medicinska revija
medical review

UDC: 616.12-073.97:621.395.721.5
ID=169308428

MEDICAL DATA
God I Broj 2 septembar 2009.

Originalni članci
Original articles

A CASE STUDY OF POSSIBLE EFFECTS OF GEOMAGNETIC ACTIVITY AND MOBILE PHONES ON HEART RATE VARIABILITY

Svetla Dimitrova[1], Ivo Angelov[2,3], Emilia Petrova[4]

[1]*Solar-Terrestrial Influences Institute*, Bulgarian Academy of Sciences, Sofia, Bulgaria;
[2]*South West University*, Blagoevgrad, Bulgaria;
[3]*Institute for Nuclear Research and Nuclear Energy*, Bulgarian Academy of Sciences, Sofia, Bulgaria;
[4]*Institute of Experimental Morphology and Anthropology* with Museum at the Bulgarian Academy of Sciences, Sofia, Bulgaria

Correspondence to:
Dr. Svetla Dimitrova, PhD Solar-Terrestrial Influences Institute - BAS
Acad. G. Bonchev Str. Bl. 3, Sofia 1113, Bulgaria

e mail: svetla_stil@abv.bg

Key words
Natural and anthropogenic EMF; Exposimeters; ECG; Cardio-vascular system; Physiological registrations

Abstract
Integral parts of our environment are natural and anthropogenic electromagnetic fields (EMF). The scientific literature has enriched in the last years with studies indicating relationship between geomagnetic activity and different human physiological and pathological processes. At the same time we witness a fast growing of mobile phones use, the public is quite concerned about their possible adverse effects on human health but the results of the studies in the field are controversial. The objectives of this case study are the possible effects of the EMF in 900 MHz band (mobile phones) and geomagnetic activity on heart rate variability (HRV), estimated by time domain and frequency domain analyses of 5-minutes morning and evening electrocardiogram (ECG) registrations. Cost optimized devices, estimating the intensity of the 900 MHz EMF in arbitrary units, combined with one-channel ECG monitor have been developed and two healthy volunteers were examined. The obtained pilot results indicate that probably both considered EMF (natural and anthropogenic) worsen HRV parameters. However we should not make any general conclusions but expanded study with large group of volunteers for a long period of time should be performed.

INTRODUCTION

Electromagnetic fields (EMF) are undivided part of our natural environment. All environmental factors, natural or anthropogenic, are in close relationship with biological processes and human physiological state.

There is a growing body of evidence during the last years that geomagnetic activity (GMA) influence on different functional systems and in particular cardiovascular system [1, 2, 3].

On the other hand the use of devices emitting EMF ranging from static to microwave frequencies has significantly increased in recent years. The most significant impact has been through the rapid expansion of personal mobile telecommunication and wireless network systems. While the benefits of such technologies are clear and widely accepted by society, significant concern continues to be expressed about consequential increases in EMF exposure of people and potential related adverse health effects. The studies carried out by now [4, 5, 6, 7] have not produced clear results, but they indicate that the frequency emitted by mobile phones may be responsible for various biological effects. It is essential to find out whether these effects may affect human health.

Continuing the investigation on the influence of the natural EMF, in particular GMA on the cardio-vascular system [3, 8, 9] we have started a study in which to record the electrocardiograms (ECG) of volunteers to assess heart rate variability (HRV). Expanding the scope of the investigations we included 900MHz EMF.

Heart rate variability (HRV) is the oscillation of the intervals between consecutive heart beats (R-R intervals) in ECG. HRV is an important marker of the autonomic nervous system activity. It is relatively new, easily applied and informative method to study heart activity for different functional and pathological states. There is an experimental evidence for a relationship between lethal arrhythmias and signs of either increased sympathetic or reduced vagal activity. Reduced HRV is a negative prognostic factor often preceding and/or concomitant different cardio-vascular diseases including sudden cardiac death [10].

