International Journal of Biometeorology (2018) 62:2109–2118
https://doi.org/10.1007/s00484-018-1605-4

ORIGINAL PAPER

Investigating the effect of climatic parameters on mental disorder admissions

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Received: 15 March 2018 / Revised: 13 July 2018 / Accepted: 22 August 2018 / Published online: 4 October 2018

Abstract

The main objective of this study was to evaluate the role of climatic parameters and phenomena including the monthly number of dusty/rainy/snowy/foggy days, cloudiness (Okta), horizontal visibility, and barometric pressure (millibar) on major depressive disorder, bipolar, schizophrenia, and schizoaffective admissions. The monthly data related to the number of admissions in Farshchian hospital and climatic parameters from March 2005 to March 2017 were extracted. Random forest regression and dynamic negative binomial regression were used to examine the relationship between variables; the statistical significance was considered as 0.05. The number of dusty/rainy/snowy/foggy days, cloudiness, and the number of days with vision less than 2 km had a significant positive relationship with admissions due to schizophrenia ($p < 0.05$). Barometric pressure had a negative effect on schizophrenia admissions ($p < 0.001$). The number of dusty/rainy/snowy/foggy days and cloudiness had a significant effect on schizoaffective admissions ($p < 0.05$). Bipolar admissions were negatively associated with rainy days and positively associated with dusty days and cloudiness ($p < 0.05$). The number of rainy/dusty/snowy days and cloudiness had a positive significant effect on major depressive disorder admissions. The results of the present study confirmed the importance of climatic parameter variability for major depressive disorder, bipolar, schizophrenia, and schizoaffective admissions.

Keywords Climate · Major depressive disorder · Bipolar, schizophrenia · Schizoaffective

Introduction

Climatic parameters are among the most important factors in controlling human activities. Changes in temperature, precipitation, and wind can affect various aspects of human life greatly. Not only do climatic conditions affect the physical health of humans but also the mental and emotional status of humans depends partly on atmospheric conditions. It has been reported that the quality of life and general health of individuals are functions of the climatic conditions (Quality and Health 2011). In addition to the physical health, humans' mood and behavior are also related to atmospheric conditions to a great extent. For example, it is believed that violence, crimes, abusing women, and nervous shocks increase significantly at high temperatures (Anderson 2012).

Mental disorders are among the most prevalent psychiatric illnesses. They can be very disabling such that all aspects of life are affected. There has been reported that nearly 450 million people suffer from this conditions worldwide (WHO 2018). There are evidences that indicate many behavioral illnesses including depressive disorder, bipolar disorder, schizophrenia, and schizoaffective are functions of natural environment like climate and climatic phenomena. It appears that meteorological factors trigger the symptoms of these illnesses and that their admissions are related to the seasons (Medici et al. 2016; Sarran et al. 2017; McWilliams et al. 2013; Wang et al. 2018). To date, several studies have been conducted to

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investigate the effect of different climatic parameters on different mental diseases. For example, Welham et al. investigated the potential impact of climatic and geographical risk factors for schizophrenia, bipolar disorder, schizophrenia, and schizoaffective (Welham et al. 2000). Messias et al. investigated the effect of rainfall and temperature on schizophrenia births in Brazil (de Messias et al. 2001). Shiloh et al. investigated the effects of climate on admission rates of schizophrenia and schizoaffective disorder patients to psychiatric hospitals (Shiloh et al. 2005). Lee et al. studied the association of climate with bipolar disorder admissions in Taiwan (Lee et al. 2007). Christensen et al. conducted a study to investigate the relationship between climatic factors (temperature, rainfall, and atmospheric pressure as well as hours of sunshine and cloudiness) and bipolar affective disorder using a group of patients with at least three previous hospitalizations for bipolar disorder (Margrethe Christensen et al. 2008). Bauer et al. investigated the relationship between latitude, climate, season, and self-reported mood in bipolar disorder in patients living in five climate zones in the northern and southern hemispheres (Bauer et al. 2009). Dominiak et al. investigated the impact of intensity of sunlight on psychiatric hospitalizations for affective disorders in Warsaw, Poland (Dominiak et al. 2015). Sarran et al. investigated the effect of sunshine, global radiation, horizontal visibility, cloud cover, and mist as well as temperature, humidity, and pressure on affective disorder (Sarran et al. 2017). Wang et al. (2018) investigated the effect of increasing temperature on daily hospital admissions for schizophrenia in China (Wang et al. 2018). However, there are several climatic parameters and phenomena that to our knowledge, their effects have not been investigated.

