

Space Weather Effects on Humans in Tabuk City, KSA

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Abstract

Solar activity, geomagnetic activity and cosmic ray activity are the major effects of space weather. These constituents affect our daily life navigation as well as human health in space and in earth. The Sun is the source of heat and light that maintains Earth's habitable environment, and serves as the ultimate source of energy for life itself. It is also the origin of visible and invisible influence that affects the Earth, Earth's space environment, and poses a health and safety threat to humans and all kinds of human activities. This work which being conducted in Tabuk city in kingdom of Saudi Arabia (geomagnetic latitude $28^{\circ} 22' 35''$ N, longitude $36^{\circ} 36' 25''$ E) is from March to September 2015. We studied the relation between emergency hospital admissions and space weather indices like Kp, FI, CME and SPE. To evaluate the risks and events during the period of our study we used the hospital admission data from KING KHALID hospital Tabuk, KSA. The effect of geomagnetic storm on hospital admissions before and after storm development was investigated by the help of geomagnetic indices. Geomagnetic storm impact up to 5 days before and 5 days after sharp geomagnetic changes was investigated. The number of admissions found to be increased in the days following the storm. The statistical method of the analysis established a statistical significance of the influence of geomagnetic activity levels in hospital admissions.

1. Introduction

Space Weather has important influence on biological and physiological systems. The geomagnetic field variations affect directly or indirectly the human physiology and health. According to a physicist's view point space weather is the application of space environmental studies to the interactions that occur between the space environment and the activities of human kind. The space weather events can induce health effects not only on the day of the event, but on subsequent days as well. Contemporary science pays considerable attention to the effects of the environment on the human organisms. Science has brought our society more dependent on various technologies. Space weather affects global technological systems and societies. The space weather events can cause extreme currents in the electric grid, widespread blackouts, phone and internet communication failure and threat to human health. Powerful electric currents cause corrosion damage to oil and gas pipe lines. Geomagnetic storm can also cause electric charges in space that affect electronic systems onboard spacecraft, degrade satellite navigation and disrupt high frequency radio propagation used in aircraft communications. A large geomagnetic storm could also threaten the sustainability of the space environment. Accurate forecast knowledge is essential to minimize socioeconomic impacts.

In the last decades, many scientists have worked on the impact of space weather parameters, through the geomagnetic field, on different diseases (Stoupel, 2002; Dimitrova et al., 2004). It has been revealed that cardiovascular, circulatory, nervous and other functional systems react under changes of geophysical factors (Cornelissen et al., 2002). It has long been claimed that geomagnetic storms and other electromagnetic variations are associated with changes in the incidence of various diseases, myocardial infarctions and strokes (Halberg et al., 2000). Some evidence has also been accumulated on the association between geomagnetic disturbances and increases in work and traffic accidents (Stoupel et al., 2004; Ptitsyna et al., 1996; Dorman, 2005). Others have also been reported on the association between geomagnetic disturbances and increases in number of road traffic and work (industrial) accidents (Stoupel et al., 2004; Ptitsyna et al., 1996; Babayev et al., 2006). These studies were based on the hypothesis that a significant part of traffic accidents could be caused by the incorrect or retarded reaction of drivers to the traffic circumstances, the capability to react correctly being influenced by the changes in the environmental physical activity, particularly, sharp fluctuations of geomagnetic field.

A timely knowledge of current conditions in space and ability to forecast space weather disturbances is a must to protect technologies and human beings. Space weather impacts human civilization on a global scale and hence calls for a global approach to research, monitoring, and operational forecasting. Over the last years, many studies have been carried out concerning the possible effect that solar and geomagnetic activity might have on human physiological state (Stoupel, 2002).

Over the past decade space weather has developed strongly as a scientific discipline that can help to address the challenges that the space environment poses to our technological and human civilization. The human body response to space weather changes is based by the adaption of our organism to external changes. The time variation of any health characteristic is to be identical for the organism's response to any influencing environmental agent. Currently, an overwhelming majority of researchers investigate solar-biospheric relationships agree with the electromagnetic nature of the effect of the sun on biosphere. The magnetic field of the Earth penetrates in a human body freely, and the geomagnetic field changes can change some body's characteristics, because the organisms are based on electricity (Khabarova & Dimitrova, 2009).

