Research article
Ερευνητική εργασία

Differential effects of earthquakes on patients with bipolar disorder versus schizophrenia: Findings from Crete, Greece, 2008–2010

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Psychiatriki 2019, 30:193–203

Electromagnetic radiation influences in many ways humans and animals, while earthquakes are known to be related with electromagnetic phenomena. We recently showed that large earthquakes reduced admissions of psychiatric patients, whereas small earthquakes were associated with increased number of admissions. Our aim was to examine the effect of seismic-related electromagnetic activity on two chronic and severe psychiatric disorders varying in terms of etiology and treatment, i.e. bipolar disorder and schizophrenia. Retrospective data concerning monthly admission rates of patients diagnosed with schizophrenia or bipolar disorder in the Psychiatric Unit of the University Hospital of Heraklion, Crete, Greece between 2008 and 2010 were analyzed in relation to the number of earthquakes with small (≥2) or larger magnitude in the Crete region in Greece. Results showed a marked reduction of acute admissions during a storm of large earthquakes, which was greater in patients with bipolar disorder (91.2%) than schizophrenia patients (52.4%). In addition there was a significant increase of admissions during a period of frequent small earthquakes, primarily among patients with bipolar disorder. The results suggest that electrostatic fields that accompany large earthquakes may have a protective effect on psychiatric disorders, particularly on bipolar disorder. These findings are consistent with the ameliorating effect of electromagnetic fields used in Electroconvulsive therapy (ECT) and Transcranial Magnetic Stimulation (TMS) in patients with bipolar disorder. Future studies focusing on the underlying mechanisms may lead to more specific treatments of psychiatric disorders.

Key words: Psychosis, mood disorders, relapses, electromagnetic fields, earthquakes, hospital admissions.

Introduction

The pathophysiology of severe mental disorders such as schizophrenia and bipolar disorder is largely unknown despite extensive research and is considered to be multifactorial. Among the factors believed to relate with adverse effects of mental disorders, excessive occupational or environmental exposure to electromagnetic radiation[1–3] and geomagnetic disturbances and storms[4–6] have been examined with promising results. A variety of naturally occurring environmental electromagnetic phenomena (Ultra Low Frequency radiation, electron precipitation, geoelectric and geomagnetic field anomalous variations, etc.) have been attributed to seismic activity.[7–9]

We have recently reported that transient seismic activity may significantly impact psychotic manifestations leading to increased admissions to a Psychiatry Unit.[10] Specifically, we found that admissions were significantly increased during periods with higher number of very small (magnitude <~3) earthquakes as compared to the period between February and July 2008, characterized by high seismicity in Southern Greece. Moreover, a daily resolution analysis revealed that an abrupt increase in the number of small earthquakes was followed by an increase in the number of admissions over the following 2 days. However, these analyses did not examine potential differences in the impact of seismic activity on schizophrenia and bipolar disorder. Despite some similarities in their clinical presentation, the mental disorders can be distinguished on several genetic and pathophysiological characteristics.[11] Of particular interest is that treatments involving electromagnetic fields, such as Electroconvulsive Therapy (ECT) and repetitive Transcranial Magnetic Stimulation (rTMS), are effective in patients with bipolar disorder, but they have only very limited utility in schizophrenia.[12,13] Based on the above, the goal of the present study was to assess whether there was a differential effect of seismic activity on hospital admissions of patients suffering from bipolar disorder versus schizophrenia in the sample of patients originally reported by Anagnostopoulos et al.[10] The geographical region surveyed in the present report (Crete, Greece) is characterized by high seismicity, given that it includes a major part of the Hellenic Arc and Trench system at the boundary, which marks the active subduction of the African lithospheric plate beneath the southern margin of the Eurasian plate. We hypothesized that large seismic activity would have a greater impact on bipolar disorder than schizophrenia patients.

Material and method

Study sample

The sample of this retrospective observational study included patients admitted to the Psychiatric Inpatient Unit of the University of Crete, between 2008–2010, based on the electronic database of the hospital with a primary diagnosis of bipolar Disorder or schizophrenia. The Psychiatric Unit consists of two separate wards: (1) the "acutely ill ward" (acute admissions), where agitated/aggressive patients are admitted, usually involuntarily, and (2) the "short-stay ward"(short-term admissions), where patients with less serious psychopathology are admitted. The Psychiatric Unit is the only public inpatient unit for adult patients in Eastern Crete, serving a population of 400,000 inhabitants. Diagnosis of bipolar disorder and schizophrenia was based on clinical evaluation by the attending psychiatrists of the Unit according to the DSM-IV TR criteria.[14]

