

## Geomagnetic Activity and Heart Rate Variability

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Our planet, the earth, revolves around its axis, resulting in day and night, exposing our metabolic functions to change under the influence of 24-hour light and dark cycles. All the organisms including animals and plants on earth are evolved to predict these cycles by developing an endogenous circadian clock, which is synchronized to external time cues. The life of all the organisms on this planet is also under influence of magnetic field. It is well known how birds and other animals are able to navigate by sensing the Earth's magnetic field [29-32]. It is possible that geomagnetic strength of magnetic fields can influence physiological functions, including circadian clock function. The organisms, including humans, ensure that physiological processes are carried out at the right time of the circadian cycle. The circadian clock resets physiological and metabolic processes, including sleep-wake cycles, temperature, functions of central nervous system, cardiovascular, endocrine, gut, liver, beta cells of pancreas, kidney and osteocyte as well as muscle function according to time structure. The functions of all these body systems are under influence of magnetic fields of the earth, sun and moon, Figure 1.

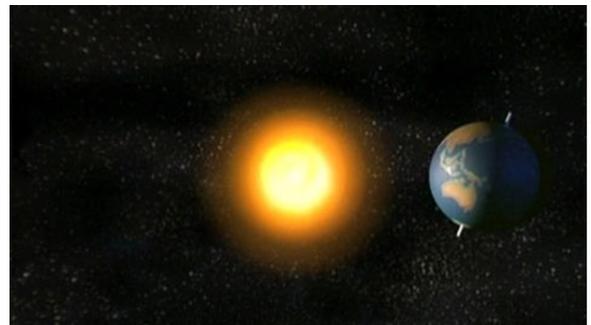


Figure 1. The earth is rotating on its axis and around the sun exposing all the organisms to magnetic forces of the sun and moon.

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Environmental factors, such as geomagnetic forces, Western diet, physical inactivity, tobacco and alcoholism, are primary risk factors for physical, social, spiritual and mental diseases of the individuals and populations [1]. Late night eating and late night sleep as well as sleep deprivation due to any cause can predispose circadian disruption of cardiovascular rhythms, resulting in increased risk of cardiovascular diseases and diabetes [1-3]. It is not clear how much risk is contributed by magnetic activity while subjects are exposed to these risk factors.

A recent review discussed over 100 studies reporting that weakening or shielding from the Earth's magnetic field can produce a wide range of biological effects in cells, plants and animals, including changes in rates of cell division, tumor growth, expression of hormones, gene expression, planarian regeneration, seed germination, plant growth, pain perception in animals, brainwave activity, and stem cell differentiation [5]. Many studies have been published describing a broad range of physiological, psychological, and behavioral changes associated with changes or disturbances in geomagnetic activity and solar activity [3-9]. Some experts consider magnetic field disturbances as a risk factor in public weather forecast reports to be important in influencing HRV [10].

On a larger societal scale, increased rates of violence, crime, social unrest, revolutions and frequency of terrorist attacks have been linked to the solar cycle and the resulting disturbances in the geomagnetic field [7, 8]. Increased solar activity has not only been associated with social unrest, and cardiovascular diseases (CVDs), but it is also associated with the periods of the greatest human flourishing with clear spurts of innovation and creativity in architecture, arts, sciences, and positive social change as well as with variable human performance in the financial markets [9-12]. Some of the studies have also shown that geomagnetic and solar influences affect a wide range of human behavioral and health outcomes with the nervous and cardiovascular systems, being the most clearly impacted, however, the specifics of the biological mechanisms in animals and humans are not yet completely understood [8-13]. Space weather hazards have been well-studied during the past few decades, mainly in connection with effects on technical

systems [7, 8]. However, the biological effects of solar and geomagnetic activity have been largely ignored because the amplitudes of the electromagnetic fields (EMF) are small, typically one to several hundreds of nanoteslas [2-8]. This is much weaker than electromagnetic noise of anthropogenic origin and about ten orders of magnitude less than the characteristic energies of biochemical reactions. Singh et al. proposed that amplitudes of electromagnetic fields may be similar to that of the amplitudes of the gravitational waves [14].

