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On prognostic connection between hard cosmic ray flux decrease and leaps of cardiovascular diseases in 2008–2009 in Vilnius

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Data on a prognostic relationship between the hard cosmic ray flux (HCRF) and the leaps of cardiovascular diseases (CVD) in Vilnius in 2008–2009 are presented. A gamma spectrometer with a scintillation detector were used to register the HCRF near the ground surface. Data on CVD over a period of 24 months (2008–2009) were obtained from the Vilnius Ambulance Service. Information on CVD was selected for all age groups in accordance with the international codes for identification of diseases (ICD). The present study was restricted to time periods when the cosmophysical and medical data could be compared. For the processing of experimental results, empirical criteria in the analysis of HCRF and CVD were used. The criterion in HCRF change is a decrease of HCRF values by 200 impulses and more during a period of 4 hours. The CVD number exceeding the monthly average value by 10, 15, 20% was analysed. A correlation between the above parameters was studied in the range of 1–3-day period. The efficiency of the prognosis of CVD leaps by HCRF decrease in 1–2 days in 2008 was 74–82% and in 2009 65–70%, and for 2–3 days in 2008 54–60% and in 2009 63–65%. The human factor was analysed, too.

Key words: hard cosmic ray flux, cardiovascular diseases, connection, human factor

INTRODUCTION

The relationship between anthropogenic variables and the living organism and humans is well known. At the same time, it is necessary to take into account the natural factors that have a harmful effect on people, namely such as changes in meteorological and geomagnetic processes, solar activity variations and others (1–10).

It is natural that the variations of these processes are most dangerous to people with an unhealthy cardiovascular system. The main factor influencing the human organism turned to be geomagnetic field variations having an aftereffect within several days (2, 11–13).

Therefore, when studying the geophysical effects on the human organism it is necessary to consider the direct external effect and the organisms' readiness to accept this effect. These two aspects are of different significance. A long-time exposure to external factors adapts the human organism to these stimuli. On the other hand, the geomagnetic effect of the solar activity can appear suddenly after a "calm" period and thus have an essential biological effect, i. e. increased morbidity (12, 13).

The direct measurement of the geomagnetic induction field change is a very complicated procedure because of its small values, i. e. from a few to several hundreds nT (2); therefore, natural hindrances often stand out above these values.

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The geomagnetic field changes the velocity of the cosmic particles arriving from the Galaxy. The primary cosmic rays, which consist mainly of protons, interact with atmospheric gases, provoking nuclear reactions. As a result of these interactions, π-mesons are formed with a maximum concentration at a height of 15 km (14). However, because of their short lifetime (26 ns), π-mesons cover a short distance (about 125 m) and turn into muons with a lifetime of 2 μs (14). During this time, muons cannot reach the ground surface from the altitude of 15 km; therefore, their flux to the ground surface is registered from lower heights (15–17). So, near the ground surface, only the secondary cosmic flux takes place. The intensive dynamic processes in the atmosphere form a continuous vertical air mass motion and change the air density. There processes are connected with cyclonic or anticyclonic activity.

As a result of changes of the geomagnetic field and meteorological processes, the flux of muons moving towards the ground surface changes, too. Thus, an indirect factor of the external influence of geomagnetic field change on the human organism – hard cosmic rays flux (HCRF) variation near the ground surface – is used as a prognostic indicator for the leaps in cardiovascular diseases (CVD). Here, a mild cosmic component is excepted because of its additional formation by non-cosmic factors.

The number of CVD cases was defined by the number of ambulance calls. Information on CVD was selected for all age groups in accordance with the international codes for identification of diseases (ICD). Heart diseases were selected according to the ICD codes I20–I22, I45, I47–I50, and vascular diseases according to the ICD I10, I11, I25, I26, I61–I64, I67, I69–I71, I73, I80. The total number of CVD cases was used for data analysis. The number of CVD cases per day exceeding an average monthly value by 10%, 15% and 20% was considered as an effect. The days when CVD leaps were observed were taken as a basis for the analysis of HCRF changes that had occurred 1–3 days before the leap in CVD incidence.

The aim of the present study was to analyse a prognostic relationship between HCRF and CVD leap frequency, using HCRF as an indirect indicator of geomagnetic field variations.

