DP and SP achieved by load (DPMAX, SPMAX – sitting on a stationary bike and pedaling at maximum power) were registered. Each physiological parameter value represents the mean daily value of all the aviators, who were examined during that day. On some days (weekends, holidays, etc.) no medical data were available. The total number of the days of measurements is equal to 1341. The data refer to the time period from January 1, 1994 until December 31, 2002.

2.2. Geomagnetic activity data

The GMA of the days, for which medical data were available, was also analyzed. Geomagnetic index Dst data were obtained from the World Data Centre for Geomagnetism, Kyoto (http://swdcwww.kugi.kyoto-u.ac.jp/). Ap-index data were obtained from Space Weather Prediction Centre at NOAA, Boulder (http://www.swpc.noaa.gov/ftpmenu/indices/old_indices.html). GMA was divided into five levels (I0, I, II, III, IV) according to Dst-index and Ap-index (Table 1). Dst-index variations for the time period under examination are shown in Fig. 1.

Table 1
Ap- and Dst-index levels and the number of days.

Ap \ Dst levels	Dst-index values, nT	Number of days	Ap-index values	Number of days
I0	$Dst \geqslant 0$	206	$Ap < 8$	615
I	$-20 < Dst < 0$	665	$8 \leqslant Ap < 15$	349
II	$-50 < Dst \leqslant -20$	390	$15 \leqslant Ap < 30$	269
III	$-100 < Dst \leqslant -50$	70	$30 \leqslant Ap < 50$	78
IV	$Dst \leqslant -100$	10	$Ap \geqslant 50$	30

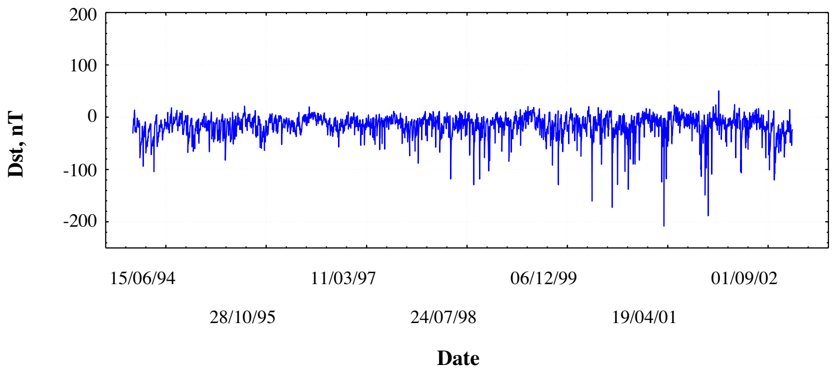

Fig. 1. Daily Dst-index (nT) variations during experiments period from January 1, 1994 to December 31, 2002.

2.3. Statistical methods

The statistical method the *ANalysis of VAriance* (ANOVA) (statistical package STATISTICA (ver. 6, StatSoft Inc., 2001), was applied to establish statistical significance levels (p) of the effect of GMA levels on the DP and SP parameters. The effect of GMA up to three days before and after the respective events on the examined parameters was also investigated by the help of ANOVA and superimposed epoch method. Significance levels p-values were calculated for the days before (−), during (0) and after (+) geomagnetic storms. The chosen level for statistical significance in the used data analysis software system STATISTICA is set to $p < 0.05$ and the same value is used for interpreting the results.

3. Results

ANOVA was used for obtaining the significance levels (*p-values*) of the effect of GMA level on DP and SP for the days before (−), during (0) and after (+) geomagnetic storms. Table 2 shows p-values for Dst-index effect and Table 3 p-values for Ap-index effect on the parameters under examination.

The main effects of GMA levels on day 0 were not statistically significant as it can be seen from Tables 2 and 3 except for the effect of Ap-index on SPMAX. In most of the cases some decrease (small in value) of the physiological parameters with GMA increase, more particularly for level III and IV was observed. Examples are Figs. 2 and 3, which show variations of SPSDL and DPFDL regarding Dst-index and respectively dynamic of SPR and DPR regarding Ap-index. However further analyses regarding the days of the storms revealed interesting results. It turned out that in most of the cases usually before and during geomagnetic storms physiological parameters sharply decreased and after that they sharply increased.