The Sun is the source of heat and light that maintains Earth's habitable environment, and serves as the ultimate source of energy for life itself. It is also the origin of visible and invisible influence that affects the Earth, Earth's space environment, and poses a health and safety threat to humans and all kinds of human activities (Bothmer and Daglis, 2006). The geomagnetic field which protects the Earth from geomagnetic and solar activities is also essential to the evolution of life. When the geomagnetic environment is disturbed, it can have direct or indirect effect on human physiology. The measures become successful with a better understanding of the basic processes of space weather impacts on Earth and humans. Possible mechanisms of influence of variations of solar and geomagnetic parameters on human health are still being discussed (Babayev and Allah, 2007). Knowledge about the relationship between solar and geomagnetic activity with human health will help to prepare for any future geomagnetic event and its impact.

There is evidence indicating that geomagnetic storms are associated with decreased heart rate variability (Watanabe et al., 2001; Cornelissen et al., 2002); elevated blood pressure (Ghione et al., 1998; Dimitrova et al., 2004), blood coagulation and platelet aggregation (Pikin et al., 1998), increased blood viscosity, and decelerated blood flow (Oraevskii et al., 1998), reduced arterial baroreflex sensitivity and microcirculation (Gmitrov, 2005). The geomagnetic storms sharply disturbs the rhythm of the external synchronizer of biological rhythms (Oraevskii et al., 1998; Breus et al., 1998) and is therefore accompanied by an adaptation stress reaction of the organism (Breus et al., 2012).

Ischemic heart disease remains the most common cause of death worldwide (Murray and Lopez, 1997). Acute coronary syndromes are an especially significant health problem, resulting in an increased risk of recurrent myocardial infarction and lethal outcome (Widimsky et al., 2010). It is established that at least 75% of magnetic storms are followed by an increase of averagely by 1.5 times of the number of hospitalized persons with cardiovascular and nervous diseases. Solar activity is known to affect human consciousness (Hether Carlini, 2014). Solar flares affect the central nervous system, all brain activity including equilibrium along with human behavior and all psycho – physiological response. Solar flares can cause us to be nervous, anxiousness, worrisome, dizzy, shaky, irritable, lethargic exhausted, have short term memory problems and to have prolonged head pressure and headaches. Heather Carlini 2014 reported many different symptoms also.

Time and space seems to be on a wobble even more erratically than before. Loose words and many are experiencing insomnia, strange dreams, nausea, body aches and pains, deep grief, visual disturbances, inner ear issues, ringing in ears, throat and thyroid, tongue dryness etc. Vencloviene et.al., studied the ambulance calls and daily space weather variables and showed that an increase in emergency ambulance calls two days after an active stormy geomagnetic activity level and during days with solar wind speed over 600Km/s. The effect of space weather conditions was stronger in women and in older patients (Vencloviene et.al., 2015). Some studies revealed that the most significant effects on myocardial infarctions, brain strokes, and traffic accidents were observed on the days of geomagnetic field disturbances accompanied with Forbush decreases (Verma,2013)A significant increase in the rate of motor vehicle accidents and of accidents at work may be due to the effects of solar activity, after strong solar flares and during geomagnetic storms has detected decrease in the driver's rate of mental reaction to audio signals after solar flares by a factor of four times. The solar activity cycle clearly controls the occurrence of other diseases.

This problem is being investigated statistically between space weather indices and daily hospital admissions, in Tabuk city, KSA. The possibility that solar activity variations and related changes in the Earth's magnetosphere can affect human life and health has been debated for many decades. In the present investigation an attempt has been made to get possible relationship between solar and geomagnetic activities with the rate of hospital admissions in Tabuk city, KSA. Protecting technologies and human beings from space weather effects requires both timely knowledge of current conditions in space and the ability to forecast space weather disturbances with adequate advance notice as well as to take protective measures. These measures will be successful only if we better understand the basic processes of space weather impacts on the Earth and humans. In this work we investigate the possible influence of space weather impacts on human health in Tabuk city by studying the hospital admissions in various medical departments. The impact of Space Weather on the human life and activities have become more and more important as the role of electromagnetic based facilities, like positioning, navigation and telecommunications has grown in economy and everyday life. Moreover with high quote long distance flights and the space exploration humans directly access regions much more affected by Space Weather than their original habitat. Correspondingly the study of how the Sun's forcing affects the near-Earth environment has grown in importance in the scientific community.

2. Materials and Methods

This work is being conducted in Tabuk city (geomagnetic latitude $28^{\circ} 23' N$ and $36^{\circ} 34' E$ longitude) in kingdom of Saudi Arabia from 21st March to 10th October 2015. The aim of the study is to assess the relation between the space weather conditions and the risk of emergency admissions due to various health problems. Data on the solar flares, solar wind, geomagnetic activity index, solar proton events (SPE) and CME were used as space weather data. Daily Kp indices were used as a measure of level of geomagnetic activity. The Kp index is the global geomagnetic storm index and is used to characterize the magnitude of geomagnetic storms. Kp is an excellent indicator of disturbances in the Earth's magnetic field. We selected all geomagnetic storms according to NOAA classification. Geomagnetic activity was divided in to several levels according to the values of the Kp index. During the period of our investigations, there were quite, a few moderate, major and severe geomagnetic storms were occurred.