Due to the importance of the number of admissions for mental disorders and its burden (due to the costs) for the families and society, we investigated those climatic parameters that their roles in mental illnesses have been less investigated by others or they have not been assessed at all yet. Therefore, we considered cloudiness, dust, visible horizon less than 2 km, the number of snowy and rainy days, pressure variations, and the number of fog that have received less attention by psychologists and behavioral researchers. In words, it can be said that in addition to climatic elements, climatic phenomena can be effective in incidence and aggravation of mood disorders (and thus on the number of hospital admissions).

Aims of the study

This study aimed to identify the impact of climatic parameters and phenomena including cloudiness, barometric pressure, the number of rainy and snowy days, the number of days with visible horizon less 2 km (km), and the number of dusty and foggy days on the number of hospitalization for mental disorders of major depressive disorder, bipolar, schizophrenia, and schizoaffective. To this end, the Hamadan province located in western Iran (a mountainous area) was selected as a case study. Due to favorable weather conditions in western Iran, Hamadan is considered a pilot and a suitable place for admission of psychiatric patients.

In this study, our main research hypotheses were as follows:

1. The dust phenomena affect the number of admissions due to major depressive, bipolar, schizophrenia, and schizoaffective disorders.
2. The cloudiness affects the number of admissions due to major depressive, bipolar, schizophrenia, and schizoaffective disorders.
3. The horizontal visibility less than 2 km affects the number of admissions due to major depressive, bipolar, schizophrenia, and schizoaffective disorders.
4. The monthly number of rainy/snowy/foggy days affects the number of admissions due to major depressive, bipolar, schizophrenia, and schizoaffective disorders.

Method

Geographical properties of the research site

The study area, Hamadan Province, is located in a mountainous area in western Iran. We utilized data from Hamadan-Airport station. The Airport station is located in an area with a geographical coordination of 34° 52′ north latitude and 48° 32′ east longitude and height 1730 m above sea level in the center of the northern part of Hamadan province. In order to reveal the relationship between climatic phenomena and psychological disorders and depressive disorder, monthly data (cloudiness (Okta), the number of snowy and rainy days in a month, the number of visible horizon less than 2 km in a month, the number of dusty and foggy days per month, and average monthly barometric pressure (millibars)) were used for the period of 2005 (the 21st of March) to 2017 (the 21st of March). Data on the mental illness and mental disorders were provided using the number of patients that were hospitalized in Farshchian hospital (the only psychiatric hospital across Hamadan Province) from 2005 to 2017. Both first and repeated admissions were included. A total number of 20,406 admissions were identified for all disorders. This study was approved by the ethics committee of Hamadan University of Medical Science. Table 1 (a) shows the summary statistics of the climatic parameters and phenomena in the study period.

Table 1 Descriptive statistics of the parameters and climatic phenomena in the studied period

a. Meteorological phenomenon/parameter (per month)		Average			Standard deviation		Minimum	Maximum
The number of dusty days		2.85			3.78		0.00	15.00
The number of foggy days		1.58			2.87		0.00	13.00
The number of rainy days		6.62			4.80		0.00	18.00
The number of snowy days		1.85			3.39		0.00	17.00
The number of days with visible horizon less than 2 km		1.78			2.61		0.00	14.00
Barometric pressure (millibar)		825.97			2.39		820.50	831.00
Cloudiness (Okta)		2.49			1.31		0.00	4.70
b. Admissions					Monthly number of admissions			
		Sum	Minimum age	Maximum age	Mean	Standard deviation	Minimum	Maximum
Major depressive disorder	Total	6295	19	84	43.41	16.43	10.00	95.00
	Male	4616	19	80				
	Female	1679	19	84				
Bipolar disorder	Total	10,767	17	88	74.26	32.52	18.00	154.00
	Male	7768	17	85				
	Female	2999	18	88				
Schizophrenia	Total	2120	18	78	14.62	5.74	4.00	33.00
	Male	1495	18	78				
	Female	625	19	74				
Schizoaffective	Total	1224	25	86	8.44	3.34	2.00	16.00
	Male	808	25	60				
	Female	416	26	86				

