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Ischemic Heart Diseases Mortality for Bulgaria Partly Depends on Solar Corpuscular Radiation?

Review article

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Abstract

Introduction: 20% of Bulgarians die of ischemic heart disease. A study was conducted in order to get more information on whether and to what extent mortality from ischemic disease in Bulgaria is related to external causes – in particular to the corpuscular solar radiation.

Material and methods: Data for mortality of ischemic heart disease from the Bulgarian National Statistical Institute were used. Data on solar corpuscular radiation was obtained from NOAA site. Correlation and regression analysis were used to process the data.

Results: Between the annual number of protons with energy above 1 MeV and alpha particles with an energy of 4 to 10 MeV on the one hand and the male and female ischemic disease mortality for Bulgaria, forms I20 to I25 according to the International Classification of Diseases 10th revision, has a high statistically significant correlation. The dependence of female ischemic heart disease on the alpha particle flux was with the highest correlation coefficient: 0,939, a statistical significance level of 0,001. The mortality from ischemic disease in Bulgaria is negatively correlated with the horizontal component of the geomagnetic field in Bulgaria (for male mortality, the correlation coefficient is -0.888, the level of statistical significance 0.001). There are no statistically significant correlations between mortality from ischemic heart disease in Bulgaria on the one hand and the average annual number of sunspots and x-ray radiation (0.1 – 0.8 nm) of the geostationary orbit, on the other hand. There are no statistically significant correlations between galactic cosmic radiation and mortality from ischemic heart disease in Bulgaria. Examples are given for a date interval with intensive proton flux and ischemic mortality, correlated with it.

Discussion: The results indicate an existence of unknown phenomenon–a causal relationship between mortality from ischemic heart disease in Bulgaria on the one hand, and the fluxes of solar corpuscular radiation on the other. The contribution of this phenomenon to the risk of mortality from ischemic heart disease in Bulgaria is about 6 – 10%. This phenomenon is observable also in the other small area mid-latitude countries.

Keywords

Mortality; Ischemic heart disease; Solar positive corpuscular radiation; Proton flux; Satellite measurement; Risk of death

Introduction and Goal

According to World Health Organization (WHO) statistics, ischemic heart disease is the first in the list of the 10 most frequent causes of death in 2016, regardless of the state's economic situation [1]. From the statistics of the

National Statistical Institute of Bulgaria, it can be estimated that 20% of the average annual mortality rate for Bulgaria is due to ischemic heart disease in its various forms [2].

A study was conducted to find out if and to what extent is mortality from ischemic disease related to external causes such as the planetary magnetic field, corpuscular solar radiation, and galactic cosmic rays [3]. In this article, more facts are given, leading to the conclusion, that such a phenomenon the dependence of ischemic heart disease mortality on corpuscular solar radiation, is real phenomenon for Bulgaria and some other countries.

Material and Methods

Data

Annual mortality is calculated as the number of deaths per 100,000 people associated with a specific cause of death in the case of ischemic heart disease in Classes I20 - I25 of the International Classification of Diseases, 10th revision (ICD-10). The annual mortality data was taken from the statistics of the National Statistical Institute of Bulgaria [2]. Hourly data at national level on deaths from ischemic heart disease at specific intervals with intense fluxes of charged solar particles during the years studied were also provided from the National Statistics. Similar annual data can also be found from Eurostat [4], but there is some discrepancy in the data from both sources. The study was based on the national statistics. Data on deaths from ischemic heart disease from the deaths of Stara Zagora Municipality, Bulgaria, were also taken. The municipality has 160108 citizens as of February 1, 2011.

Data for reaching the Earth solar electromagnetic and corpuscular radiation were obtained from a site of the National Oceanic and Atmospheric Administration (NOAA), USA [5]. Data were recorded by the Geostationary Operational series Environmental Satellites (GOES) in a geostationary orbit (circular orbit with a radius of 42164 km above the Earth equator). The onboard equipment of the GOES satellites measures the flows of charged particles, distributed by type in energy intervals. In addition, the X-ray radiation and the induction components of the planetary magnetic field in the area of the geostationary orbit are measured.