The time period examined, i.e. 2008–2010, was selected because of the well-known storm of great earthquakes in Greece in 2008.[15] Earthquakes of magnitude ≥2.0 obtained by the European Mediterranean Seismological Centre (www.emsc-csem.org) were included in the analysis. Earthquakes were characterized based on their magnitude, as large (magnitude≥4.5), small (2.0≤magnitude<4.5), and very small (2.0≤magnitude<3.0). The time period examined was divided into two windows, based on the seismic activity: Period I (January-October 2008), characterized by an unusual storm of large earthquakes (i.e. 4.5≤magnitude≤6.9), and Period II (November 2008–December 2010), characterized by rarity of large earthquakes and a higher relative number of small earthquakes (magnitude<~3).

Statistical analysis

In the current analysis we included (1) monthly acute admissions associated with more severe psychopathology and loss for daily function, and (2) monthly total admissions, i.e. admissions in both

acute and short stay wards. The acute admissions were analysed during the two distinct time-periods with different seismological characteristics, i.e. Period I (large earthquakes) and Period II (small earthquakes). Associations between earthquakes and patient admissions data were analysed using linear regression.

In order to further investigate the effect of small earthquakes on schizophrenia versus bipolar disorder a correlation "peak to peak" analysis was conducted between the number of small earthquakes and the number of admissions. Furthermore, we explored the associations between the number of earthquakes with magnitude 2–4.5 for Periods I and II and admissions of patients with schizophrenia and bipolar disorder using Ordinary Least Square (OLS) regression. Finally, the time association between the number of earthquakes with magnitude 2–4.5 and admissions of patients with schizophrenia and bipolar disorder in Period II was assessed using lagged cross-correlation analyses, with time unit=1 month and lags ranging from k=0 tok=±8. Statistical levels of significance was set at $p<0.05$.

Results

During Period I (large earthquakes) the average number of acute admissions, were significantly reduced compared to the corresponding number in Period II, for both bipolar disorder and schizophrenia patients (figure 1). The reduction rate was significantly higher in bipolar disorder (91.2%) compared to schizophrenia patients (52.4%; $p<0.05$).

During Period II, when an increasing presence of small Earthquakes were recorded we found a strong and significant association between acute admission rates of schizophrenia ($r=0.659$; $p<0.001$) and bipolar disorder patients ($r= 0.661$; $p<0.001$) and the total number of earthquakes (figure 1). In the same period there was a positive trend of association between monthly acute admissions and total number of earthquakes in both schizophrenia ($\beta=0.170$, $p=0.138$) and bipolar disorder patients (trend $\beta=5.848$, $p<0.001$) (figure 1, grey lines).

To verify that the marked difference in admissions between Period I and Period II was not mainly due to the overall increase of admissions during Period II, but reflected a veritable reduction during Period I, we further compared Period I admissions to the admissions' during 2011 (01-01-2011 to 31-12-2011), which was a time-period without extreme seismic activity (large or small earthquakes). This comparison revealed similar results (data not shown).

We further investigated the effect of small earthquakes on admissions during Period II, using "peak to peak" correlation analysis (figure 2) and found that the rising trend of small earthquakes over time ($\beta=5.848$, $p<0.001$) was paralleled by a similar, rising trend of admissions of bipolar disorder patient ($\beta=0.298$, $p<0.001$). No such trend was noted for hospital admissions of schizophrenia patients.

Focussing on small earthquakes (magnitude 2–4.5) using OLS regression we found a positive association between the number of earthquakes and the number of admissions of both schizophrenia (figure 3c; $r=0.484$, $p=0.039$) and bipolar disorder patients (figure 3d; $r=0.703$, $p<0.001$). However, the effect on the bipolar disorder patients was much stronger compared to the effect on the schizophrenia patients ($p<0.001$ vs $p=0.039$). In contrast, during Period I characterized by large earthquakes this association did not approach significance neither for schizophrenia (figure 3a; $r=-0.214$, $p=0.498$) nor for bipolar disorder patients (figure 3b; $r=0.214$, $p=0.498$). The lack of association could be explained by the superseding effect of the large earthquakes (i.e. magnitude ≥ 4.5) over the effect of the small ones during this period.