Statistical analysis

Random forest regression

The random forest technique is one of the ensemble methods that works based on combining the prediction of several decision trees (Breiman 2001). In this approach, a random sample (say n) with replacement from the training set (S_n) is selected (called bootstrap) and a regression tree is fitted. Therefore, one sample may appear several times. In this way, many independent bootstrap samples are selected and a decision tree algorithm is applied to each of them to get a collection of say K predicting. The outputs of all these predictors are then aggregates. In this formulation, in each decision tree (that can be applied for a classification and regression problems), a recursive splitting is applied in several nodes in order to create a tree. The decision is then made in the final nodes (called leaves). To split a node, the random forest chooses *mtry* inputs (a predefined number) and it tries to find the best cut point among them. The *mtry* is considered fixed for all the trees in the forest. Usually, the *mtry* is the square root of the input number p. The cut-off points are chosen through minimizing a cost function. Then after full growing all the trees in the forest, the results of all these trees will be averaged to aggregate their votes and to produce forests final result. A random forest is not sensitive to the noises due to the aggregating outcome of several uncorrelated trees and the independent splitting of each tree in the forest. Moreover, it calculates out-of-bag error (known also as generalization error which is a measure of internal cross validation) and a measure of variable importance (calculated by using removing a feature and taking average of the difference in out of bag before and after removing over the trees) (Breiman 2001; Liaw and Wiener 2002). In the present study, we used the number of 1000 trees and $mtry = 3$ variables in each tree. All data analysis were implemented using the package "*randomForestSRC*" in the open-source R statistical programming language. The values of variable importance were also provided by this package. Values equal or greater than 0.002 are considered important (Ishwaran et al. 2008).

Negative binomial time series regression

In the present study, to indicate significant parameters, the negative binomial time series regression was used in addition to RF which is suitable to analyze time series data when the response variable is measured as count data. Considering t as the time variable, this method provides a model according to the previous observations (say α_r) as follows:

$$g(\lambda_t) = \alpha_0 + \sum_{r=1}^{R} \alpha_r Y_{t-r} + \theta Y_{t-k} + \sum_{i=1}^{p} \beta_i X_i$$

where r stands for order autocorrelation, θ stands for the conditional mean of k units back in time as the seasonal effect, and

β_i indicates estimated effect size of covariate X_i (Liboschik et al. 2015). The significance level was considered 0.05. The data analysis was done using the package "tscount" in the open-source R statistical programming language.

Results

The information and summary statistics related to climatic parameters (the number of foggy, dusty, rainy, and snowy days per month and the number of days with visible horizon less than 2 km, barometric pressure (millibars) and cloudiness (Okta)) during March 2005 to March 2017 are presented in Table 1(a). There were 20,406 identified admissions (6295 with major depressive disorder, 10,767 with bipolar, 2120 with schizophrenia, and 1224 with schizoaffective) in the time period between 2005 and 2017. Table 1(b) shows the characteristics of the data used. According to the table, the majority of the admissions were male (> 60%) and the patients' age ranged between 17 and 88.

Moreover, Fig. 1a–d depicts time series plot of depressive disorder, bipolar disorder, schizophrenia, and schizoaffective disorders. In these plots, the trend of the diseases was shown. As seen, there are nonlinear trends for all disorders that cannot be captured by traditional time series techniques efficiently. In addition, the seasonal amplitude did not increase or decrease over time and all remainders (white noises) were approximately random without any special increasing/decreasing patterns.