MATERIALS AND METHODS

A gamma-spectrometer with a scintillation detector was used to measure HCRF. The detector of the device, made of crystal NaI(Tl) and a photomultiplier, was placed into a lead-protected chamber with 10–12 cm thick walls to absorb the mild component of cosmic radiation. The muon spectrum (0.3–4.0 MeV) was formed by the interaction of muons with the detector's crystal and registered as a result of Compton's scattering. The operating stability of the device was controlled by radionuclide ^{137}Cs radiation. Measurements were carried out continuously every 15 min. The experimental error was 1% at the probability of 95%. Deviations from the average HCRF value exceeding the mentioned error during the exposure time of 1 h were due to the external action on the gamma-spectrometer concerning the analysis of the obtained results. Over 70000 HCRF measurements were analysed.

Data on CVD over a period of 24 months (2008–2009) were obtained from the Vilnius Ambulance Service. During this period, there were 44732 CVD-related ambulance call-outs.

The present study was restricted to the time periods when the cosmophysical and medical data could be compared. The calculated coefficients of correlation were used to compare the daily variations of HCRF and CVD. Results of 65–80% were considered as strong trends. More details on the analysis methods are given in (12).

RESULTS

The present investigation refers to the local effects. A prognostic correlation has been analysed in detail between HCRF and CVD leap variations. HCRF is unstable near the ground surface and can vary for one or several days both at individual time intervals and all-day-long. CVD leaps were found to appear within 1–3 days after a HCRF decrease.

To define a quantitative relationship between HCRF decrease and CVD leaps in some days, the criteria have to be proposed. The HCRF value variation was studied in the 0.3–4.0 MeV spectrum of energies in the Vilnius city to predict the leaps of CVD.

The processing of experimental information was accomplished in the following way:

1. The number of cosmic particles was registered every 15 min. The obtained results were averaged up to one-hour time interval.

2. A decrease in HCRF values (more that 200 impulses) during a 4-hour period was chosen to be a criterion to predict CVD leaps.

3. The number of CVD cases per day exceeding an average monthly value by 10%, 15% and 20% was used as an effect.

4. A correlation between HCRF decrease and an increase in CVD leaps in 1–3 days was identified.

5. The predictive reliability for an increase in the number of CVD cases after 3 or more days sharply decreased.

6. The seasons of the year and the patients' age were not considered.

7. The human factor in CVD leaps was taken into consideration.

The data on the average monthly value produce an analogous course of HCRF and CVD with the maximum in winter and the minimum in summer (Fig. 1, curves 1, 2). The annual course of these characteristics can be explained by the different distance between the Earth and the Sun in different seasons.

The other decisive factor in the trend of these parameters is the 11-year solar cycle. The tendency of a gradual decrease of the maxima of monthly average values of HCRF in 2001–2007 (12, 13) coincide with solar activity decrease, and a tendency of HCRF increase was observed in 2008–2009 (Fig. 1, curve 2) according to solar activity increase.

Thus, it is possible to confirm a correlation between the monthly average value of HCRF and CVD with the obtained average correlation coefficient of 0.71 for the period 2008–2009.

A correlation between HCRF decrease and CVD leaps was analysed in detail. The prognosis of CVD leaps was considered within 2 days simultaneously with the information on ambulance calls which often arrive close to or just in the midnight, and this complicates the dating. Measurement results of HCRF decrease and CVD leaps within 1–2 and 2–3 days in 2008–2009 are presented in Tables 1 and 2. A similar analysis for 2001–2003 and 2004–2007 was published elsewhere (12, 13, 18).

Data in Tables 1 and 2 show that the highest correlation between HCRF decrease and CVD leaps exceeding the monthly average value by 10, 15 and 20% occurs within 1–2 days. In the first case, this connection for the period 2008–2009 reached 70–74%, in the second case 70–82%,