For the purposes of the study, data on flows of the electrons with energy over 0.6 MeV, protons with energy above 1 MeV and alpha particles with energy from 4 to 10 MeV were used. Satellites measure the fluxes – the number of particles passed across a unit of area per unit of time in unit spatial angle [number/(cm^2.s.sr)]. Geostationary data on magnetic field components are available in nT and the intensity of X-ray radiation is measured in W/m^2. Data with different time averages are available from the source. For the purpose of the study, 5-minute mean data was used.

Data on the horizontal and vertical component (in nT) of the ground level geomagnetic field for Bulgaria were obtained from the geomagnetic observatory in Panagurishte, Bulgaria (42.52°N, 24.18°E, Altitude 556 m [6,7]).

Data on galactic cosmic radiation, registered by five relatively nearby Neutron Monitors–Alma-AtaB

(43.25°N, 76.92°E), Lomnicky Stit (49.20°N, 20.21°E), IGY Jungfraujoch (46.55°N, 7.98°E, two monitors) and Kiel (54.32°N, 10.12°E), were retrieved from the NMDB database [8,9].

Data Processing

The relatively short life of satellites in a geostationary orbit necessitates their replacement with new ones, and despite similar measurements, the new devices are different from the previous ones. Three GOES satellites have been used for the 11-year interval covered by the study: GOES 12 (from 2005 to 2010), GOES 11 (9 months) and GOES 13 (from 2011 to 2015), which is a prerequisite for the inhomogeneity when their data is used together. In order to homogenize each parameter used in the study within the scope of 11 years, the data from each of the satellites were individually transformed in order to get the three satellites to obtain a common uniform set of data. For this purpose, the so-called Z-values were calculated from the data of each satellite. The average value and the standard deviation for the data in the time span of a satellite life were calculated first. Then to calculate Z-values, from each measured value for a given parameter the average value was subtracted and the difference was divided by the standard deviation. Z-values homogenize the array of data from the three satellites. The inconvenience of working with them is that they also have negative values. Z-values were calculated for the flow intensity of protons, alpha particles and electrons as well as for the intensity of X-ray radiation, registered by the satellites. Different approaches to climatic data homogenization are discussed in [10].

The series of Z-values for the parameters used were averaged for each year in the interval 2005 – 2015. Their annual values were statistically processed together with the annual mortality data for Bulgaria, in particular for the ischemic heart disease.

Correlation and regression analyzes were used to process the data.

A Causal Relationship between Mortality and Influencing Factors

The annual mortality rate for Bulgaria, on the one hand, by type of cause (separately for women and men) and the annual solar radiation parameters were analyzed by the statistical method of correlation analysis. The method produces a quantitative expression (correlation coefficient) of the degree of consistency in the changes of the two datasets. The more coherent are the changes, the greater is the probability for an existence of a causal relationship between solar radiation and mortality. The correlation method is applicable to cases of linear dependence between the ranges of consistently changing data. In the absence of consistency between the changes in the two series, the correlation coefficient is zero. Coherence can be expressed both in a coordinated increase and/or decrease of the two series (positive correlation) and in a concerted increase of one, combined with a decrease of the other and vice versa (negative, reverse correlation). When there is complete consistency in the change of the two sets of numerical values, the correlation coefficient has a value of 1,000 for a positive correlation or -1,000 for a negative correlation. As the correlation coefficient is closer to a unit of absolute value, the two sets of data are more strongly correlated and the more likely a causal relationship between them is to exist. Complex processes such as diseases are due to a multitude of simultaneously acting causes. The solar radiation components could be just one of the possible. The presence of a strong correlation between mortality from a given disease and a parameter characterizing solar radiation does not mean that radiation is the only cause of mortality from this disease. It means only that radiation could be among the causes of mortality and there is a linear relationship between mortality and radiation parameter. In the following, only dependencies are assumed, suggesting a strong positive causal relationship between a given solar radiation parameter and the mortality rate in Bulgaria. The existence of a strong positive causal relationship was assumed at a correlation coefficient values above 0,9.