The results of fitting negative binomial time series model are presented in Table 2 for four mental disorders. According to the results shown in Table 2, the number of dusty days had a significant increasing effect on admissions due to schizophrenia ($p = 0.047$). This effect was also significant for lag1 ($p = 0.024$) and lag2 ($p = 0.005$). The number of rainy and snowy days had also a significant increasing effect on the number of admissions ($p = 0.009$ and $p = 0.002$ respectively). Moreover, the number of days with vision less than 2 km had an increasing effect on the number of schizophrenia admissions ($p = 0.008$). The number of schizophrenia admissions was negatively associated with barometric pressure ($p < 0.001$) and positively associated with cloudiness ($p = 0.041$). The number of foggy days had a significant positive effect on schizophrenia admissions ($p < 0.05$).

For the schizoaffective disorder, the number of dusty days had a significant increasing effect on admissions ($p = 0.009$), while the number of snowy and rainy days had a significant increasing effects on admissions due to schizoaffective disorder ($p < 0.05$). Also admissions due to schizoaffective disorder were positively associated with cloudiness ($p < 0.05$) and the number of foggy days ($p < 0.05$). However, there was no significant effect for barometric pressure and vision less than 2 km ($p > 0.05$).

For the bipolar disorder, the number of dusty days with one-month delay ($p = 0.016$), cloudiness ($p = 0.017$), and cloudiness with a two-month delay ($p = 0.021$) was positively associated with admissions. Moreover, the number of rainy days with lag2 was negatively associated with the number of admissions due to bipolar disorder (0.016). However, other variables of the number of snowy and foggy days and the number of days with vision less than 2 km as well as barometric pressure were not significantly associated with the number of admissions.

For depressive disorder, there was observed a positive significant relationship between the number of dusty ($p = 0.047$) days, the number of rainy days ($p < 0.001$) (and rainy days with lag1 and lag2; $p < 0.001$), the number of snowy days ($p = 0.002$), and the number of days with vision less than 2 km ($p = 0.002$) and cloudiness ($p = 0.010$), while the number of foggy days and barometric pressure did not have a significant impact on depressive disorder admissions ($p > 0.05$).

The potential impact of selected variables was also assessed using random forest technique to account for any high-order interactions as well as nonlinear effect of the variables. The variable importance values (values equal or greater than 0.002 are considered important) along with their ranks are shown in Table 3. According to the results, barometric pressure (lag1), cloudiness (lag1), and the number of rainy days (lag2 and lag0) were the four topmost ranked variables affecting the number of admissions due to schizophrenia. For schizoaffective disorder, the number of dusty days (lag2), cloudiness (lag2), the number of dusty days (lag0), and cloudiness (lag2) were the four topmost ranked variables in admissions. For bipolar disorder admissions, the four topmost ranked variables were the number of dusty days (lag0, lag1, and lg2) and cloudiness (lag1), and for depressive disorder admissions, these four top variables were cloudiness (lag2 and lag1), the number of foggy days (lag1), and the number of dusty days (lag0).

To see the impact of interactions of some important variables on the number of admissions due to four disorders, we provided interaction plot. Figure 2a–d shows how the RF model displays interaction between the number of dusty days, cloudiness, and rainy days and predicted number of admissions from four disorders. As seen for major depressive disorder and bipolar disorder, the number of admissions increases as the number of dusty days and cloudiness increases simultaneously. Moreover, the number of admissions due to schizophrenia and schizoaffective disorders increase as the number of dusty and rainy days as well as cloudiness increases simultaneously.

Discussion

Climatic conditions affect many aspects of human activities including health. It seems that changes in climate leads to