Lagged cross-correlation analyses examining the temporal association between earthquakes of magnitude ≥ 2, and hospital admissions revealed that the highest correlation occurred at zero time lag in both patient groups (figure 4a,b). The zero-lag correlation coefficient was especially pronounced in patients with bipolar disorder ($r=0.703$, $p=0.001$; figure 4b). To further explore associations between admission rates and the type of earthquakes over time, we computed time-lagged cross-correlations between admission numbers and monthly ratio between "very small" ($2 \leq$ magnitude < 3) and larger earthquakes (magnitude ≥ 3). It should be noted that during this period, the ratio very small over magnitude ≥ 3 earthquakes was significantly reduced due to the increased number of "very small" Earthquakes

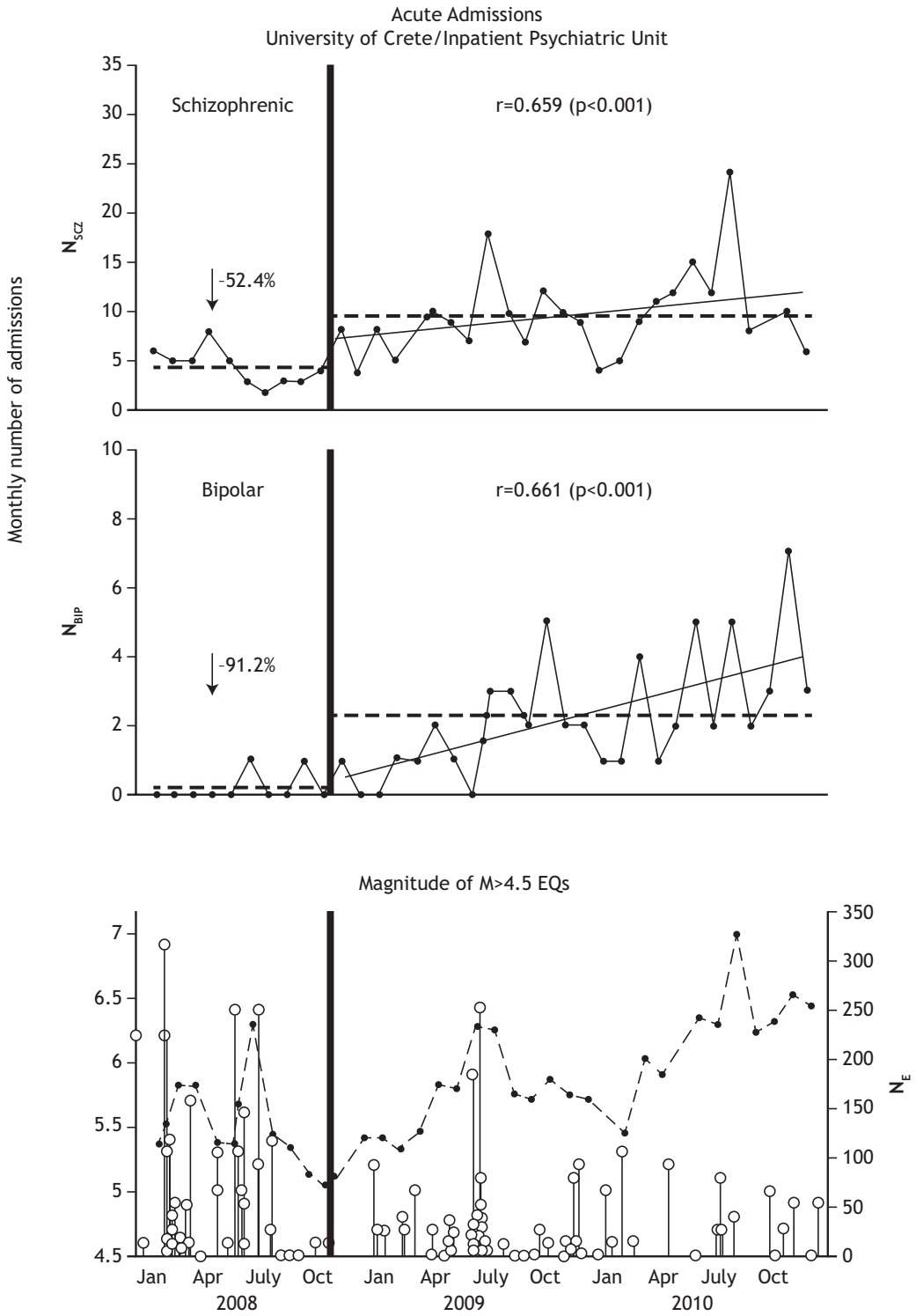

Figure 1. Monthly acute admissions to the Acute Psychiatric Unit of patients with Schizophrenia (N_{SCZ}, panel a) and the Bipolar Disorder (NBIP, panel b). The vertical line in each panel separate the period characterized by frequent, large-magnitude earthquakes (Period I) from the period of increased frequency of small earthquakes (Period II). Panel c displays the monthly variation in the number of M≥2 earthquakes (right-hand axis) M≥4.5 earthquakes (left-hand axis) in the region surrounding Crete during the years 2008–2010.