MATERIAL AND METHODS

Cost optimized devices, estimating the intensity of the 900 MHz in arbitrary units, combined with one channel ECG monitor have been developed. Description of the devices is presented in [11]. Two prototypes were made and tested and 2 healthy volunteers were measured - the first one (35-years old female) for about 10 months and the second one (39-years old male) for 8 months. The devices were carried in the pocket or in the bag of the persons. Fig. 1 shows an example of the registered signal strength of 900 MHz EMF by one of the tested exposimeters.

The volunteers recorded two 5 minutes ECG every day - in the morning after awakening and in the evening before falling asleep. ECGs were processed by custom software

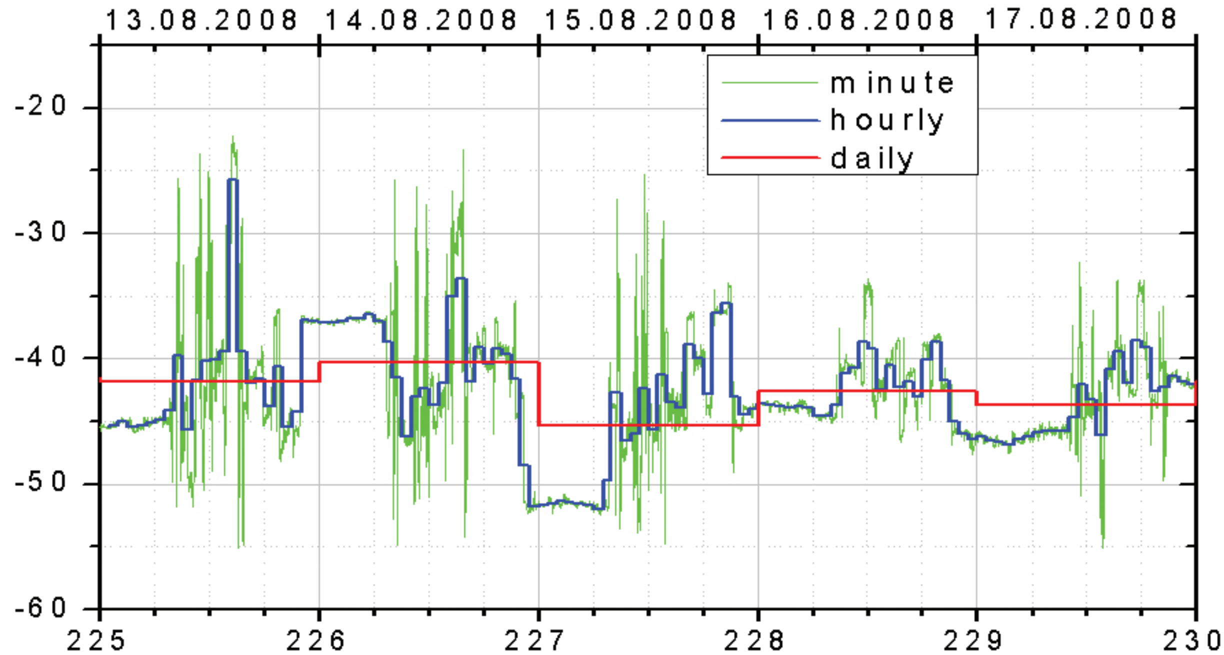

Fig. 1. Example for the registered signal strength of 900 MHz EMF averaged for 1 minute, 1 hour and 1 day for the time period 13.08.2008 - 17.08.2008

and HRV parameters in time domain and frequency domain were derived.

The following parameters in time domain were assessed from ECG:

- RRavg, RRmin, RRmax - these values are respectively the average length of R-R intervals, minimal and maximal value of the length of R-R intervals . This index is directly related to the heart rate (HR): high values of RRavg correspond to low values and on the opposite.