## **Magnetic Activity and Myocardial Infarction**

In previous studies, Breus et al. reported the effect of geomagnetic activity on the regulation of heart rhythm of cosmonauts during the expeditions on board of the Soyuz spacecraft, and the MIR orbital space stations showing adverse effects on heart rhythm depending on the duration of the flight and pre-existing integrity of the myocardium [2, 3]. Cornelissen et al. reported the nonphotic solar associations of heart rate variability and myocardial infarction [6]. An association of inflammation, heavy meals, magnesium, nitrite, and coenzyme Q10 deficiency and circadian rhythms has been reported among patients with acute coronary syndromes, which may be confounders and may increase the risk of decreased heart rate variability due to magnetic activity among these patients [9]. A clinical study included 435 males and 268 females diagnosed with myocardial infarction who attended the Department of Cardiology at the Hospital of Lithuanian University of Health Sciences (LUHS) [17]. The results support the hypothesis that the Earth's magnetic field has a relationship with the number of acute myocardial infarctions with ST segment elevation (STEMI) per week and the average weekly geomagnetic field strength in different frequency ranges. Another recent long-term study examined relationships between solar and magnetic factors and the time course and lags of autonomic nervous system (ANS) responses to changes in solar and geomagnetic activity [18]. HRV was recorded for 72 consecutive hours each week over a five-month period in 16 participants in order to examine ANS responses during normal background

environmental periods. The study confirmed that daily ANS activity responds to changes in geomagnetic and solar activity during periods of normal undisturbed activity and it is initiated at different times after the changes in the various environmental factors and persist over varying time periods [18]. Increase in solar wind intensity was correlated with increases in heart rate, which we interpret as a biological stress response. Increase in cosmic rays, solar radio flux, and Schumann resonance power was all associated with increased HRV and parasympathetic activity. It is possible that energetic environmental phenomena affect neuro-psychophysical mechanisms that can affect people in different ways depending on their sensitivity, health status and capacity for self-regulation [9, 17-24]. In the MAMIS study, Singh et al. observed an increased circadian rhythm of acute myocardial infarctions in the second quarter of the 24-hour day, which may be attributed to the influence of geomagnetic activity on circadian clock [19]. These authors also reported an association of chronophysiological and psychological risk factors among patients with acute coronary syndromes, which may be due to increased contractility of the myocardium and can also be related to greater magnetic activity, apart from changes in behavior [20-22].

In a recent study, McCraty et al. found that during solar storms, the heart rhythms of study participants

changed in ways that suggest changes in nervous system activity relevant to health, well-being and how we respond to stress [24]. It is possible that solar storms directly influence the Earth's magnetic field, and solar geomagnetic activity may be associated with a variety of effects in humans, including changes in melatonin/serotonin balance, blood pressure, immune system activity, and reproductive, cardiac, and neurological processes [24]. The increased intensity of solar storms may also predispose changes in blood flow, aggregation and coagulation, increased blood pressure, cardiac arrhythmias, and poorer outcomes for existing diseases, e.g., increases in incidence and mortality due to heart attacks and increased rates of seizures in epileptics. It is also possible that investors in business become more risk-averse at times of high solar geomagnetic activity [25]. McCraty et al. collected data on heart rate variability (HRV), studying changes in the rhythms of the heart associated with nervous system activity and responses to stress [26]. HRV regulated predominantly by cardiac vagal tone is a measure of autonomic nervous system activity that can be used as a health index and as a biofeedback tool [27]. It is possible that the cardiac rhythms are under influence of physiological, neuropsychological, lifestyle and environmental factors, disease conditions, and other factors such as age and genetics [28], Figure 2.