The statistical parameter "level of statistical significance" characterizing the reliability of the correlation dependence was also determined. It shows the probability that the correlation is due to the accidental coincidence of circumstances. The smaller this probability the more reliably is found a correlation between the two changing data sets, i.e. the more likely there is a causal relationship between them. The correlations with a level of statistical significance less than 0,05 were considered statistically significant in the study described. I.e. the combination of a correlation coefficient of more than 0,9 with a significance level of less than 0,05 was used as a criterion for an existence of a causal relationship between mortality and solar radiation parameters.

Risk assessment of death

The risk of death due to a factor such as solar corpuscular radiation has been calculated for the cases where a causal relationship between the factor and mortality was suspected (according to the above-mentioned criterion). Regression models were used for risk assessment.

A high numerical value of the correlation coefficient means the existence of a linear relationship between ischemic disease mortality and the given factor as solar corpuscular radiation. The linear dependence was modelled with a linear regression model, a linear function between an independent variable – a parameter (value) characterizing the factor (solar radiation) and a dependent variable – the mortality. A separate regression model was obtained for each of the two fluxes of solar radiation – protons and alpha particles, considered as an independent variable.

The regression models used had the general form:

$$\textit{Annual mortality} = \textit{Intercept} + k * (C - C_{min}), \quad (1)$$

where k is the coefficient in front of the independent variable $(C - C_{min})$, C is the annual value of the respective flux, and C_{min} is the minimum of the annual values of this parameter for the studied interval.

The above mentioned difference was used as an independent variable in the regression models because in this case, the smallest value of the independent variable is zero. If the minimum value of the independent variable is zero, the intercept in the regression model shows the fraction of mortality not explained by the independent variable in the regression model, i.e. the contribution of genetic, physiological, and other causes on the mortality. The intercept in (1) was used to calculate the contribution of all impact factors on death from ischemic disease.

The product between the value of the independent variable in (1) and the coefficient in front of it determines the contribution of the studied factor to the mortality. The contribution of the studied factor was calculated by the mean value of the independent variable for the studied years.

The total contribution of all influencing factors to the mortality was calculated as the sum of the contribution of the studied factor and the intercept in the model.

The risk of death related to Sun radiation was calculated as the ratio of the studied factor's contribution to the total contribution of all factors. A risk is a number between 0 and 100%.

The determination coefficient R^2 determines the quality of the model, i.e. the extent to which the change in the independent variable explains the change in mortality rate assessed by the regression model. Its maximum value of 1,000 would be reached when the change in mortality is explained only by changes in the independent variable (i.e., there are no other influencing factors).

Results and Discussion

Results

The flows of positively charged particles from the Sun reaching the Earth's orbit are most often in the form of short-term impulses lasting hours to a few days on the background of long intervals of very low-intensity. The peaks in the positively charged streams appear unpredictable over time, with a typical frequency in the range of several peaks per month. Figure (1) shows the change in time of one intense positive corpuscular radiation peak in the years of the study, averaged at 5-minute intervals. The peaks are always a mixture of protons and alpha particles, alphaparticles are hundreds of times less. The fluxes of proton and alpha particle streams are strongly correlated. The recorded electron concentration has a different behavior – it varies widely in time, sharply decreases during a peak in said positive charge streams.

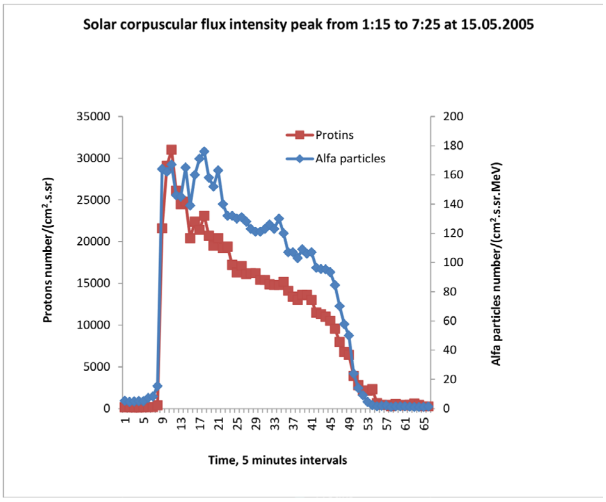

Figure 1: The corpuscular flows emitted by the Sun and reaching the Earth are short-lived peaks (usually up to several hours) of varying intensity.