The solar flux is used as the basic indicator of solar flare activity, which determines the level of radiation being received from the Sun. The daily flare index values were used as the measure of the level of solar flares having frequency of 2800 MHz (10.7 cm) wave length. Solar flux varies from 50 to 300sfu. Kp and the flare indexes were downloaded from the joint USA/European solar and Heliospheric Observatory (web site: ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/). The solar proton events is defined as integral five minute averages of proton energies $> 10\text{MeV}$ exceeding 10 proton/($\text{cm}^2\text{-s-sr}$). Daily average of proton $> 10\text{MeV}$ flux which was downloaded from the National Geophysical Data Centers OMNI Web data base (<http://omniweb.gsfc.nasa.gov/>) was used as a measure of the level of SPE. According to the specification of our study SPE was considered to have occurred if the daily average of proton $> 10\text{MeV}$ flux was over 10. Solar flares also produce geomagnetic storms. Most of the storms are associated with flare, CME and SPE. Space weather alerts can be collected from Space weather prediction center, national oceanic and atmospheric administration. To evaluate the risks and events during the period of our study we used the hospital admission data from KING KHALID hospital Tabuk, KSA.

The aim of this study is to assess the hospital admissions during seven months with relation to the space weather effects like geomagnetic activity, solar flares, coronal mass ejections and solar proton events. Data in hospital admissions for departments like general medicine, pediatric, ophthalmic, Road transport accidents, Assault, cardiac intensive care unit (CICU) and ICU were collected from the daily hospital admission register. Unfavorable environmental events such as geomagnetic storms can induce health effects not only on the days of the event, but on subsequent days as well.

3. Results

The main results are described below. The analysis gives the influence of space weather on the hospital admissions of people in Tabuk. During the period of study (203 days) the geomagnetic storms were observed on 19 (9%) days. The high solar flares were observed on 25(12.3%) days. The Coronal mass ejections were reported on 3(1.4%) days. Solar proton events (SPE) were reported on 1 (.5%) day. Solar proton event occurred along with solar flare. Hospital admissions were studied during storm days, along with five days before and five days after it. The admissions show an increase in number of patients in various departments like general medicine, pediatric, ophthalmic and gynecology, cardiac ICU, general ICU etc.

In this work we analyze five major storms during the period of study during the declining phase of solar cycle 24. Here we present some examples of severe space weather events to illustrate what we know of their impacts on humans and what we know of the physics of such events. These examples are not intended to be complete catalogue but rather a set that illustrate the extent of our knowledge. Here we consider the major events on 10-04-2015, 13-05-2015, 22-06-2015, 23-06-2015, 13-07-2015, 9-09-2015, 7-10-2015. Analysis of the studies conducted during the periods of weak geomagnetic disturbances showed a lesser number of hospital admissions. During the days with severe geomagnetic storms the hospital admissions were found to be increased.

The effect of geomagnetic storm on hospital admissions before and after storm development was investigated by the help of geomagnetic indices. Geomagnetic storm impact up to 5 days before and 5 days after sharp geomagnetic changes was investigated. The number of admissions found to be increased in the days following the storm. The statistical method of the analysis established a statistical significance of the influence of geomagnetic activity levels in hospital admissions. Figures 1-7 depicts the hospital admissions at the onset of geomagnetic and solar activity.