- SDNN - standard deviation of normal sinus RR intervals

- RMSSD - the square root of the mean squared differences of successive RR intervals

- pNN50 - percentage of adjacent RR intervals that vary by more than 50 ms

Spectral analyses (Lomb-Scargle periodogram) [12, 13] were used to analyze the R-R interval series. Power spectral density (PSD) represents power as a function of frequency. Usually interest is directed toward two frequency bands of the spectrum: LF band (0.04-0.15 Hz) and HF band (0.15-0.4 Hz). LF and HF powers and the ratio of LF/HF were calculated. The relation between LF and HF components of HRV represents the balance between the two branches of the autonomic nervous system. The HF component reflecting sinus arrhythmia has been attributed to the modulation of the parasympathetic output. The LF component has been referred to both sympathetic and parasympathetic activity [10, 4].

Correlation coefficients between HRV parameters and GMA and 900 MHz signal strength were calculated.

The statistical method of the ANalysis Of VAriance (ANOVA) was applied to establish a statistical significance of the influence of GMA levels and 900 MHz signal strength on HRV parameters.

The chosen level for statistical significance was $p<0.05$.

RESULTS

3.1. 900 MHz signal strength and HRV parameters

Results revealed for the 1st person for the evening measurements (300 measurements) statistically significant negative correlations between some of HRV parameters and EMF signal strength. SDNN, RMSSD and HF decreased with the increase of the averaged signal strength for the previous day. RMSSD and HF decreased with the increase of the averaged signal strength for the last 2 hours before the ECG registra-

HRV parametar	900 MHz					
SDNN↓	EMF daily averaged	EMF previous day averaged				
RMSSD↓	EMF 8h before registration	EMF 6h before registration	EMF daily averaged	EMF previous day averaged		
pNN50↓	EMF 8h before registration	EMF 6h before registration	EMF 4h before registration (trend)	EMF daily averaged	EMF previous day averaged (trend)	
HF↓	EMF 8h before registration	EMF 6h before registration	EMF 4h before registration	EMF daily averaged	EMF maximun	EMF previous day averaged
LF↑	EMF daily averaged					
LF/HF↑	EMF daily averaged	EMF previous day averaged				
RRmax↓	EMF daily averaged					

Table 1. Statistically significant effects ($p<0.05$) and trends for significant effects ($p<0.1$) for 900 MHz signal strength on HRV parameters obtained by ANOVA for the 1st person for the evening measurements.

HRV parametar	900 MHz				
HF↓	EMF 2h before registration	EMF previous day averaged			
LF/HF↑	EMF 8h before registration	EMF 6h before registration	EMF 4h before registration	EMF 2h before registration	EMF previous day averaged
HR↓	EMF 8h before registration	EMF 6h before registration	EMF 4h before registration	EMF 2h before registration	EMF previous day averaged
RRavg↑	EMF 8h before registration	EMF 6h before registration (trend)	EMF 4h before registration	EMF 2h before registration	

Table 2. Statistically significant effects ($p<0.05$) and trends for significant effects ($p<0.1$) for 900 MHz signal strength on HRV parameters obtained by ANOVA for the 1st person for the morning measurements.

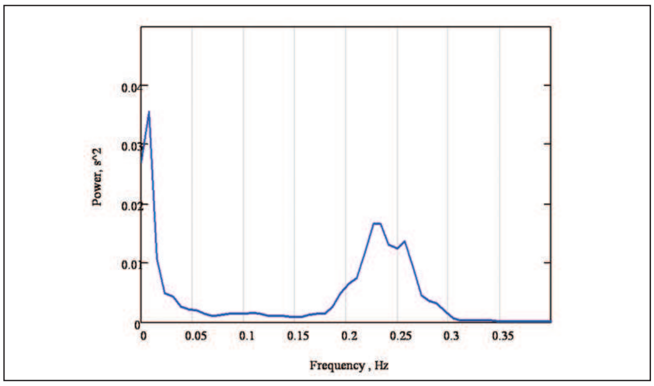

Fig. 2a. Spectral analysis of HRV (LF/HF=0.11) of an evening measurement of the 1st person after exposure on a lower signal strength at 900 MHz (≈ -51dB for 8,6,4,2h before ECG registration and -52dB daily averaged signal strength).