The Galactic cosmic rays behavior also indicates arriving solar substance (Figure 2). They decrease at the same time, phenomenon known as Forbush effect [11].

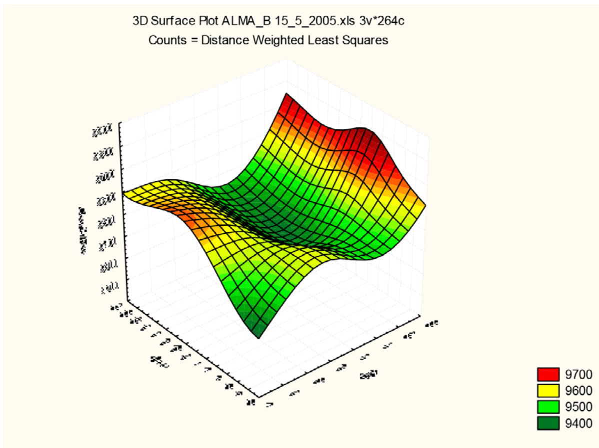

Figure 2: Forbush decrease of galactic cosmic rays intensity at the Earth's surface (ALMA-B neutron monitor) as a consequence of the Solar Mass Ejection (SME), reached the Earth on 15 May 2005 (illustrated by STATISTICA 7).

Figure(4) shows the same data in Figure(3) after being recalculated in Z-values separately for each of the two satellites.

The two ranges of data expressed in Z-values are homogenized to a significant extent.

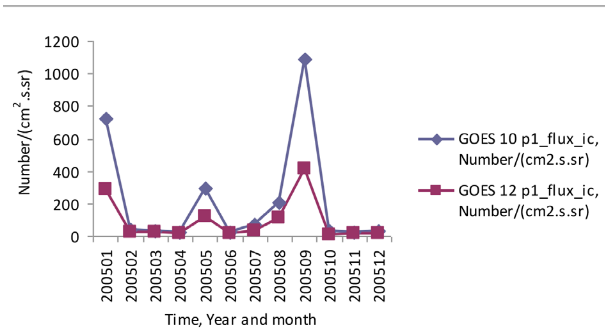

Figure 3: The flux of solar protons of geostationary orbit for 2005, registered simultaneously by GOES 10 and GOES 12. There is a certain inhomogeneity – the data from GOES 10 are on average higher than those of GOES 12.

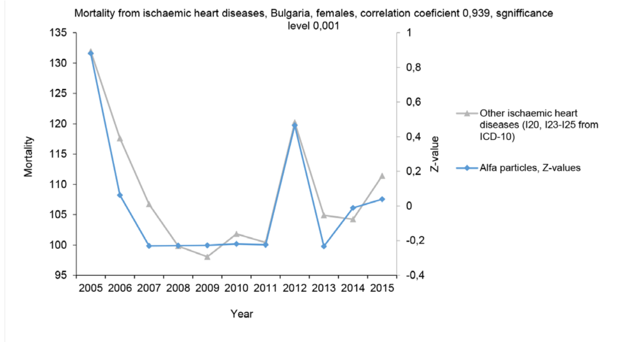

Figure 5: There is a high correlation between females' mortality from ischemic heart disease in Bulgaria and the annual flux of alpha particles of geostationary orbit.

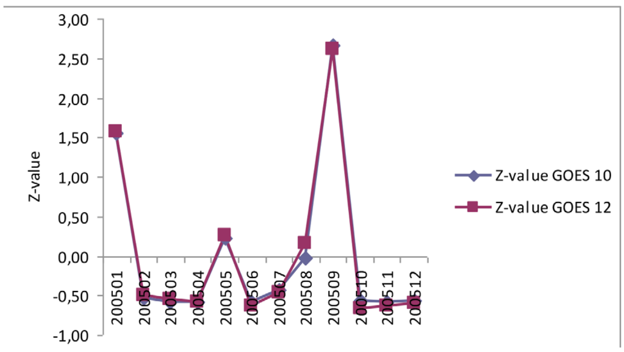

Figure 4: The data shown in Fig. 3 are substantially homogenized after Z-homogenization.