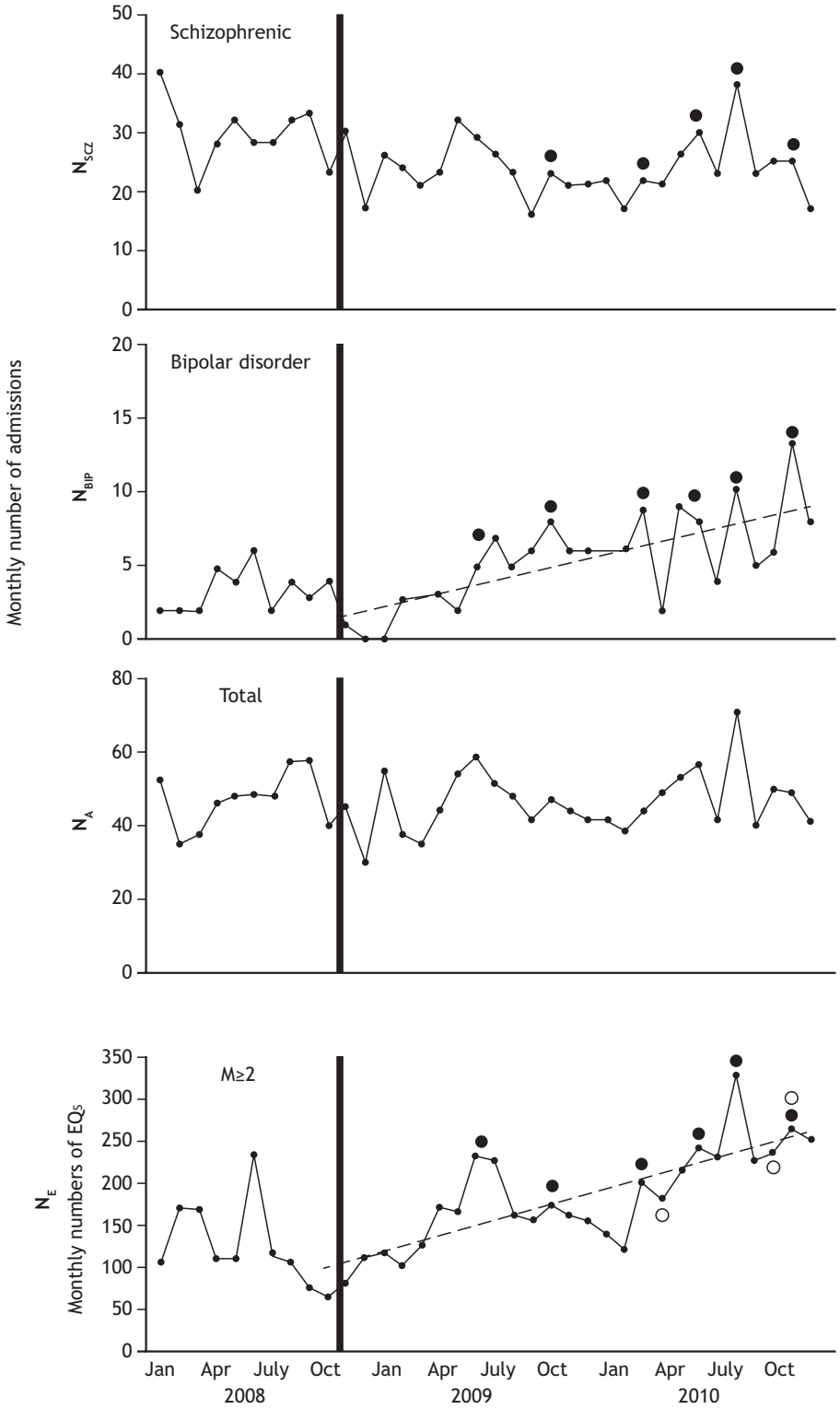

Figure 2. Peak to peak analysis of the monthly course of (a) Total admissions (acute and short-term units) of Schizophrenia patients [N_{SCZ}], (b) Bipolar Disorder patients [N_{BIP}], (c) the total numbers of admissions [N_A] in the acute psychiatric unit and, (d) number of earthquakes of magnitude ≥2 in the region surrounding Crete [N_E]. Solid circles indicate times of positive correlations between the four curves.