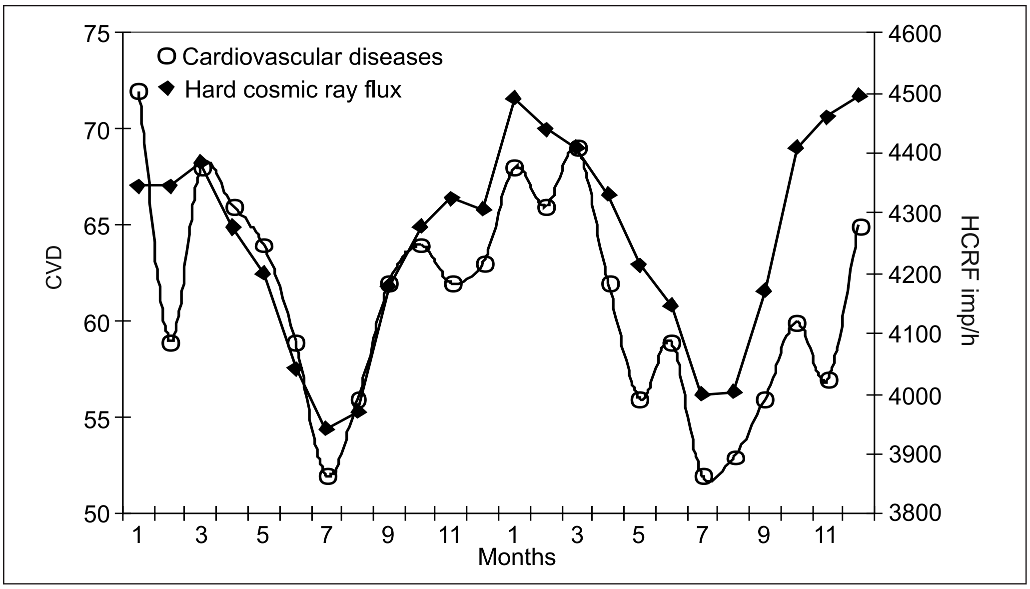

Fig. 1. Average monthly values in Vilnius in 2008–2009

Table 1. **CVD leap numbers exceeding the monthly average values by 10%, 15%, 20% and the number of occurrence of this increase as predicted by a decrease in HCRF of ≥200 impulses during 4 hours and more in Vilnius in 2008**

Months	CVD number over the average monthly value			Number of occurrences					
				Within 1–2-day interval			Within 2–3-day interval		
	10%	15%	20%	10%	15%	20%	10%	15%	20%
January	8	6	4	8	6	4	3	2	2
February	8	3	3	2	0	0	1	0	0
March	6	3	2	3	3	2	2	2	2
April	9	6	5	9	6	5	4	3	3
May	6	3	2	5	3	2	6	3	2
June	10	6	4	5	3	1	3	2	0
July	9	4	3	8	3	3	5	2	1
August	8	7	4	5	5	4	7	6	4
September	9	8	7	9	8	7	8	7	7
October	3	1	1	2	1	1	2	1	1
November	5	4	4	4	4	4	4	3	3
December	7	5	4	5	4	2	3	1	1
Total	88	56	43	65	46	35	48	32	26
Total, %				74	82	81	54	57	60

Table 2. **CVD leap numbers exceeding the monthly average values by 10%, 15%, 20% and the number of occurrence of this increase as predicted by a decrease in HCRF of ≥200 impulses during 4 hours and more in Vilnius in 2009**

Months	CVD number over the average monthly value			Number of occurrences					
				Within 1–2-day interval			Within 2–3-day interval		
	10%	15%	20%	10%	15%	20%	10%	15%	20%
January	7	5	3	4	2	1	3	2	1
February	8	1	1	8	1	1	4	1	1
March	7	2	1	7	2	1	7	2	1
April	8	6	5	5	4	3	4	2	1
May	8	5	4	5	4	3	4	3	3
June	10	8	6	8	6	4	7	5	3
July	10	6	5	8	5	4	7	4	4
August	9	6	3	7	5	3	6	4	3
September	8	4	4	3	2	2	4	2	2
October	6	2	2	2	1	1	3	2	2
November	8	7	7	5	4	4	7	7	7
December	8	8	5	6	6	3	5	5	2
Total	97	60	46	68	42	30	61	39	30
Total, %				70	70	65	63	65	65

and in the third case 65–81%. The correlation between these parameters within 2–3 days was lower, i. e. 54–65%.

The increased prognostic relation between HCRF decrease and CVD leaps in 1–2 days in comparison with previous results (12, 13) can be explained by frequent cases of HCRF decrease in 2008–2009 according to the chosen criterion.