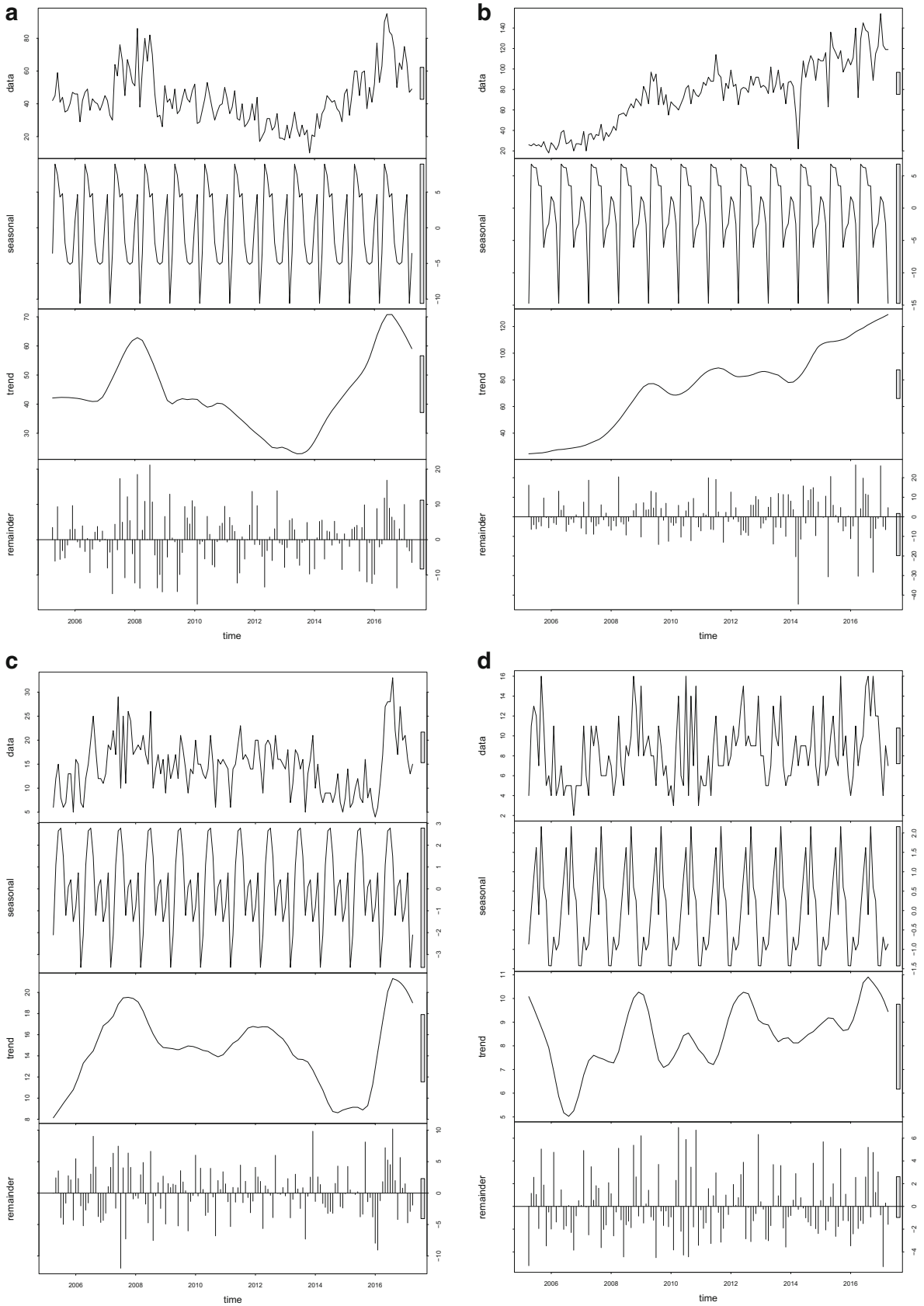

Fig. 1 Time series plots for the number of selected mental disorders. **a** Major depressive disorder. **b** Bipolar. **c** Schizophrenia. **d** Schizoaffective