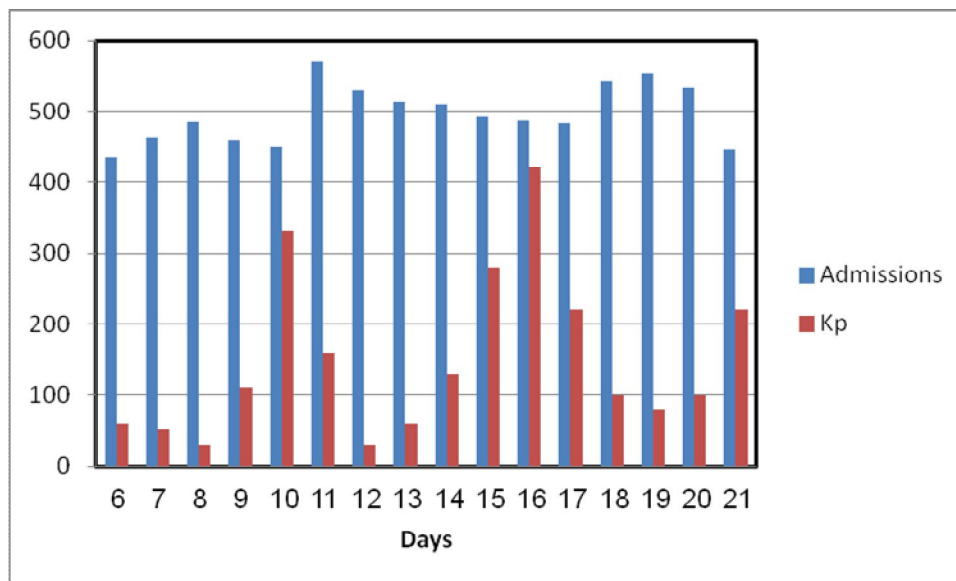


Fig.1 Geomagnetic activity from 6-04-2015 to 21-04-2015

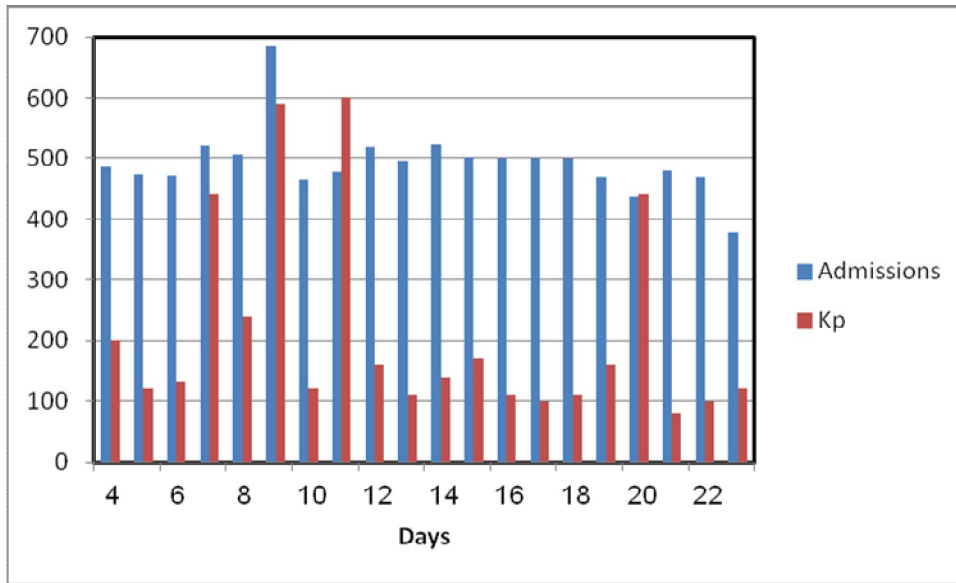


Fig.2: Geomagnetic activity from 4-09-2015 to 23-09-2015

Fig. 1 and Fig.2 represents variations of hospital admissions with geomagnetic activity. In Fig. 1 two geomagnetic storms were reported namely on 10-04-15 (Kp 331) and 16-04-15(Kp 421). In the following days of this geomagnetic storms, hospital admissions were found to be increased.