Upon analysing the interrelation of the above parameters, it was necessary to consider another phenomenon – the human factor provoking leaps in CVD (Fig. 2). Data in Fig. 2 illustrate the fact that the majority of CVD leaps occurred in the first half of a week.

The extremal numbers of CVD leaps in 2008–2009 refer to Monday and Saturday. In the case of comparison of average data for Monday and Saturday during a two-year period and the average value for the other days of the week, the results were almost the same, i. e. 13 and 12 in 2008, 13 and 14 in 2009 (Fig. 2). On the whole, the increased human factor in CVD leaps on Monday is compensated by the lower results for Saturday. This means that HCRF variations after geomagnetic field change lead to the averaging of the obtained results during the period of a week and rise the efficiency of a prognostic relation of CVD leaps to HCRF decrease.

DISCUSSION

The HCRF monitoring was carried out in Vilnius, employing a gamma-spectrometer with a scintillation detector. This detector is sensitive to muons and gamma quanta within energies in the range 0.3–4.0 MeV.

The primary cosmic particles (protons and α-particles) have an electric charge and therefore are influenced by

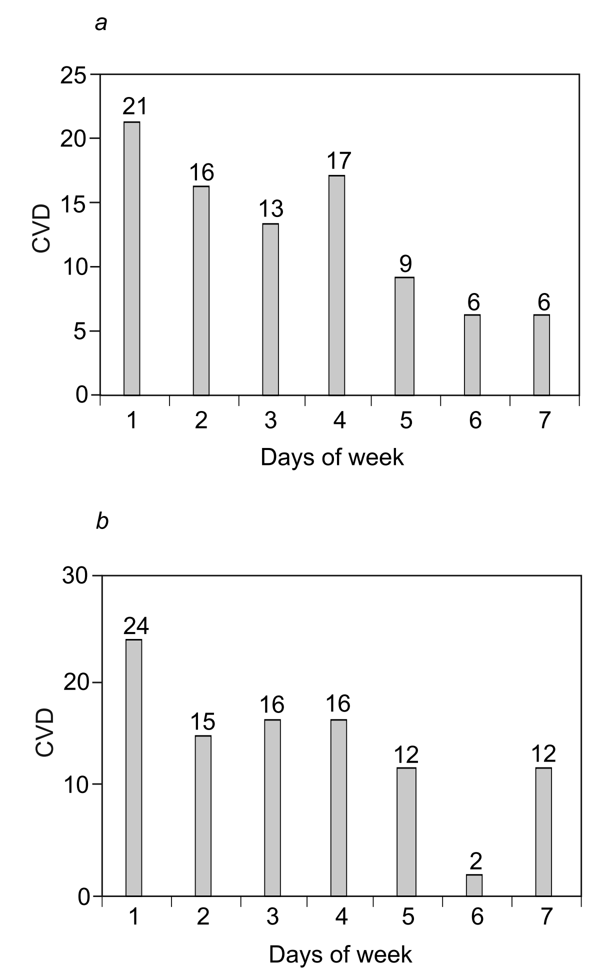

Fig. 2. Dependence of CVD leap numbers exceeding the monthly average value by 10% on days of the week: *a* – in 2008, *b* – in 2009

the Earth's geomagnetic field; they change their energies and near the ground surface turn into secondary cosmic radiation. This means that the spectrum is formed by secondary cosmic radiation only while passing the lead protection 12 cm thick. So, the analysis of the obtained data refers to the hard cosmic rays only. The geomagnetic activity varies in the range 0–550 nT (19). Changes in geomagnetic activity produce a parallel variation in the energy of these particles. Simultaneously, the geomagnetic field exerts an effect on human health and may provoke undesirable effects such as an increase in CVD incidence, changes in cardiac rhythm, etc., and perhaps even death (3, 9, 19–21).

The effect of the geomagnetic field on humans is manifested only after a certain time, because the human organism has an "inertia" in the perception of geomagnetic changes (11). This means that the variation in the number of cosmic particles becomes prognostic for human health change.

The influence of geomagnetic field variations on the human body is most pronounced in certain situations. In particular, it occurs when geomagnetic field variations appear after a long period of stability. Bodily response occurs after a certain period of time (in the present study within 1–3 days). That is why an indirect indicator – the HCRF of geomagnetic field variations – can predict CVD leaps. After a continuous HCRF decrease (during some days), the number of CVD leaps decreases because the organism adapts to external influences.