Table 2 shows that all of the examined parameters were statistically significantly affected on +3rd day of geomagnetic storms, estimated by Dst-index, and DPSDL was affected on +1st day as well.

Further analyses revealed that SPFDL, SPSDL, SPMAX, DPSDL, DPMAX for level IV decreased significantly from −1st till 0 day and after that increased sharply from +1st day till +2nd day. Afterwards on +3rd day the blood pressure parameters were normalized. For level III the decrease and increase were delayed by one day. An example for these variations is presented in Fig. 4, which shows dynamic of SPMAX in dependence of Dst-index classification for different geomagnetic storms and days. In some of the cases like variations of SPR, DPR (Fig. 5) and DPFDL there were just peak increases and decreases on the different days for level IV and III but the trend for obtaining minimal values during IV level on −1st day and maximal values on +2nd day of IV level and again on +3rd day of III level was kept.

Table 3 shows that SPMAX was statistically significantly affected on 0 day and +1st day of geomagnetic

Table 2
Significance levels (p-values) of Dst effect on the physiological parameters for the days before (−), during (0) and after (+) geomagnetic storms (results marked with ⟨∗⟩ are statistically significant).

Day	p-Values (Dst)							
	DPR	DPMAX	DPFDL	DPSDL	SPR	SPMAX	SPFDL	SPSDL
−3	0.69359	0.18878	0.56501	0.54967	0.28007	0.33845	0.52260	0.25511
−2	0.61007	0.29944	0.40561	0.52146	0.15888	0.13661	0.27832	0.44135
−1	0.09098	0.46883	0.61261	0.36882	0.18042	0.51424	0.41089	0.41301
0	0.34181	0.50361	0.35710	0.52160	0.77808	0.19865	0.42493	0.64462
+1	0.27568	0.13068	0.10520	0.01404*	0.27445	0.19175	0.76355	0.37106
+2	0.13525	0.23740	0.31969	0.56027	0.17498	0.16290	0.45766	0.36437
+3	0.00205*	0.00005*	0.02729*	0.00739*	0.00930*	0.01096*	0.00639*	0.01048*

Table 3
Significance levels (*p*-values) of Ap effect on the physiological parameters for the days before (+), during (0) and after (−) geomagnetic storms (results marked with ⟨*⟩ are statistically significant).

Day	*p*-Values (Ap)							
	DPR	DPMAX	DPFDL	DPSDL	SPR	SPMAX	SPFDL	SPSDL
−3	0.80659	0.32021	0.55846	0.39388	0.71725	0.71176	0.84320	0.75778
−2	0.95352	0.77508	0.87058	0.53198	0.57445	0.59295	0.96877	0.51069
−1	0.08259	0.57159	0.48158	0.56111	0.07149	0.68977	0.40236	0.46797
0	0.19515	0.89386	0.51358	0.71292	0.30602	0.00741*	0.51190	0.19558
+1	0.94179	0.76291	0.77119	0.46628	0.50420	0.04754*	0.84703	0.68301
+2	0.47109	0.55006	0.36854	0.25280	0.23089	0.97438	0.25678	0.27234
+3	0.78762	0.37157	0.77563	0.34515	0.20386	0.58176	0.67002	0.96683

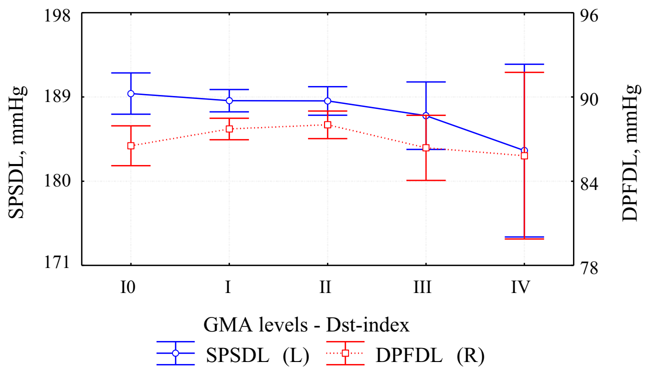

Fig. 2. GMA effect, estimated by Dst-index, on SPSDL and DPFDL (date 0) (±95% CI).