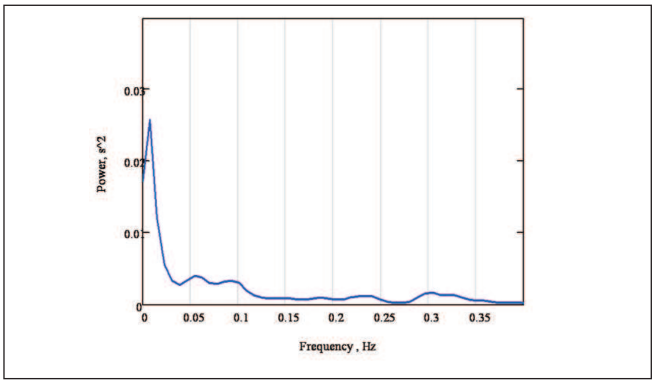

Fig. 2b. Spectral analysis of HRV (LF/HF=1.11) of an evening measurement of the 1st person after exposure on an increased signal strength (≈ -40dB for 8,6,4,2h before ECG registration and -40.9dB daily averaged signal strength).

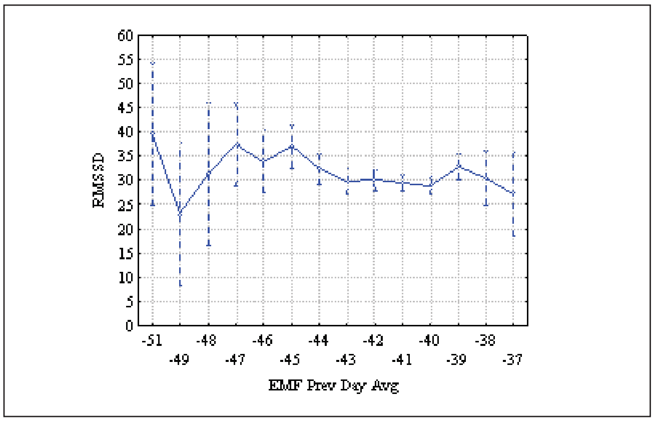

Fig. 3. RMSSD and EMF average signal strength on the previous day for the 1st person for the evening measurements (±95% CI); p=0.037

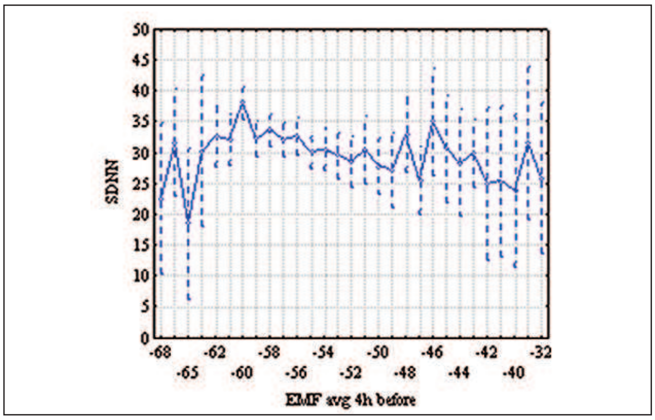

Fig. 4. SDNN and EMF averaged signal strength for the last 4 hours before ECG registrations for the 2nd person for the evening measurements (±95% CI); p=0.006

tions. It indicates that HRV parameters were worsened although HR decreased.

Similar results were obtained for the same person for the morning measurements (288 measurements). SDNN and HF decreased with the increase of the averaged signal strength for the last 8, 6, 4 and 2 hours before the ECG registrations and the averaged signal strength for the previous day and the maximum value of the signal strength on the previous day.