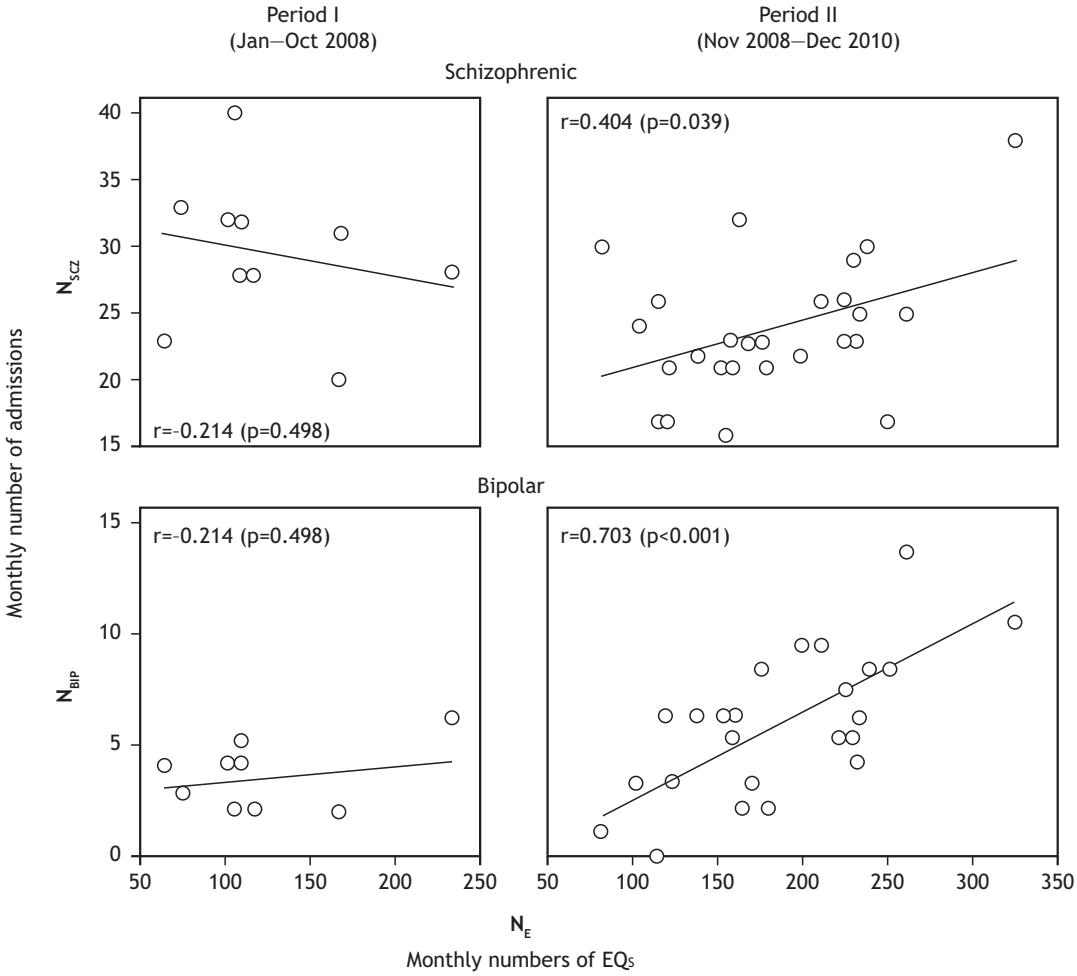

Figure 3. Ordinary Least Square (OLS) regression of the total number of admissions of Schizophrenia (N_{SCZ}) and Bipolar Disorder patients (N_{BIP}) against the total number of earthquakes (N_E) of magnitude ≥2 during Period I (featuring increased number of large earthquakes; panels a-b, respectively) and Period II featuring increased number of small earthquakes; panels c-d, respectively).

compared with the number of magnitude ≥3 earthquakes. Again, strong significant, negative correlations were found at lags around t=0 (–1 to 1) in bipolar disorder patients (figure 4d), whereas no significant correlation was found in schizophrenia patients at any time lag (figure 4c). This result suggests that the number of admissions in the former patient group is more closely associated with small than with magnitude ≥3 earthquakes.