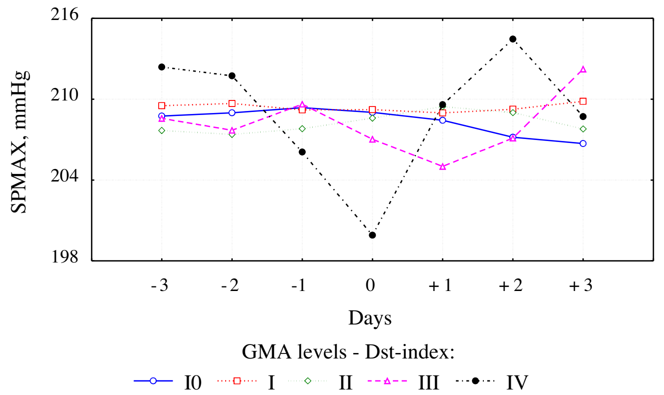

Fig. 4. GMA effect, estimated by Dst-index, on SPMAX before (−), during (0) and after (+) geomagnetic storms.

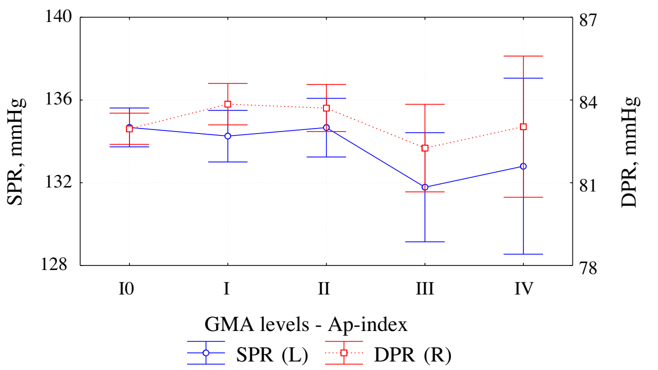

Fig. 3. GMA effect, estimated by Ap-index, on SPR and DPR (date 0) (±95% CI).

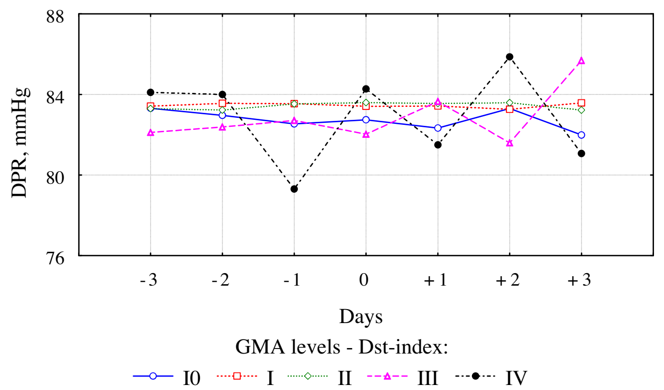

Fig. 5. GMA effect, estimated by Dst-index, on DPR before (−), during (0) and after (+) geomagnetic storms.

storms, estimated by Ap-index. It was established that SPMAX values decreased statistically significantly with the increase of GMA on these particular days. Its variations are shown in Fig. 6. It can be seen from the figure that SPMAX sharply decreased from −1st till 0 day for level IV of the Ap-index classification and then sharply increases after day +1.

Similar variations were established for the other physiological parameters regarding Ap-index and they resemble dynamics regarding Dst-index. It concerns especially SP parameters. DP parameters variations had mainly peak increases and decreases. Interesting dynamic was observed for DPFDL (Fig. 7). Additionally to the peak values on the different days for IV level DPFDL had peak increases on 0 day for most of the GMA levels.

4. Discussion and conclusion

The relationship between solar, geomagnetic and cosmic ray activity and changes in human physiological state has been widely investigated. Stoupel (1999) has published a series of studies concerning the changes in the way a human

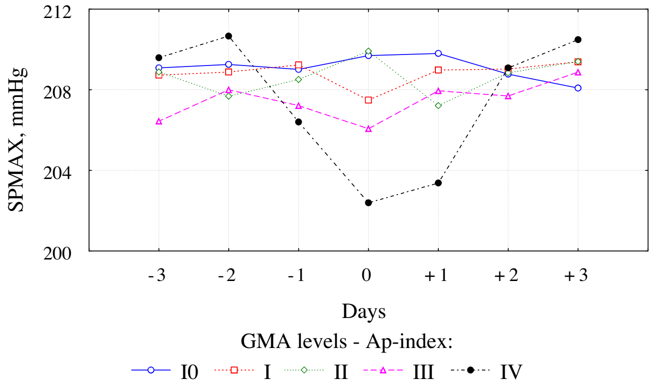

Fig. 6. GMA effect, estimated by Ap-index, on SPMAX before (–), during (0) and after (+) geomagnetic storms.