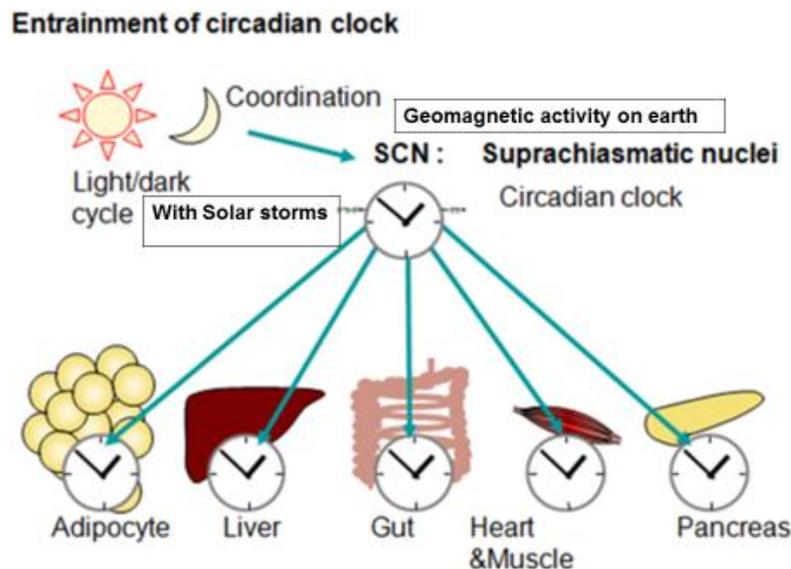


Figure 2. Entrainment of circadian clock by magnetic activity and resulting dysfunction in the body systems including coronary thrombosis and myocardial infarction.

The researchers gathered heart rate data around the clock from 9 subjects who went about their normal daily lives during the 31-day course of the study. The results showed that three significant solar storms occurred during the 31-day experiment, providing the researchers with a unique opportunity to test how these events were correlated with HRV indices of the subjects. McCraty et al. identified several statistically significant correlations, reporting that changes in several HRV indices were associated with solar geomagnetic activity due to the storms that occurred during the study [23, 24, 26]. The study also reported that HRV activity was synchronized with changes in *Schuman resonance* power: when the solar wind strikes our planet's magnetic field, the Earth itself acts as a kind of spherical magnetic field drum, producing standing waves at particular frequencies called Schumann resonances. It is possible that these correlations between Schumann resonances and HRV activity suggest that our nervous system is somehow 'tuned' to these characteristic resonance frequencies in the Earth's magnetic field. The study also found that during a period of relatively quiescent solar geomagnetic activity, the participants' group-averaged HRV activity was synchronized, producing a clear pattern of oscillations with an average period of about 67 hours. However, a sample size of 9 participants limits the strength of this preliminary finding. Another study of over 100 participants was conducted in five widely separated countries [24]. The results indicated that HRV synchronization occurs globally, and that the rhythms in SRP (Schumann resonance power) and ULF (ultra-low frequency power) appear to be the primary environmental factors that underlie group synchronization [24]. These findings may have remarkable implications for our understanding of the interaction of the nervous system with solar storms and our planet. These results offer a new look at how life on our planet is connected with the Earth and the Sun. It is possible that all human beings are somehow connected physically through the Earth's magnetic field. It seems that we respond to one another through magnetic fields on earth [17, 18, 26]. There is a need to study all parts of the collective social organism of our planet. It is unclear what happens to our physiology and metabolism when we meditate on the Earth as our Mother, for peace on Earth, or during turbulent times [1, 17, 18].

In several experiments in *Drosophila*, cryptochromes have been shown to mediate light-dependent magnetosensitivity by an unconventional photochemical mechanism [29, 30]. A chemical compass model of avian magneto-reception has also been observed [31], indicating that sensing of magnetic directions in birds may be due to radical pair processes involving cryptochrome [32]. Cryptochromes are proteins that sense blue light, and in plants these proteins play important roles in regulating growth, development, and circadian responses.

In brief, the above studies indicate that human physiology and metabolism are possibly related with changes in solar activity and geomagnetic activity. It is clear that changes in several HRV indices may be associated with solar geomagnetic activity due to the storms that occurred during different periods of the year. The cardiac rhythms are under the influence of physiological, neuropsychological, lifestyle and environmental factors, disease conditions, and other factors, such as age and genetics. It is possible that cryptochrome proteins present in cells mediate light-dependent magnetosensitivity by an unconventional photochemical mechanism, which mediates the effects of geomagnetic activity on our body systems.

## Ethical Compliance

The authors have stated all possible conflicts of interest within this work. The authors have stated all sources of funding for this work. If this work involved human participants, informed consent was received from each individual. If this work involved human participants, it was conducted in accordance with the 1964 Declaration of Helsinki. If this work involved experiments with humans or animals, it was conducted in accordance with the related institutions' research ethics guidelines.

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