Discussion

In summary, the present results revealed (a) a negative association between high magnitude seismic activity and hospital admissions with two major psychiatric diagnoses (Schizophrenia and, primarily, bipolar disorder) and, (b) a positive association between low magnitude seismic activity and hospital admissions, which was, again, greater among patients with bipolar disorder and followed a clear temporal pattern. These results extend our earlier report[10] by documenting that although seismic activity is a major factor influencing the stability of patients with bipolar disorders and schizophrenia, patients in the former group may be more sensitive to seismicity than patients in the latter group. These results may have a significant impact in developing new methods to prevent and treat major psychiatric disorders, such as bipolar disorder, and enhance our understanding of the underlying mechanisms.

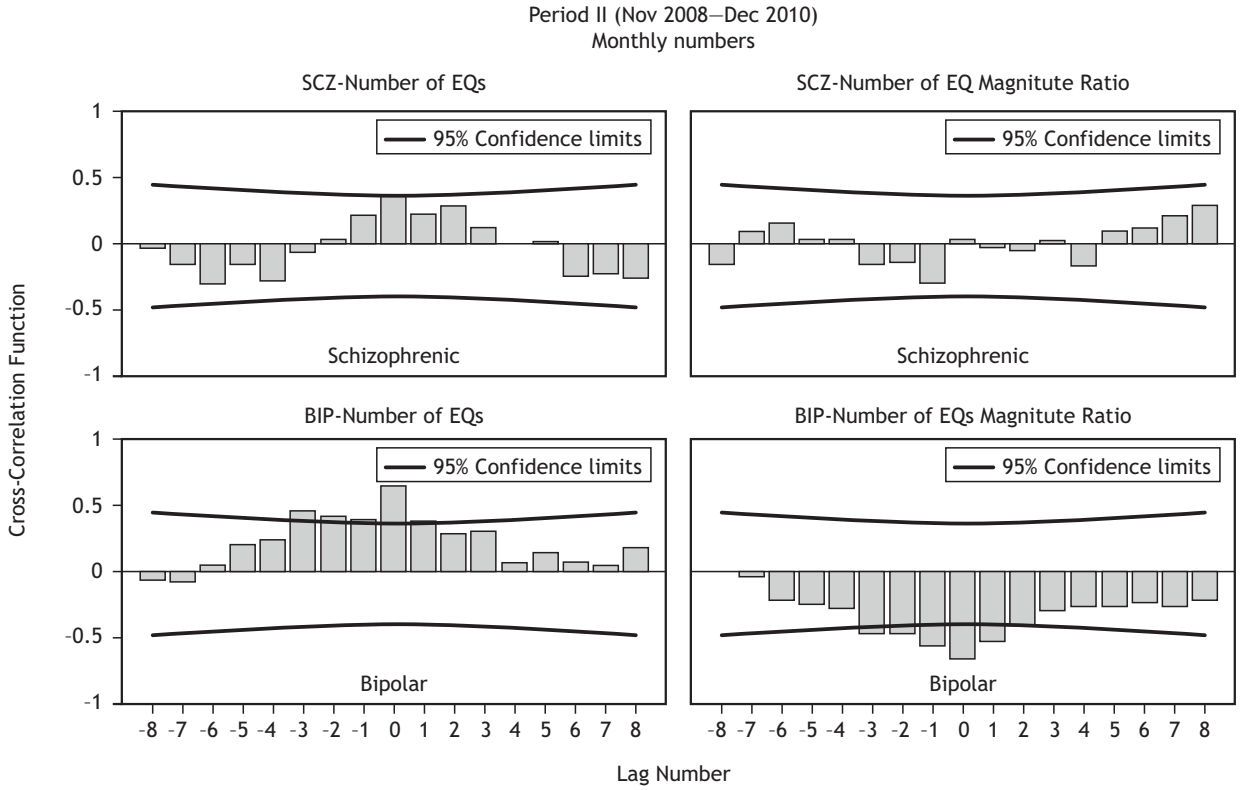

Figure 4. Cross-correlation coefficients and associated 95% confidence intervals for lags k=0, ±1, ±2,..., ±8 between monthly admission rates and the number earthquakes of magnitude M≥2 for schizophrenia (a) and bipolar disorder patients (b). Corresponding cross-correlations between monthly admission rates and the monthly ratios of the number of M≥3 earthquakes to the number of 2≤M<3 earthquakes (panels c, d) are displayed in panel (c) for patients with Schizophrenia and panel (d) for Bipolar Disorder patients during Period II (increased number of small earthquakes).