Table 2 Results of fitting negative binomial time series model

	Schizophrenia			Schizoaffective			Bipolar			Depressive disorder		
Independent variables	*B*	SE	*p* value	*B*	SE	*p* value	*B*	SE	*p* value	*B*	SE	*p* value
Intercept	16.978	1.342	< 0.001	1.374	0.255	< 0.001	0.009	0.167	0.957	1.372	0.251	< 0.001
B1	0.336	0.090	< 0.001	0.153	0.097	0.115	0.421	0.085	< 0.001	0.509	0.091	< 0.001
B2	0.184	0.093	0.046	0.120	0.097	0.215	0.167	0.092	0.070	0.119	0.099	0.226
Dust												
Lag0	0.016	0.008	0.047	0.021	0.008	0.009	0.004	0.005	0.475	0.621	0.310	0.047
Lag1	0.018	0.008	0.024	0.017	0.009	0.060	0.011	0.005	0.016	0.003	0.006	0.638
Lag2	0.377	0.133	0.005	0.006	0.009	0.501	0.008	0.004	0.063	− 0.001	0.011	0.877
Rainy days												
Lag0	0.230	0.087	0.009	0.014	0.007	0.052	0.004	0.004	0.386	0.641	0.128	< 0.001
Lag1	0.356	0.149	0.018	0.019	0.008	0.014	− 0.001	0.004	0.745	1.044	0.064	< 0.001
Lag2	0.739	0.164	< 0.001	0.020	0.008	0.009	− 0.010	0.004	0.016	0.744	0.071	< 0.001
Snowy days												
Lag0	0.407	0.128	0.002	0.022	0.010	0.030	0.006	0.006	0.345	0.941	0.295	0.002
Lag1	−0.010	0.009	0.275	0.032	0.011	0.006	0.005	0.006	0.372	− 0.002	0.008	0.755
Lag2	−0.006	0.009	0.493	0.026	0.011	0.027	0.004	0.006	0.485	− 0.003	0.007	0.672
Vision												
Lag0	0.416	0.154	0.008	0.002	0.013	0.845	0.010	0.008	0.220	0.020	0.012	0.899
Lag1	0.009	0.012	0.451	− 0.001	0.014	0.903	0.008	0.008	0.349	0.025	0.008	0.002
Lag2	− 0.008	0.012	0.505	− 0.018	0.014	0.180	− 0.024	0.008	0.329	− 0.005	0.009	0.594
Barometric pressure												
Lag0	− 0.659	0.179	< 0.001	− 0.024	0.020	0.249	1.7e−4	0.009	0.984	− 0.002	0.012	0.855
Lag1	− 0.001	0.013	0.920	− 0.001	0.015	0.942	− 0.002	0.011	0.860	− 0.002	0.012	0.888
Lag2	− 0.001	0.013	0.921	− 0.001	0.015	0.956	− 0.002	0.011	0.860	− 0.002	0.012	0.877
Cloudiness												
Lag0	0.738	0.357	0.041	0.168	0.056	0.004	0.031	0.013	0.017	0.058	0.023	0.010
Lag1	− 0.045	0.023	0.513	0.077	0.028	0.006	0.014	0.015	0.359	− 0.002	0.018	0.890
Lag2	0.046	0.023	0.048	0.070	0.028	0.011	0.034	0.015	0.021	− 0.032	0.018	0.860
Fog												
Lag0	0.154	0.076	0.044	0.029	0.013	0.020	0.006	0.007	0.375	0.004	0.008	0.625
Lag1	0.869	0.058	< 0.001	0.034	0.013	0.011	− 0.001	0.007	0.865	3.1e−3	0.008	0.968
Lag2	0.915	0.059	< 0.001	− 0.021	0.013	0.099	0.004	0.007	0.607	− 0.005	0.008	0.537

different reactions in the human body and soul and affects human mood and behavior. Considering the importance of this issue, the main focus of this study was to reveal the impact of meteorological phenomena (cloudiness, the number of snowy and rainy days in a month, the number of visible horizon less than 2 km in a month, the number of dusty and foggy days per month, and average monthly barometric pressure) on mental disorders including depressive disorder, bipolar, schizophrenia, and schizoaffective.