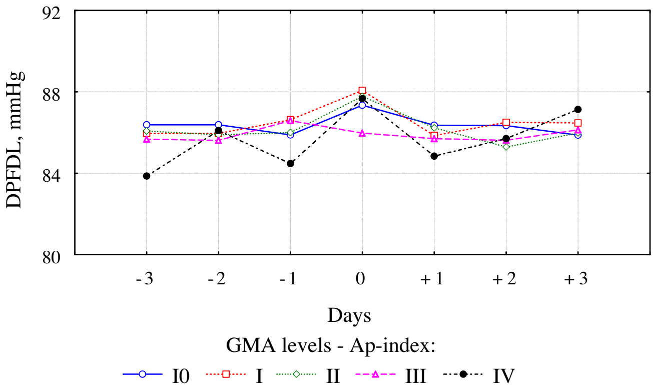

Fig. 7. GMA effect, estimated by Ap-index, on DPFDL before (–), during (0) and after (+) geomagnetic storms.

organism responds to different levels of daily and monthly GMA. As it is mentioned in Stoupel et al. (2006b) the analysis of data concerning the daily and monthly temporal distribution of sudden cardiac death in the Baku area showed that 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.

According to a research performed in Kaunas registry for 204 consecutive months the monthly number of acute myocardial infractions correlates with solar, geomagnetic and cosmic ray activity. This relationship is stronger in women (Stoupel et al., 2005). Similar results are also mentioned in Stoupel et al. (2007b) for the Baku area during the period 2003–2005. The monthly number of acute myocardial infractions was inversely related to monthly solar activity and correlated with cosmic ray activity.

Furthermore more recent studies focus on the influence of the human cardiovascular functionality, through changes of physiological parameters, such as arterial blood pressure, heart rate, heart rate variability, etc. (Babayev and Allahverdiyeva, 2007; Mavromichalaki et al., 2008, 2009; Dimitrova et al., 2009a; Papailiou et al., 2009, 2010).

In previous investigations, during periods of high GMA, arterial diastolic and systolic blood pressure increased during intense GMA whereas results concerning heart rate were not statistically significant (Usenko et al., 1989; Ghione et al., 1998; Dimitrova et al., 2004a; Dimitrova, 2008). Usenko et al. (1989) studied a group of pilots and obtained results which showed a significant increase of systolic blood pressure and heart rate during years of maximal solar activity in comparison with years of minimal solar activity. Furthermore decrease in parameters of heart rate variability has also been found for periods of high GMA (Baevsky et al., 1997; Cornelissen et al., 1999; Otsuka et al., 2001; Stoilova and Dimitrova, 2008; Dimitrova et al., 2009b).

In this study the effect of GMA, through variations of the Ap and Dst geomagnetic indices, on the physiological parameters of aviators was examined with interesting results. High GMA levels (when geomagnetic storms occur) are associated to variations in DP and SP. The physiological parameters under study seem to take their minimum value for Ap- and Dst- indices levels III and IV on the days of geomagnetic storms. Results, concerning the variations of the parameters on the days before and after geomagnetic storms according to the Ap- and Dst-indices classification, show that mainly for levels III and IV a sharp decrease, noticed on the days before or during the geomagnetic storms, is usually followed by a sharp increase on the days after the storms and then the parameters decrease again. In some cases peak increases and decreases on different days for the same levels of GMA are registered. The first trend concerns mainly SP parameters, while the second refers to DP parameters.