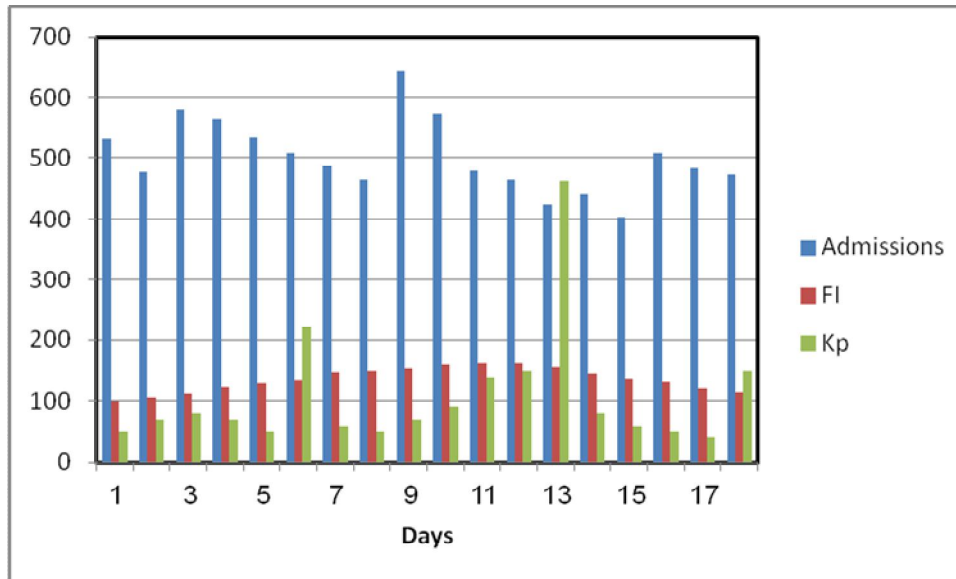


Fig.3: Geomagnetic and solar X-flare activity from 20-04-2015 to 18-05-2015

Figure 3 depicts the variation in hospital admissions with solar flare and the geomagnetic storm followed by the flare. The geomagnetic storm started on 13-05-2015 associated with an intense X-flare with magnitude 2.7. Sun is very active and a number of solar flares were reported from 1st to 10th of May 2015. 23 flares were reported on 5th May. Flare index shows enhancement during this period. Due to the combined effect of solar flares and geomagnetic storm the hospital admissions were found to be increased during this period. A large X 2.7 flare is reported on may 5th during the study period. The solar flares serve a useful indicator of solar activity since more flares occur when the Sun is more active. On the flare day there is a significant increase in the ophthalmic admissions. On the Following days of the flare there is an increase in the number of total admissions due to the increase in gynaec, pediatric and ophthalmic departments. A continuous flare activity is reported from 8th -12th March. The rate of admissions is found to be increased here also.

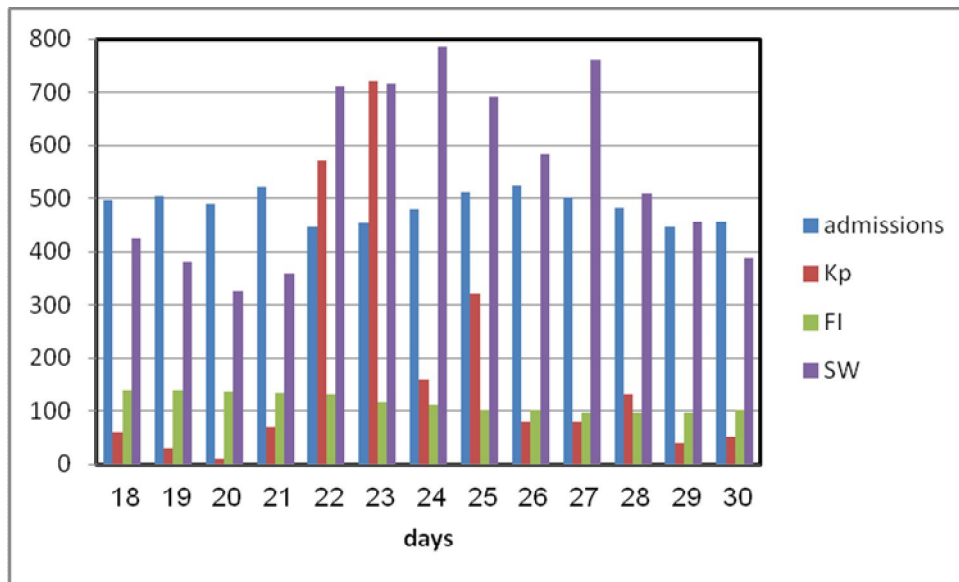


Fig.4: Geomagnetic and solar activity from 18-06-2015 to 30-06-2015

Figure 4 depicts the variation in hospital admissions with combined effect of geomagnetic storm, solar flare and solar wind. All the associated parameters exhibit a sharp enhancement during this period. . A Solar proton event is reported on 18th June associated with solar flare and geomagnetic activity. During the period of study of seven months only one solar proton event is reported. CME is also reported in these days. These days are highly disturbed and the space weather is very active. As result of this combined effect hospital admissions were found to be increased significantly.

Figure 5 represents variation of hospital admissions with geomagnetically quiet days against Flare index and solar wind velocity. In the days of weak geomagnetic disturbances, no significant changes in the admissions were observed. It remains steady in geomagnetically quiet period. The risk of hospital admissions were slightly increased which it is attributed to high solar wind speed.