Protective effect

This is the first large study demonstrating the potential protective effect of a natural phenomenon, i.e. large-magnitude earthquakes, on both major types of severe mental disorders. Specifically, we showed that during the historic storm of large earthquakes in the area of Crete[15] with one earthquake with magnitude 6.9, three earthquakes with magnitude ≥6.4 and about 60 earthquakes with magnitude ≥4.5 during the 6-month period between January and October (2008), there was a marked reduction in the mean monthly acute admission rates of patients with bipolar disorder and schizophrenia in the order of 91.2% and 52.4% respectively, compared to the mean values of the admissions during the remaining portion of the 3-year period examined (2008–2010).

Electromagnetic treatments, such as ECT and rTMS, are well established methods for severe depressive illness, a prolonged or severe episode of mania, or catatonia.[12,13] It is also known that before large earthquakes the near-ground atmospheric electric field is increased from ~0.1 kV/m to values as high as 1–2 kV/m.[9,16] The present results raise the possibility that the low admission rate of patients with bipolar disorder and, to a lesser but still significant degree of patients with schizophrenia during periods of large earthquakes, is associated with increases of the near-Earth atmospheric electric field.[10]

Adverse effects

The second main finding of this study concerns the effect of small earthquakes on patients with psychotic disorders. Our analysis suggests a significant

positive correlation between the monthly number of small earthquakes and the number of acute admissions of patients with Bipolar Disorder, indicating that increased number of small earthquakes (magnitude 2–4) is associated with increased hospitalization rate of both bipolar and schizophrenia patients. Moreover, the positive correlation between hospital admissions and earthquakes became even stronger, mainly among patients with bipolar disorder, when only very small ($2 \leq M < 3$) earthquakes were considered.

The small earthquakes that either precede a large one for time periods as long as >1 month or those that often occur at the boundaries of tectonic plates, as is the case of the island of Crete, emit electromagnetic radiation at the Ultra Low Frequency (3–30 Hz) and the Extra Low Frequency (30–300 Hz) bands.[8,17–19] There is also evidence that Ultra Low Frequency and Extra Low Frequency radiation may interact with neurophysiological processes involved in emotion-related and cognitive functions.[10] Therefore, we suggest that the earthquake-induced Ultra Low Frequency/Extra Low Frequency electromagnetic radiation may exacerbate symptoms of schizophrenia and bipolar disorder, leading to increased hospital admissions among patients living in seismically active regions.

The present results are consistent with several other reports that physical and man-made Low Frequency/ Extra Low Frequency electromagnetic fields, such as geomagnetic disturbances and storms,[20] as well as Schumann resonances,[4,6] are partially responsible for inducing mental disorders and suicides.[21,22] Also, epidemiological studies have shown an association between symptoms of depression, anxiety, psychosis and suicides in people living near transmission lines, which radiate at 50–60 Hz[23,24] and workers in High Voltage Substations,[2] although this subject has been still controversial.

Neurophysiological mechanisms

The underlying mechanisms of the effects of electromagnetic Ultra Low Frequency/Extra Low Frequency emissions on mental disorders are still very poorly understood, but the existence of the electromagnetic effects themselves are supported by numerous reports. The effect of electromagnetic fields on neurotransmitter release and synaptic activity has been already known since the 80's.[25,26] Furthermore, the effects of electromagnetic Ultra Low Frequency/ Extra Low Frequency emissions on the function of specific brain structures are supported by an increasing number of studies in the last three decades. Although still under debate,[27] there have been reports that Extra Low Frequency fields reduce melatonin secretion produced by the pineal gland which in turn modify the monoamine activity in neuronal synapses.[28–31] Melatonin levels affects serotonin and dopamine release, which, by acting in the neuronal synapses in the temporal lobe and other cortical and limbic areas of the brain, may lead to hallucinations. The role of the hypothalamus in the regulation of cognition, as well as its important contribution to the maintenance of energy homeostasis and circadian rhythms has also been recognized.[32] Also, electromagnetic fields may modify the alignment of dendritic arbors and ion channel dendritic distribution in areas of the limbic system, such as hippocampus and mammillary bodies,[33–36] which are principally involved in emotion and behavior processes, the hippocampus's being one of the most electrically excitable parts of the brain, given that it is very sensitive to kindling.[37,38]

The mechanism by which large earthquakes may exert a protective effect on patients with bipolar disorder and schizophrenia is not understood, as is the case of rTMS. However, as we mentioned above, we suggest that an electric field most probably mediates the occurrence of large earthquakes and the protective mental effects.