This reaction of the physiological parameters under examination for most of the cases is according to the General Adaptation Syndrome theory by Hans Selye (Selye, 1956). The typical reaction of the human organism to any lasting stress-factor (the non-specific stress-response) consists of three stages. During the first stage (Alarm), the body's physiological system drop below optimal functioning. The second stage (Resistance) is characterized by peak-capacity work of the physiological compensatory systems at the levels above homeostatic. After the organism's energy depletion, the Exhaustion stage starts and physiological parameters drop. This stage is the most dangerous for the organism, as it cannot continuously resist to environmental stressors. The body becomes susceptible to any disease. All the complaints of the patients and ambulance calls usually correspond to this stage (Khabarova and Dimitrova, 2009). Similar results were obtained for blood pressure of persons examined in Sofia and Moscow. A decrease of blood pressure prior both to weather and space weather changes, an increase during and after the environmental changes and sharp decrease after the events was established (Khabarova and Dimitrova, 2009). The results in the presented study confirm again the potential effects of GMA on human physiological state but show, as it was pointed out in the last mentioned reference, that it is a necessary adaptation reaction and not something exceptional according to the General Adaptation Syndrome.

Acknowledgements

We thankfully acknowledge the contribution of the medical staff and aviators who participated in the examinations. K. Kudela wishes to acknowledge support of grant agency VEGA, Project 2/0081/10.

References

Aschikaliev, Y.F., Drobjev, V.I., Somsikiv, V.M., Turkeeva, V.A., Yakovets, T.K. Influence of heliogeophysical parameters on ecology. Biofizika (Biophysics) 40, 1031–1037, 1995.

Babayev, E.S., Allahverdiyeva, A.A. Effects of geomagnetic activity variations on the physiological and psychological state of functionally healthy humans: some results of Azerbaijani studies. Adv. Space Res. 40, 1941–1951, 2007.

Baevsky, R.M., Petrov, V.M., Cornelissen, G., Halberg, F., Orth-Gomer, K., Akerstedt, T., Otsuka, K., Breus, T., Siegelova, J., Dusek, J., Fiser, B. Meta-analyzed heart rate. Variability exposure to geomagnetic storms, and the risk of ischemic heart disease. Scripta Med. 70, 201–206, 1997.

Cornelissen, G., Halberg, F., Schwartzkopff, O., Delmore, P., Katinas, G., Hunter, D., Tarquini, B., Tarquini, R., Perfetto, F., Watanabe, Y., Otsuka, K. Chronomes, time structures, for chronobioengineering for 'a full life'. Biomed. Instrum. Technol. 33, 152–187, 1999.

Cornelissen, G., Halberg, F., Breus, T., Syytkina, E., Baevsky, R., Weydahl, A., Watanabe, Y., Otsuka, K., Siegelova, J., Fiser, B., Bakken, E. Non-photic solar associations of heart rate variability and myocardial infarction. JASTP 64, 707–720, 2002.

Cornelissen, G., Halberg, F., Kovac, M., Mikulecky, M., Otsuka, K., Bakken, E. Geographic and extraterrestrial aspects of morbidity and/or mortality patterns from myocardial infarction and stroke. Biomed. Pharmacother. 59, 68–75, 2005.

Dimitrova, S., Stoilova, I., Cholakov, I. Influence of local geomagnetic storms on arterial blood pressure. Bioelectromagnetics 25, 408–414, 2004a.

Dimitrova, S., Stoilova, I., Yanev, T., Cholakov, I. Effect of local and global geomagnetic activity on human cardiovascular homeostasis. Arch. Environ. Health: Int. J. 59, 84–90, 2004b.

Dimitrova, S. Different geomagnetic indices as an indicator for geo-effective solar storms and human physiological state. JASTP 70, 420–427, 2008.

Dimitrova, S., Angelovm, I., Petrova, E. A case study of possible effects of geomagnetic activity and mobile phones on heart rate variability. Medical Data: Med. Rev. 1, 13–16, 2009a.

Dimitrova, S., Mustafa, F.R., Stoilova, I., Babayev, E.S., Kazimov, E.A. Possible influence of solar extreme events and related geomagnetic disturbances on human cardio-vascular state: results of collaborative Bulgarian-Azerbaijani studies. Adv. Space Res. 43, 641–648, 2009b.

Dorman, L.I., Iucci, N., Ptitsyna, N.G., Villoresi, G. Cosmic ray as indicator of space weather influence on frequency of infract myocardial, brain strokes, car and train accidents, in: Proceedings of the 27th ICRC (Hamburg), pp. 3511–3514, 2001.

Dzvonik, O., Stetiarova, J., Kudela, K., Daxner, P. A monitoring of space weather effects on some parameters of mental performance and health in aviation personnel. Stud. Psychol. 48, 273–292, 2006.