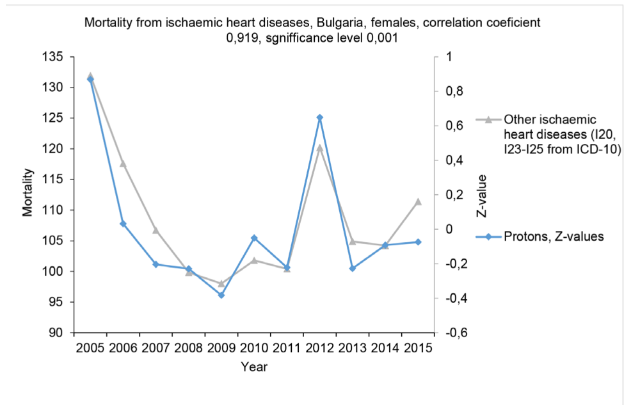

Figure 6: There is a high correlation between females' mortality from ischemic heart disease in Bulgaria and the annual intensity of protons of geostationary orbit.

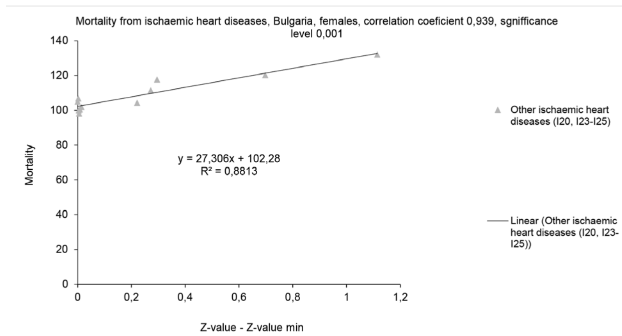

Figure 7: The regression model of the dependence of Fig. 5.

Between the annual average fluxes (in Z-values) of protons and alpha particles in geostationary orbit on the one hand and mortality in Bulgaria from ischemic disease (forms I20 – I25 from the International Classification of Diseases 10th revision) has a high statistically significant correlation. The greatest is the correlation of female mortality from ischemic heart disease with the alpha particle flux (correlation coefficient 0,939, level of statistical significance 0,001, Figure (5,6).

Figure(7) shows the regression model, the line, and the formula, of the dependence of Figure(5). The abscissa is the difference of Z-values with their minimum value, which allows the intercept in the model to be used for calculating the risk of death.

According to the above-mentioned risk calculation, as a result of the invasion of positively charged particles from the Sun into Earth's orbit, the risk of death for women in Bulgaria from the above-mentioned forms of ischemic heart disease is increased by 6%. The average annual mortality in the years of study was 132 cases per 100,000 (for the above-mentioned forms of the ischemic disease) [2], i.e. mortality is higher by 8 cases per 100,000 populations as a consequence of positively charged fluxes from the Sun.

The calculation does not include all forms of the ischemic disease. Other forms – I21, I22 and I23 also correlate with the fluxes of positive Sun particles, i. e. the real estimate of the risk of death from ischemic heart disease for women in Bulgaria is higher than indicated.

Mortality from ischemic heart disease was examined for the days and hours of the main streams of solar charged particles over the studied interval of years. Figure (8) shows the coincidence in death rates from ischemic heart disease and proton flux that reached Earth in the interval March 5 – 15, 2012, with a maximum intensity of 75461/ (cm^2.s.sr) on 8 March 2012 at 13:00 local time. March 8th is a woman's holiday in Bulgaria and, if the weather permits, many people go out into the open, unaware that they are exposed to an invading flow of protons that day.