Conclusions

In conclusion, our study provides evidence that large earthquakes are protective of relapses of major psychiatric disorders, primarily bipolar disorder. On the contrary, increased number of small earthquakes, not experienced by our senses, are associated with increased number of patients' admissions; these results support the hypothesis that these effects are mediated through earthquake-related electromagnetic phenomena and not through mechanical/ physical impact per se. The protective effect is consistent with the differential effectiveness of treatment methods, entailing application of electromagnetic fields, such as rTMS and ECT.

This new knowledge may serve to develop new tools for prevention and treatment of severe psychiatric disorders, since electromagnetic protection

from earthquake-induced Ultra Low Frequency/ Extra Low Frequency electromagnetic radiation is a rather simple application. For example, various types of protection from harmful electromagnetic radiation generated by electric/electronic and radiocommunication devices is available. Similarly, electromagnetic protection could be used to reduce relapses of psychotic disorders, such as bipolar disorder, by applying electromagnetic shielding to the human head and to buildings (homes and workplaces).

Διαφοροποιημένη επίδραση των σεισμών σε ασθενείς με διπολική διαταραχή έναντι σχιζοφρένειας: Ευρήματα από την Κρήτη, Ελλάδα 2008–2010

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Ψυχιατρική 2019, 30:193–203

Η ηλεκτρομαγνητική ακτινοβολία επηρεάζει με πολλούς τρόπους, τόσο τους ανθρώπους, όσο και τα ζώα. Οι σεισμοί είναι γνωστό ότι σχετίζονται με ηλεκτρομαγνητικά φαινόμενα. Σε μια πρόσφατη μελέτη δείξαμε, ότι οι μεγάλοι σεισμοί συσχετίστηκαν με μείωση των εισαγωγών, ενώ οι μικροί σεισμοί με αύξηση των εισαγωγών ασθενών με ψυχικές παθήσεις. Ο σκοπός της παρούσας μελέτης ήταν να διερευνηθεί η επίδραση της ηλεκτρομαγνητικής δραστηριότητας που σχετίζεται με σεισμούς, σε δύο χρόνιες και σοβαρές ψυχικές διαταραχές, όπως η διπολική διαταραχή και η σχιζοφρένεια. Αναλύθηκαν αναδρομικά στοιχεία που αφορούσαν τον μηνιαίο αριθμό εισαγωγών ασθενών με διάγνωση διπολικής διαταραχής και σχιζοφρένειας στην Ψυχιατρική Κλινική του Πανεπιστημιακού Γενικού Νοσοκομείου Ηρακλείου Κρήτης, μεταξύ 2008–2010, σε σχέση με τον αριθμό των μικρής και μεγάλης έντασης σεισμών στην περιοχή της Κρήτης την περίοδο αυτή. Η ανάλυση έδειξε ότι κατά τη διάρκεια περιόδου «καταιγίδας» μεγάλης έντασης σεισμών, υπήρξε σημαντική μείωση των εισαγωγών στο Τμήμα Οξέων Περιστατικών (κυρίως ακούσιες νοσηλείες), η οποία ήταν περισσότερο εκσεσημασμένη σε ασθενείς με διπολική διαταραχή (91,2%) σε σχέση με ασθενείς με σχιζοφρένεια (52,4%). Επίσης, κατά την περίοδο συχνών, μικρών σεισμών, βρέθηκε σημαντική αύξηση των εισαγωγών σε ασθενείς με διπολική διαταραχή. Από τα ευρήματα της μελέτης αυτής φαίνεται ότι τα ηλεκτροστατικά κύματα που συνοδεύουν τους μεγάλους σεισμούς πιθανόν να έχουν έναν προστατευτικό ρόλο σε ασθενείς με ψυχικές νόσους, κυρίως σε πάσχοντες από διπολική διαταραχή. Αυτά τα ευρήματα είναι σε συμφωνία και με την ευεργετική δράση των ηλεκτρομαγνητικών κυμάτων που χρησιμοποιούνται στην Ηλεκτροσπασμοθεραπεία (ECT) και τον Διακρανιακό Μαγνητικό Ερεθισμό (TMS) σε ασθενείς με διπολική διαταραχή. Μελλοντικές μελέτες που θα εστιάσουν στους υποκείμενους μηχανισμούς, πιθανόν να οδηγήσουν σε πιο εξειδικευμένες θεραπείες των ψυχικών παθήσεων.

Λέξεις ευρετηρίου: Ψύχωση, διαταραχές διάθεσης, υποτροπές, ηλεκτρομαγνητικά πεδία, σεισμοί, νοσοκομειακές εισαγωγές.

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