It was obtained by the help of ANOVA that all of the HRV parameters got worsened with the increase of the signal strength. Some of the results were statistically significant and they are written in Table 1 for the evening measurements

HRV parametar	900 MHz		
SDNN↓	EMF 4h before registration	EMF 2h before registration	
RMSSD↓	EMF 4h before registration	EMF 2h before registration	
pNN50↓	EMF 8h before registration (trend)	EMF 4h before registration	EMF maximum value
HF↓	EMF 4h before registration		
LF/HF↑	EMF 4h before registration	EMF 2h before registration	

Table 3. Statistically significant effects ($p<0.05$) and trends for effects ($p<0.1$) for 900 MHz signal strength on HRV parameters obtained by ANOVA for the 2nd person for the evening measurements.

of the 1st person. All of the parameters decreased except LF and the ratio LF/HF.

The spectral analysis of the R-R interval series revealed mostly a presence of changes in HF and less pronounced changes in LF (Fig. 2 a,b). The changes are represented mainly in an amplitude decrease in HF and some increase in LF after the exposure on an increased signal strength.

Table 2 shows the respective results for the same person but for the morning measurements. Fig. 3 is an example for the decrease of RMSSD. It shows the averaged values of RMSSD for the different signal strengths values. Vertical bars in the figure denote confidence intervals (CI).

Similar results were obtained for the 2nd person. For the evening measurements (224 measurements) HRV parameters SDNN, RMSSD and HF correlated negatively with the averaged signal strength for the last 8, 6, 4 and 2 hours before ECG registrations. The ratio LF/HF increased for the same EMF parameters mainly at the expense of HF decrease. For the morning measurements (222 measurements) HR correlated negatively and RRmin, RRmax and RRavg positively with the averaged signal strength for the last 8, 6, 4 and 2 hours and the averaged EMF for the previous day.

ANOVA revealed significant effects of the increased signal strength at 900 MHz for the evening measurements of the 2nd person (Table 3). HRV parameters were worsened. Fig. 4 is an example for the SDNN decrease under variation of EMF averaged signal strength for the last 4 hours before ECG records. For the morning measurements significant effects were not obtained for the 2nd person.

3.2. GMA and HRV parameters

HRV parameters were analyzed regarding GMA, estimated by daily planetary Ap- and Dst-indices, as well. Gradation of GMA levels was described in [3].

Results revealed for the morning measurements for the 1st person significant increase of HR (Fig. 5) and decrease of RRmax and RRavg. For the same person for the evening measurements increase in HF with GMA increase was established.

For the 2nd person SDNN was significantly worsened (decreased) for both morning (Fig. 6) and evening measurements with GMA increment.

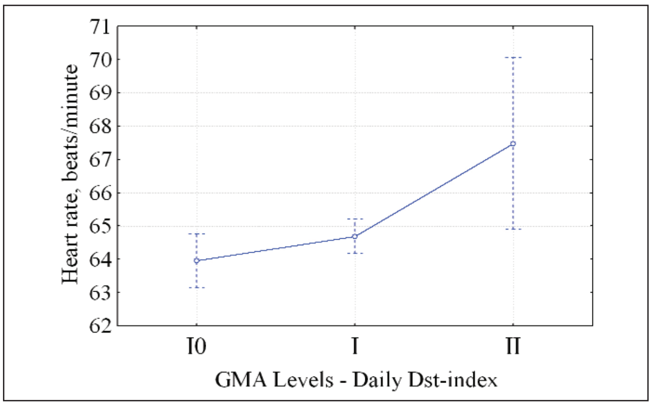

Fig. 5. HR and daily GMA, estimated by Dst-index, for the 1st person for the morning measurements (±95% CI); p=0.028