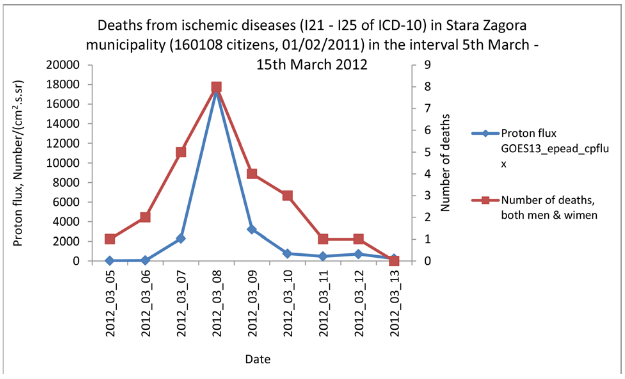

Figure 8: The picks of the proton flux and the mortality of ischemic disease for Stara Zagora municipality, Central Bulgaria, on the interval March 5 – 15 2012 coincide.

The highest number of deaths during the said interval of days is among the elderly, aged between 60 and 90 years, Figure(9).

Detailed hourly dynamics of proton flux and mortality from ischemic heart disease both males & females at national level of Bulgaria, for March 8 – March 9, 2012, are shown in Figure (10). It appears that mortality does not immediately follow the peak of protons, but with a delay of about 12 hours follows the peak of death, after which the process gradually subsides. According to Eurostat data for the national range and the studied interval of 11 years, the average number of deaths from ischemic heart disease in Bulgaria (population 7204687, a census in 2011 [12]) were 26 deaths per day. For March 8 and March 9, 2012, deaths are 105 and 107, respectively. This is more than four times the average daily mortality rate.

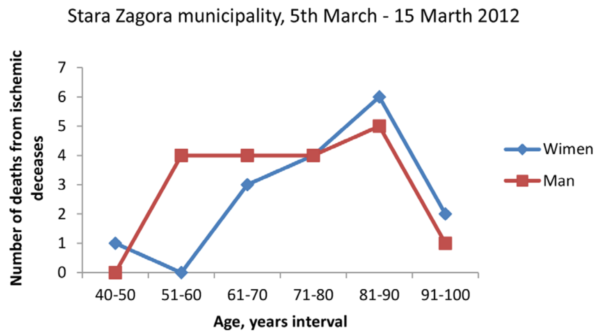

Figure 9: Distribution by age of ischemic heart disease victims in Stara Zagora Municipality during the interval March 5 - March 15, 2012

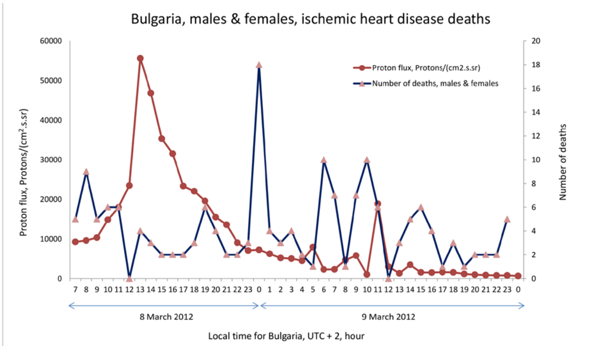

Figure 10: Hourly dynamics of proton flux and mortality from ischemic disease at national level for Bulgaria.

Not every intense stream of positively charged solar particles results in increased mortality from ischemic heart disease. Death is only related to the intense currents that reach Earth orbit around noon when many people are out in the open. The intense flows of solar protons reaching the Earth when it is night for Bulgaria do not lead to a change in mortality. Noticeable increase of mortality in Stara Zagora municipality for the studied interval was also found after proton flows on January 19, 2005, maximum intensity 26000 / (cm^2.s.sr) at 11:30 local time, on August 24, 2005, maximum intensity 13300 / (cm^2.s.sr) at 12:40 local time, on December 15, 2007, maximum intensity 22900 / (cm^2.s.sr) at 14:15 local time, on april 5, 2010, maximum intensity 150000 / (cm^2.s.sr) at 11:05 local time, on January 24, 2012, maximum intensity 47143 / (cm^2.s.sr) at 17:15 local time. There was not noticeable increase of mortality after peaks of proton flows on May 15, 2005, maximum intensity 35800 / (cm^2.s.sr) at 4:30 local time, on January 18, 2010, maximum intensity 815 / (cm^2.s.sr) at 0:10 local time.

