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The Effects of Solar Activity and Geomagnetic Disturbance on Human Health

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ABSTRACT

Heliobiology is a new branch of science that deals with the influences on human health caused by solar activity and investigates the possible mechanisms to explain the reported associations. In the last decades, many researchers have considered geomagnetic storms, cosmic rays, and solar flares to be hazardous to human health. They have established that these space weather indicators could play a role in regulating external factors in human health. Heliobiological results have attracted scientists from various branches of science to do more work in this field. In this short paper, the concepts of solar activity, space weather, and heliobiology will be briefly introduced and discussed. The main findings of the effects of solar activity on human health will be summarized.

KEYWORDS: Space weather; Solar activity; Heliobiology; Human health

INTRODUCTION

The sun is the main source of energy for life on Earth. Without its heat and light, life would not exist. The energy generated inside the sun through nuclear fusion reaches us as electromagnetic radiation, which covers all wavelengths from gamma rays to radio waves. The Earth's atmosphere absorbs almost all of the sun's gamma rays and X-rays and part of the ultraviolet radiation. At certain geographical location, solar radiation is affected by astronomical factors, such as season, day of the year, and meteorological conditions (e.g., temperature, humidity, clouds, and aerosols) [1]. In addition to the electromagnetic radiation and in quiet conditions, the sun expels a constant amount of solar plasma and magnetic fields, known as solar winds. At the Earth's orbit, the solar wind has a density of about 3 cm-3, a mean velocity of about 400 km/s, and a mean magnetic field of about 5 nT [2,3].

The sun is an active star with an 11-year periodic variation known as a solar activity cycle. During this period, the sun undergoes changes characterized by variations in its output of electromagnetic radiation and charged particles due to the different degrees of activity. Each cycle is divided into three phases: the rise phase, with an increasing range of active phenomena; the maximum phase as the phenomena peak; and the decline phase as they gradually decay to the quiet sun levels. Although solar activity accounts for only 1% of the energy produced by the sun, it exerts a significant influence on the Earth and its surrounding environment [4,5]. During the solar activity period, the number of sunspots increase and galactic cosmic rays decrease. In addition, solar disturbances, large amounts of X-ray radiation, and energetic events (e.g., solar flares, coronal mass ejections, solar energetic particle events, and high-speed solar wind streams) are frequently observed [6]. These events result a considerable amount of radiation; highly energetic particle fluxes and magnetic fluxes are released into the interplanetary medium [2,5]. The Earth' atmosphere, which protects it from dangerous electromagnetic radiation, is surrounded by a magnetic field, known as the magnetosphere, which protects it from charged particles. The Earth and its surroundings are very sensitive to changes in solar activity [7]. When solar events occur, major disturbances affect the Earth's magnetosphere, causing geomagnetic storms and perturbations in the upper atmosphere (mainly the ionosphere) that may be considered potential hazards for terrestrial processes [8]. The sun is the main driver of the state of near-Earth space on all spatial and temporal scales. Spatial scales extend from the

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interplanetary medium, the magnetosphere, and the ionosphere. Temporal scales range from 1 to 5 days for propagation of solar wind from the sun to the earth, depending on the velocity of the interplanetary structure imposed on the terrestrial magnetosphere, to a few hours for solar energetic particles events or 8 minutes for electromagnetic radiation [2].

HELIOPHYSICS

Space weather (or heliophysics) is a branch of space physics that describes the conditions on the sun, solar wind, interplanetary magnetic fields, the magnetosphere, and the ionosphere. With the advancement in technology during the 20th century and due to the disturbances caused by solar activity that affects the performance and reliability of space-born and ground-based technological systems, the interest in space weather has increased and it has become an important branch of science [9]. The effects of space weather phenomena are many and varied. They include electronic and power transmission failures, interruptions in telecommunications and navigational systems, hazards to astronauts, aircraft crews, and passengers, and disruptions of oil and gas pipelines, railway traffic, and human health [7,8,10-13].

Space weather data are collected from ground-based detectors and operational satellites. Data from ground-level stations include cosmic ray data from neutron monitors the number of sunspots, total electron content, and solar flux at 10.7 cm radio frequencies. Moreover, magnetic storms and the level of geomagnetic activity are recorded by magnetometers through the global network of magnetic field observatories. Various indices, such as Kp, Ap, and Dst, have been introduced to represent geomagnetic activity [5].

On the other hand, several orbital and geostationary satellites conduct space weather observations from space. They include NASA's Advanced Composition Explorer satellite, which has monitored solar wind parameters (velocity, density, and temperature) since 1997. In addition, the Geostationary Operational Environmental Satellite measures the solar X-ray flux from solar flares in two frequency bands and records the charged particles from coronal mass ejections. The Deep Space Climate Observatory satellite is a space weather satellite that launched in February 2015 to give advance warning of coronal mass ejections [5,8].

HELIOBIOLOGY

Heliobiology [13] (sometimes referred to as cosmobiology, heliomedicine or clinical cosmobiology in the literature) is a new branch of science that deals with the influences on human health caused by solar activity and investigates the possible mechanisms to explain the reported associations.