Ghione, S., Mezzasalma, L., Del Seppia, C., Papi, F. Do geomagnetic disturbances of solar origin affect arterial blood pressure? J Hum. Hypertens. 12, 749–754, 1998.

Khabarova, O.V., Dimitrova, S. On the nature of people's reaction to space weather and meteorological weather changes. Sun Geosphere 4, 60–71, 2009.

Mavromichalaki, H., Papailiou, M., Dimitrova, S., Babayev, E.S., Mustafa, F.R. Geomagnetic disturbances and cosmic ray variations in relation to human cardio-health state: a wide collaboration, in: Proceedings of the 21st ECRS (Kosice), pp. 351–356, 2008.

Mavromichalaki, H., Papailiou, M., Kudela, K., Stetiarova, J., Dimitrova, S. Physiological state of Slovak aviators in relation to geomagnetic disturbances and cosmic ray intensity variations, in: Proceedings of the 31st ICRC (Lodz) icrc0673, 2009.

Mendoza, B., Sánchez de la Peña, S. Solar activity and human health at middle and low geomagnetic latitudes in Central America. Adv. Space Res. 46, 449–459, 2010.

Otsuka, K., Cornelissen, G., Weydahl, A., Holmeslet, B., Hansen, T.L., Shinagawa, M., Kubo, Y., Nishimura, Y., Omori, K., Yano, S., Halberg, F. Geomagnetic disturbance associated with decrease in heart rate variability in a Subarctic Area. Biomed. Pharmacother. 55, 51–56, 2001.

Papailiou, M., Dimitrova, S., Babayev, E.S., Mavromichalaki, H. Analysis of changes of cardiological parameters at middle latitude region in relation to geomagnetic disturbances and cosmic ray variations, in: (AIP) Conference Proceedings, vol. 1203, ISBN 978-0-7354-0740-4, pp. 748–753, 2009.

Papailiou, M., Mavromichalaki, H., Kudela, K., Stetiarova, J., Dimitrova, S. The effect of cosmic ray intensity variations and geomagnetic disturbances on the physiological state of aviators. ASTRA, in press, 2010.

Selye, H. The Stress of Life. McGraw-Hill, NewYork, 1956.

Singh, A.K., Singh, D., Singh, R.P. Impact of galactic cosmic rays on Earth's atmosphere and human health. Atmos. Environ. 45 (23), 3806–3818, 2011.

Stoilova, I., Dimitrova, S. Geophysical variables and human health and behavior. JASTP 70, 428–435, 2008.

Stoupel, E. Effect of geomagnetic activity on cardiovascular parameters. J. Clin. Basic Cardiol. 2, 34–40, 1999.

Stoupel, E., Domarkiene, S., Radishauskas, R., Israelevich, P., Abramson, E., Sulkes, J. In women myocardial infarction occurrence is much stronger related to environmental physical activity than in men – a gender or an advanced age effect? J. Clin. Basic Cardiol. 8, 59–60, 2005.

Stoupel, E. Cardiac Arrhythmia and geomagnetic activity. Indian Pacing Electrophysiol. J. 6, 49–53, 2006a.

Stoupel, E., Babayev, E.S., Mustafa, F.R., Abramson, E., Israelevich, P., Sulkes, J. Clinical Cosmobiology – sudden cardiac death and daily/monthly geomagnetic, cosmic ray and solar activity – the Baku study (2003–2005). Sun Geosphere 1, 13–16, 2006b.

Stoupel, E., Kalediene, R., Petrauskiene, J., Starkuviene, S., Abramson, E., Israelevich, P., Sulkes, J. Monthly deaths number and concomitant environmental physical activity: 192 months observation (1990–2005). Sun Geosphere 2, 78–83, 2007a.

Stoupel, E., Babayev, E., Mustafa, F., Abramson, E., Israelevich, P., Sulkes, J. Acute myocardial infarction occurrence: environmental links – Baku 2003–2005 data. Med. Sci. Monit. 13, 175–179, 2007b.

Usenko, G.A., Deriapa, N.R., Kopanev, S.I., Panin, L.E. Influence of the heliogeophysical factors on some professional and physiological functions of the Sibir's pilots, in: Biophysical and Clinical Aspects of Heliobiology. House Nauka, Leningrad, pp. 52–65, 1989.