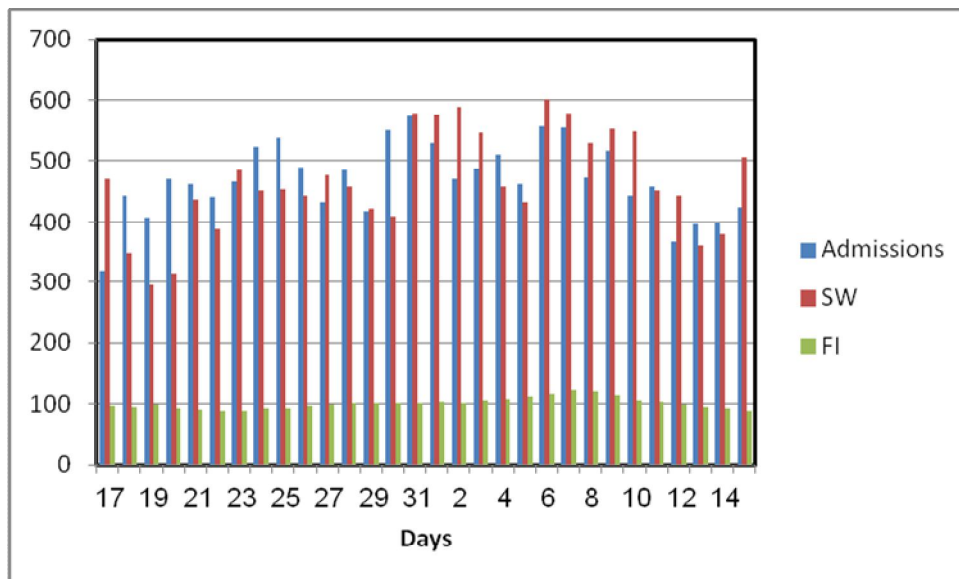


Figure.5: Geomagnetically quiet days from 17-07-2015 to 15-08-2015

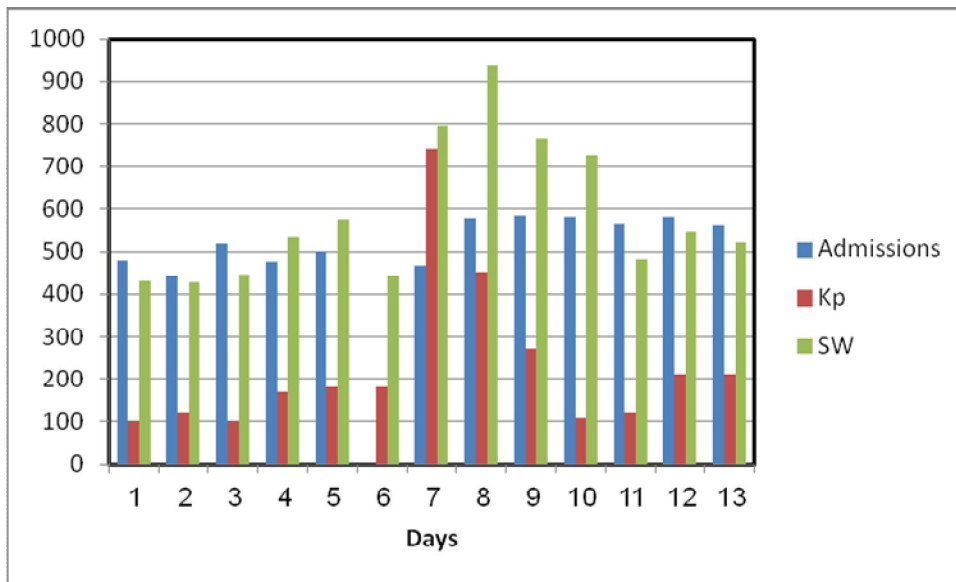


Fig.6 Geomagnetic activity and Solar wind from 1-10-2015 to 13-10-2015

Fir.6 depicts the hospital admissions with solar wind and geomagnetic activity. The admissions are found to be increased with solar wind and Kp index.