Over the last 20 years, heliobiology has become a subject of interest that has attracted scientists from various disciplines. Numerous studies have been carried out, and the evidences suggest that space weather activity has a broad range of adverse effects on human health, such as mental illness, cardiovascular mortality, and neurological system diseases [14-16]. On the other hand, other studies have reported no such of relationships exist [15]. Although contradictions have been found between these studies, this field of research has become increasingly important in the present context of a consistent weakening of the Earth's magnetic field.

One challenging problem (more of a controversial issue) in heliobiology is the search for mechanisms by which different events and processes on the sun can have either direct or indirect effects on human health and physiology. Although several possible mechanisms have been proposed to explain this connection, there is widespread skepticism about the reality of such relationships.

One of the proposed mechanisms is the effect of geomagnetic storms on the Earth's electric and magnetic fields. It is well-established that all biological systems on Earth are exposed to external and internal fluctuating magnetic and electric fields of a wide range of frequencies (0.1-10 Hz) [15,17-18]. The oscillations over these frequencies are close to the frequency of many internal organs. These oscillations, which are active by the magnetosphere and ionosphere due to geomagnetic storms resulting from solar activity events, may in a resonant way act on the function of living organisms at a cellular level to a greater or lesser degree. The fundamental difficulty when studying the effect of natural electric and magnetic field variations on human health is the fact that the field strengths involved are very small. When the geomagnetic environment is disturbed, it seems plausible that this could have either a direct or an indirect effect on human physiology [17-19].

Another possible mechanism to explain the association of geomagnetic disturbances and human behaviour (depression) involves the alteration of melatonin levels in the body due to geomagnetic disturbances [18, 20-21].

The effects of space weather activities on human health have been qualitatively and quantitatively examined using two quantifiable measures: the direct and indirect indicators. The indirect indicators are long-term medical data, such as the temporal distribution of emergency calls and hospital admissions [15].

The relationship between indirect indicators and space weather indicators is usually investigated using two statistical approaches:

a) Correlation analyses and their associated statistical tests between the time series of the space weather variables and medical data [15,22].

b) Cyclic variations to investigate the common periodicities between medical data and space weather data over wide ranges of frequencies using appropriate analytical methods (e.g., Fourier transform) [23].

c) The direct indicators, on the other hand, include all the physiological parameters that can be verified and are acquired either in vivo, directly from the subject (e.g., heart rate variability, blood pressure measurements, microcirculation parameters, and reaction time), or in vitro by laboratory diagnostics or tissue investigations.

RESULTS FROM HELIOBIOLOGICAL INVESTIGATIONS

Over the last 20 years, several research papers have presented the results of investigating the relationships between space weather parameters and human health. Some of these results are summarized below [13,15,24]:

a) High values of geomagnetic activity have a negative effect on human cardiovascular health that includes significant variations in heart rate variability [13,25].

b) The number of incidents of alterations in blood flow is increased (increased systolic and diastolic blood pressure and epileptic seizures) during the solar activity periods [24,26].

c) Incidents of coronary disease and myocardial infarction increase during spans of high solar activity, as compared to years with low solar activity [13-15-16].

d) Sharp or sudden variations in geomagnetic and solar activity can act as stressors, which alter regulatory processes such as breathing, reproductive, and increase total deaths total deaths [13].

e) Several studies support the idea that geomagnetic disturbances decrease the melatonin levels in the human body [20-21].

f) Positive correlations exist between neurological system diseases (e.g., depression and mental illness) and geomagnetic activity [12-13,27-28].

g) The standard metabolism and behaviour patterns of humans and other species are affected by solar activity [13,29-30].

h) Solar disturbances are associated with significant increases in hospital admissions for suicide attempts, homicides, and traffic accidents [12,31].

i) Investigations of the blood of tested patients have shown that the viscosity of blood during solar activity periods increases sharply, so the risk of developing morbid cardiovascular system disease is increased [32].

j) A relationship between solar activity and some congenital anomalies such as Down syndrome has been established [33-34].

k) The fluctuations in solar activity are associated with oscillations in concentrations of vitamin D [35].

l) Solar activity is related to many parameters of new-born development and homeostasis, such as number of births, number of premature births, new-born weight and length, and syndromes associated with chromosome aberrations and hormone production [36-37].

m) Solar activity may contribute to the development of and be a trigger of the exacerbation of nervous and mental disorders, such schizophrenia, Alzheimer's disease, and multiple sclerosis [38].

CONCLUSION

The results from heliobiological investigations carried out in the last 20 years have reported evidence that suggests solar activity has direct or indirect influences on human health. Although there are speculations about the reality of such relationships, the results have attracted the scientific community to heliobiology and encouraged them to conduct more research in this field and search for mechanisms that can explain such relationships. For more conclusions to be made in the field of heliobiology, more investigations and medical data from different places around the world are needed. In this regard, a national-scale project led by the first author of this paper has been proposed and submitted to the Ministry of Health and other research organizations In Saudi Arabia. The main aim of this project is to investigate the effects of solar activity parameters on physiological and mental disorders and other parameters related to human health status in Saudi Arabia.

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