Is this phenomenon – a relationship between mortality from ischemic disease and the flows of solar positive particles are typical only for Bulgaria? Figures (11,12) show that similar dependencies are also observed in other mostly small, mid-latitude countries such as Malta and Hungary [4]. There is also a similar statistically significant correlation in Austria. In several countries in Europe, particularly in Switzerland, although no statistically significant correlation between mortality from ischemic heart disease and streams positively charged solar particles, increased mortality for 2012 was observed, the year with a peak of these flows.

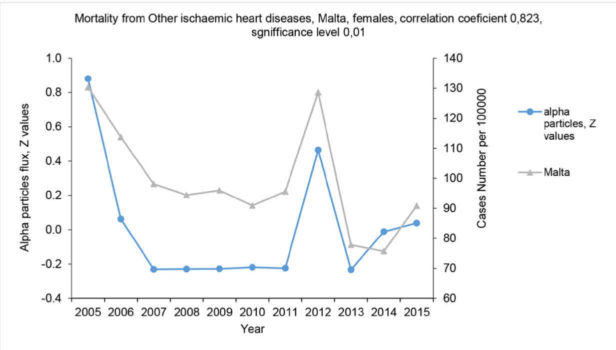

Figure 11: A relationship between mortality from ischemic disease and the flows of solar positive particles was observed for Malta too.

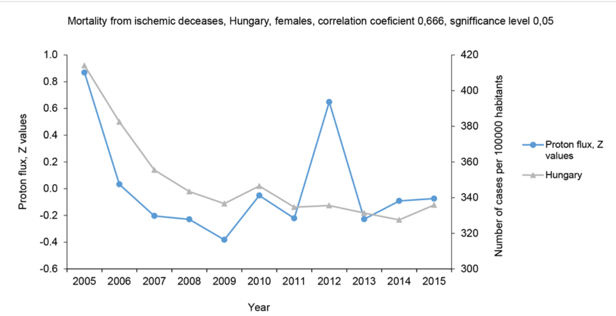

Figure 12: A relationship between mortality from ischemic disease and the flow of solar positive particles was also observed for Hungary.

The mortality of ischemic disease in Bulgaria is negatively correlated with the horizontal component of the geomagnetic field in the region of Bulgaria (data from Panagyurishte geomagnetic observatory). For male ischemic mortality, the correlation coefficient was highest (-0.888, a statistical significance level of 0.01). The mortality does not correlate significantly with the vertical component of the geomagnetic field in the region of Bulgaria.

There is no statistically significant correlation for the studied interval between the mean monthly values of the fluxes of positively charged particles and the average monthly Sun Spots Number [13].

There are no statistically significant correlations between mortality from ischemic heart disease in Bulgaria on the one hand and the average annual number of sunspots and X-rays of geostationary orbit on the other.

There is no statistically significant correlation between the annually averaged fluxes of positively charged particles from the Sun and the annual average horizontal and vertical component of the geomagnetic field at the surface in Bulgaria for the studied interval.

There are no statistically significant correlations between galactic cosmic radiation and mortality from ischemic heart disease in Bulgaria.

Discussion

The study argues in favor of the existence of a phenomenon of positive causal relationship, albeit weak, between mortality from ischemic heart disease in Bulgaria and other small mid-latitude countries on the one hand and the fluxes of positively charged particles from Sun on the other. The fact that this phenomenon is noticeable in countries with small areas means that the phenomenon affects limited areas and is only noticeable for statistics on mortality in small countries but remains unnoticed in statistics for large area countries. The phenomenon appears to be limited

within the mid-latitudes. The correct outline of its action on the surface of the planet is critically dependent on the accuracy of statistics on mortality from ischemic heart disease in each country.

The phenomenon seems to manifest itself during the day, most when the sun is around its climax, mainly during the warm part of the year, when more people are outdoors, unprotected by buildings. These observational facts suggest the direct effect of corpuscular solar radiation on the surface of the planet and the biosphere, in particular the mortality of ischemic heart disease in man.

Work on the study of this phenomenon continues and in a future article, a possible mechanism will be discussed that gives rise to the phenomenon observed.

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