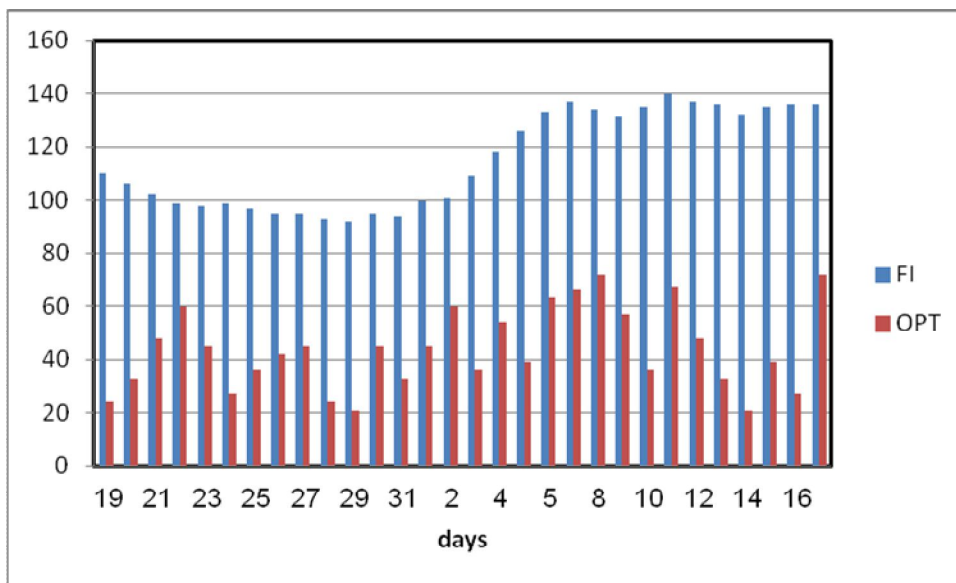


Fig.7: Flare index and Ophthalmic admissions from 19-05-2015 to 17-06- 2015

A rare and interesting observation is seen in flare index and an admission in ophthalmology department. Figure 7 depicts the relation between the flare index and hospital admissions in ophthalmology department. The correlation coefficient between flare index and the admissions were found to be 0.35 (12 %). This scale of correlation shows good medium relationship.

The daily admissions in the cardiac ICU were analyzed in two instances. The indices Kp and solar wind velocity were selected for the analysis of possible influence of space weather. During the days when the Space weather index $Kp > (300)$ and Solar wind velocity (> 600), the admissions of the patients increased by 22% when compared to days without any of the space weather activity. During the days when the solar wind velocity > 700 and $Kp > 500$, the hospital admissions were found to be increased by 28% compared to days without any of the events. At the same time in analysis the general ICU admissions were found to be increased by 20% compared with days without any of the active events. The daily medical admissions indicated that there is an increase in the rate of motor vehicle accidents, ICU, CICU and assaults along with the solar active days. In such cases the number of hospital admissions, were found to be increased significantly during space weather conditions.

4. Discussion

Solar activity, geomagnetic activity and cosmic ray activity respectively are major constituents of space weather that affects our daily life-navigation (Ptitsyna et al., 1996) as well as human health in space and in the Earth (Breus, 2003). Over the last years, many studies have been carried out concerning the possible effect that solar and geomagnetic activity might have on human physiological state (Stoupel, 2002; Dorman et al., 2001; Cornelissen et al., 2002; Dimitrova et al., 2004). Cosmic ray intensity and GMA variations can influence not only the performance and reliability of space-borne or ground-based technological systems, but also human life (Cornelissen et al., 2002; Stoupel et al., 2007). The results of our study showed that the risk of hospital admissions was affected by space weather conditions on 1-2 days before, during and 3-5 days after it.

There is evidence indicating that space weather has effects on the human health. A number of studies show effects of space weather condition for increased risk of myocardial infarction and stroke, number of hospitalizations for acute MI, blood pressure, platelet aggregation and blood coagulation and decreased heart rate variability. Geomagnetic storms would have a negative impact on patients with diabetes mellitus, impaired glucose tolerance and the metabolic syndrome. Earlier studies reported that the risks increased during days of extreme space weather events, 1-5 days before and after it. This result agreed with the results of our study (Vencloviene ., et al., 2015). It is established that at least 75% of magnetic storms are followed by an increase of averagely by 1.5 times of the number of hospitalized persons with cardiovascular and nervous diseases (Allahverdiyev et al., 2007). Breus *et al.* reported that the degree of the sensitivity of the cardiovascular system in humans increases with the current average level of geomagnetic activity. The findings suggest that human cardiovascular system was affected by high solar wind speed and space weather conditions. The correlation coefficients between geomagnetic activity indices and human health characteristics usually do not exceed 0.3 for rather long-time series. Previous results have shown that the blood pressure increases with the increase of geomagnetic activity during the days prior and after the geomagnetic storms (Khaborava and dimitrova, 2009). Some studies show correlations between high solar and geomagnetic activity and increased number of traffic accidents (Stoupel et al., 2004).

We evaluated the associations between space weather conditions and the daily number of hospital admissions. It is observed that an increase in the risk of hospital admissions in various departments during solar and geomagnetically active days. The findings suggest that the effect of hazardous space weather conditions on human health depends on the strength of geomagnetic storm during the investigated period. According to our results, the geomagnetic storm occurring in conjunction with solar flares and after SPE had the strongest effects on the risk of adverse cardiovascular events. The increased number in CICU establishes the result. The pathogenesis mechanism of the effect of geomagnetic storm on the risk of coronary effects may be explained by a sharp disturbance of biological rhythms (Breus et al ., 2012), change in cardiovascular parameters (Zenchenko et al., 2010), and a reduction of melatonin level (weydahl et al., 2001). A stronger effect of geomagnetic storm on human health was stated by other authors also.