The instability of the geomagnetic field is often accompanied by a change of weather. However, changes in the atmospheric pressure do not affect considerably the human cardiovascular system (13). On the other hand, the present results (2008–2009) show that CVD occurrence is two times more frequent during anticyclonic than cyclonic activity.

It is known that CVD frequency variations may be caused by a season of the year, population ageing, health care system, ect. This means that geomagnetic variations exert only an extra effect. However, an increase in CVD numbers by 10–20% above the average monthly level sometimes took place in the absence of the corresponding HCRF criterion within previous 1–3 days. This phenomenon is possible because of incorrect data on the time of ambulance calls. The other reason is thunderstorm activity which increases the secondary cosmic radiation near the ground surface (12), leading to the registration of extra errors of HCRF. Cyclones and anticyclones also influence the results of HCRF measurement (12). Tectonic processes influence the flux of cosmic particles, too (12). The accuracy of CVD leap prognosis by HCRF decrease depends also on the human factor.

These phenomena can change the course of HCRF value tendency at any moment and simultaneously decrease the reliability of the prognosis in the incidence of CVD leaps. This explains why there were situations when no increase in the number of cases of CVD leaps occurred, in spite of the presence of an appropriate HCRF decrease criterion (Tables 1, 2). The situations are possible when the factors affecting the incidence of CVD leaps are not essential and the additional effect of the geomagnetic field becomes negligible, too. Thus, to predict a correlation between these characteristics with the accuracy close to 100% is practically impossible.

CONCLUSIONS

The obtained results confirm a prognostic connection between HCRF decrease and CVD leaps within 1–3 days. To estimate this correlation, the optimum criterion of HCRF decrease by 200 impulses and more over a period of 4 hours for the available measurement installation was found. The efficiency of the prognosis of the number of CVD leaps exceeding the monthly average value was higher in 1–2 days than in 2–3 days after an HCRF decrease in 2008–2009. The maximum result of 82% of the prognostic efficiency was registered in 2008. A relation between HCRF decrease and CVD leaps in 1–3 days should be considered as a natural phenomenon.

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APIE PROGNOZINĮ SĄRYŠĮ TARP KIETOSIOS KOSMINĖS SPINDULIUOTĖS SRAUTO SUMAŽĖJIMO IR ŠIRDIES BEI KRAUJAGYSLIŲ LIGŲ PAŪMĖJIMO 2008–2009 m. VILNIUJE

Santrauka

Šiame darbe pateikti prognozinio sąryšio tarp kietosios kosminės spinduliuotės srauto (KKSS, angl. HCRF) ir širdies bei kraujagyslių ligų (ŠKL, angl. CVD) Vilniaus mieste 2008–2009 m. tyrimo rezultatai. KKSS matavimams prie Žemės paviršiaus ir registracijai naudotas gama spektrometras su scintiliaciniu jutikliu. Darbe panaudoti 24 mėnesių ŠKL duomenys (2008–2009 m.), kurie buvo gauti iš Vilniaus greitosios pagalbos stoties ir suskirstyti pagal tarptautinę ligų klasifikaciją. Šių tyrimų tikslas – palyginti ŠKL ir KKSS pokyčių tendenciją. Eksperimentinių rezultatų apdorojimui naudotas empirinis KKSS ir ŠKL pokyčių analizės kriterijus. KKSS pokyčių kriterijumi parinktas KKSS sumažėjimas 200 impulsų ir daugiau, kuris truko keturias valandas ir ilgiau. Darbe analizuojami atvejai, kai ŠKL skaičius 10, 15, 20 % viršijo mėnesio vidurkį. Koreliacija tarp nurodytų parametrų buvo tiriama 1–3 dienas. ŠKL paūmėjimų prognozės pagal KKSS sumažėjimą prieš 1–2 dienas yra 74–82 % 2008 m. ir 65–70 % 2009 m., prieš 2–3 dienas – 54–60 % 2008 m. ir 63–65 % 2009 metais. Darbe taip pat analizuojama žmogiškojo veiksnio įtaka.

Raktažodžiai: kietoji kosminė spinduliuotė, širdies ir kraujagyslių ligos, sąryšis, žmogiškasis veiksnys