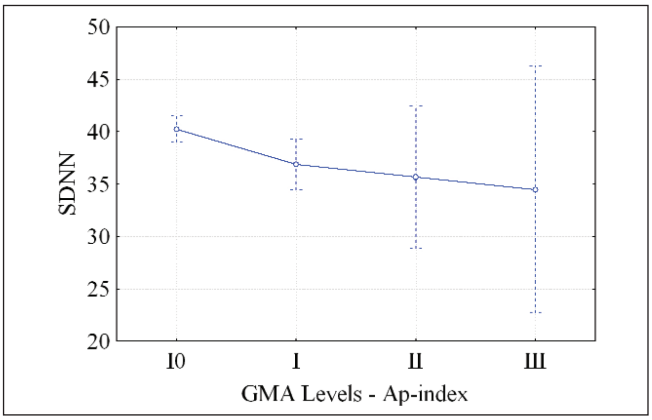

Fig. 6. SDNN and daily GMA, estimated by Dst-index, for the 2nd person for the morning measurements (±95% CI); p=0.05

4. CONCLUSION

On the basis of these pilot results we should not make any general conclusions. However they indicate that probably EMF at 900 MHz and GMA effect cardio-vascular health state and expanded study with large group of volunteers for a long period of time should be performed.

REFERENCES

1. K. Otsuka, G. Cornélissen, A. Weydahl, B. Holmeslet, T.L. Hansen, M. Shinagawa, et al. ”Geomagnetic disturbance associated with decrease in heart rate variability in a subarctic area”, Biomedicine and pharmacotherapy, vol. 55, 2001, pp. 51s-56s.
2. E. Stoupel, E.S. Babayev, F.R. Mustafa, E. Abramson, P. Israelevich, and J. Sulkes. ”Acute myocardial infarction occurrence: environmental links Baku 2003-2005 data”, Med. Sci. Monit. vol. 13 (8), 2007, pp. BR175-BR179.
3. S. Dimitrova, S. ”Different geomagnetic indices as an indicator for geo-effective solar storms and human physiological state”, Journal of Atmospheric and Solar-Terrestrial Physics, vol. 70, 2008, pp. 420-427.
4. M. Parazzini, P. Ravazzani, G. Tognola, G. Thuróczy, F.B. Molnar, A. Sacchettini, G. Ardesi, . Mainardi. Electromagnetic fields produced by GSM cellular phones and heart rate variability. Bioelectromagnetics. Vol. 28(2), pp. 122-129, 2007.
5. S.M.J. Mortazavi, J. Ahmadi, M. Shariati. Prevalence of subjective poor health symptoms associated with exposure to electromagnetic fields among university students. Bioelectromagnetics. Vol. 28(4), pp. 326-330, 2007.
6. J. Wilén, A. Johansson, N. Kalezic, E. Lyskov, M. Sandström. Psychophysiological tests and provocation of subjects with mobile phone related symptoms. Bioelectromagnetics. Vol. 27(3), pp. 204-214, 2006.
7. A.A. Marino, E. Nilsen, C. Frilot. Nonlinear changes in brain electrical activity due to cell phone radiation. Bioelectromagnetics. Vol. 24(5), pp. 339-346, 2003.
8. Dimitrova S., I. Stoilova, I. Cholakov. 2004a. Influence of local geomagnetic storms on arterial blood pressure. Bioelectromagnetics, Vol. 25(6), pp. 408-414.
9. Dimitrova, S., E. S. Babayev, N. B. Crosby; Space Weather Changes and Human Cardio-Vascular Health State in Middle Latitudes; Global Telemedicine and eHealth Updates: Knowledge Resources, Vol. 2, 2009, Ed.: M. Jordanova, F. Lievens, ISSN 1998-5509, Luxemburg, pp. 399 - 405.
10. Task Force. 1996. Heart rate variability: Standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. European Heart Journal Vol. 17, pp. 354-381.
11. Dimitrova S., Angelov I. Possible effects of 900 MHz EMF and geomagnetic activity on heart rate variability parameters. Proceedings of the Third International Scientific Conference FMNS-2009, (in print).
12. Clifford G. D., Azuaje, F., McSharry P.E. (Eds): Advanced Methods and Tools for ECG Analysis, Artech House Publishing, 2006
13. Lomb N.R: Least-squares frequency analysis of unequally spaced data, Astrophysical and Space Science, vol 39, pp. 447-462, 1976

The paper was accepted 01. 07. 09