During the last decade a number of studies have analyzed the risk of cardiovascular events, nervous system, brain activity, human behavior and all psycho-physiological, irritable, exhausted, lethargic, anxiousness, prolonged head pressure and headaches during the time of solar active days. The results of our study showed that the risk of some events was affected by space weather conditions one or two days before, during and following two to three days. The number of hospital admissions is found to be increased in various departments accordingly. One of the mechanisms of the influence of geomagnetic activity on human health may be Schumann resonance (partonen et.al. 2004) and ULF pulsations Pc1-Pc5 (Zenchenko et al., 2010). Schumann resonance (SR), are resonant electromagnetic waves in the cavity between the earth and the ionosphere with a fundamental frequency of about 8Hz. The first and second order frequency in SR is respectively observed on average 7.8 and 14.2 Hz; the alpha waves during human brain activity lie in the same frequency range as the first two modes of SR. The first and the second resonance modes are associated with solar activity (Vencloviene et al., 2013). During the high energy solar proton events, the first and second SR modes decrease and the first mode damping increases. The change in SR parameters during SPE may affect human health (Roldugin et al., 2004). The change in solar wind parameters before and during geomagnetic storm increases the activity of the ULF pulsations. The Pc1 geomagnetic pulsations are frequently correlated with the frequency of the human heart rhythm (2-5 Hz) and the frequency of pc3-Pc4 oscillations is similar as the frequency of endothelial oscillations (Zenchenko et al., 2010), therefore the increase in Pc1-Pc4 may be a potential risk factors of the coronary events in a subsequent period.

According to our findings solar flares occurring increases the hospital admissions. Solar flares along with coronal mass ejection produce high energy protons and ions within SPE and short wavelength radiation, ionizing the upper atmosphere. During solar flares X-rays and UV-radiations were emitted. Majority of the geomagnetic storm occurred after solar flares and the effect of non recurrent GS on human health may be stronger. This increases the hospital admissions. It is usually assumed that the influence of the solar activity is adverse and it is more adversely affecting the enfeebled and diseased organism (Zakhorov and Tyrnov,2001). The result shows that significant increase in the rate of motor vehicle accidents due to the effects of solar activity, after strong solar flare and during geomagnetic storms. This is because space weather creates specific and non specific stress reaction in people. This is due to the effects of weak electromagnetic fields on the human organism. It was previously shown that magnetic storms lead to an increase in the level of cortisol and other stress hormones in healthy and sick people with cardio vascular diseases, increase in blood glucose levels. Thyroid hormones are involved in the regulation of the heart rate , blood pressure, motor and mental activity which in turn increases hospital admissions during space weather.

Currently an overwhelming majority of researchers, investigating solar biospheric relationships, agreed with the electromagnetic nature of the effect of the sun on biosphere. The magnetic field of the Earth's parameters in a human body can change some body's characteristics, because the organism is a conductive medium and a lot of processes in our organism are based on electricity. Short time changes of the normal functioning of biological objects can be associated with short period variations of space weather and geomagnetic field, which produce an increase in the number of cardiac and infectious diseases, traffic and industrial accidents, heart attacks, strokes, brain problems, sudden cardiac deaths, cellular changes etc. Unfavorable environmental events such as space weather can induce health effects not only on the day of the event but on subsequent days.

5. Conclusions and Recommendations

The results allowed to conclude that the disturbances of the geomagnetic fields can affect human organisms having an effect of functional activity of humans and hence an increase in the number of hospital admissions. A better understanding of the relationship between space weather conditions and the daily number of hospital admissions will facilitate the introduction of previous strategies into practice with respect to space weather conditions. Study of geomagnetic activity effects has practical importance for human health. One of the important effects is an influence of the space weather on human health and life, on different biological and physiological systems. It is established that magnetic storms are followed by an increase in the number of hospitalized persons. There have been numerous recent advancements in space weather mitigation, particularly in the arena of international efforts to collaborate on research and development of policies and programs to mitigate risk to society and technology. Space weather forecasting has improved dramatically over the past decades. The international workshops recommended the specific use of social media to educate the public on space weather and its impacts. So that with the knowledge of the space weather forecast, the work of medical services can be organized accordingly. Several organizations are currently using social media to promote space weather. Space weather forecasting through social media can promote space weather awareness to public. These results may help in the understanding of the people's sensitivity under different space weather conditions. There is an urgent need to develop methods for quantifying the risks from severe space weather. It is of great importance to conduct complex, long period, detailed and synchronic investigations of geomagnetic storms effects on human beings with different health problems.

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