The results of this study indicated that the increase in the monthly number of dusty days had a direct impact (positive coefficients) on the number of schizophrenia admissions. According to the results, the destructive effect of this phenomenon continued up to two months later (lag2 and lag1 had also a significant relationship). Moreover, results indicated that with increasing the number of rainy days and the number of days with vision less than 2 km as well as the amount of cloudiness and the number of foggy days, the number of hospitalization due to schizophrenia increases. With the occurrence of each of these phenomena, the duration and intensity of sunlight are diminished, and the sunshine hours in a day even reaches zero in these cases. Therefore, it seems that most patients with schizophrenia feel uncomfortable in cloudy and rainy days (unclear sky). What is definite is that the increase in the number of rainy, dusty, snowy, and foggy days as well as the increase in cloudiness and the number of days with vision less than 2 km are climatic phenomena that mostly occur in February and March in the studied area. Therefore, after the onset of the spring, the daytime increases and the phenomena mentioned above diminish. As a result, the sunlight and

Table 3 Variable importance (VIMP) obtained by using random forest method

Independent variables	Schizophrenia VIMP	Rank	Schizoaffective VIMP	Rank	Bipolar VIMP	Rank	Depressive disorder VIMP	Rank
Dust								
Lag0	0.316	7	1.000	1	1.000	1	0.254	4
Lag1	0.162	13	−0.098	20	0.613	4	−0.165	21
Lag2	0.030	16	0.496	3	0.724	3	0.061	14
Rainy days								
Lag0	0.650	4	0.128	11	0.153	11	0.241	5
Lag1	0.490	6	−0.0570	19	0.054	15	−0.060	17
Lag2	0.784	3	0.308	5	−0.017	16	0.163	8
Snowy days								
Lag0	0.019	17	0.305	6	0.301	9	0.078	13
Lag1	0.012	18	0.096	12	0.498	8	0.116	11
Lag2	0.086	14	0.208	9	−0.128	21	0.169	7
Vision								
Lag0	0.264	10	−0.043	18	−0.084	20	−0.128	20
Lag1	−0.076	20	0.009	16	−0.026	18	−0.062	18
Lag2	−0.118	21	0.245	8	−0.031	19	−0.126	19
Barometric pressure								
Lag0	0.183	12	0.141	10	0.252	10	−0.007	15
Lag1	1.000	1	0.090	13	0.501	7	0.111	12
Lag2	0.591	5	0.079	14	0.594	5	0.172	6
Cloudiness								
Lag0	0.305	8	−0.002	17	0.136	13	0.137	10
Lag1	0.980	2	0.532	2	0.882	2	0.678	2
Lag2	−0.073	19	0.327	4	0.585	6	1.000	1
Fog								
Lag0	0.030	15	0.279	7	0.077	14	0.153	9
Lag1	0.284	9	−0.099	21	0.138	12	0.273	3
Lag2	0.231	11	0.014	15	−0.021	17	−0.010	16

*Values greater than 0.002 are considered important and significant

sunshine hours increase and lead to a decrease in the number of admissions due to schizophrenia in hospitals. Previous studies have suggested that there is a significant relationship between rainfall and the number of schizophrenia births three months later (de Messias et al. 2001; Messias et al. 2006). Results also showed that low atmospheric pressure was associated with increasing admissions due to schizophrenia which was in concordance with findings of other studies (Talaei et al. 2014). Therefore, it can be said that the climate can play a very important role in the number of hospitalized patients with schizophrenia.

In schizoaffective disorder, some parameters and meteorological phenomena had a direct impact on the number of people admitted. According to the results obtained in this study, the phenomenon of dust (the number of dusty days) led to an increase in the number of admitted patients. Moreover, an increase in cloudiness and the number of foggy/snowy/rainy days were associated with an increase in the number of hospitalized cases. To our knowledge, there were no studies to investigate the effect of these parameters on hospitalization/admissions due to schizoaffective disorder. The only study was related to the effect of meteorological parameters like cloud cover and rainfall on seasonal affective disorder over a sample of 291 patients over winters. The results of this study showed that there is a positive relationship between cloud cover and mood in people with SAD. It seems that schizoaffective disorder, more often, has a hereditary root. More researches are needed to reveal the effects of meteorological factors on this disorder.

While the influence of weather depends on different factors like susceptibility of a person and geographic location (that in turn affects the reaction to weather), our findings showed that climate has a significant impact on depressive disorder. Based on the findings of the present study, among several potential climatic phenomena and parameters, the number of snowy and rainy days had a significant effect on the number of

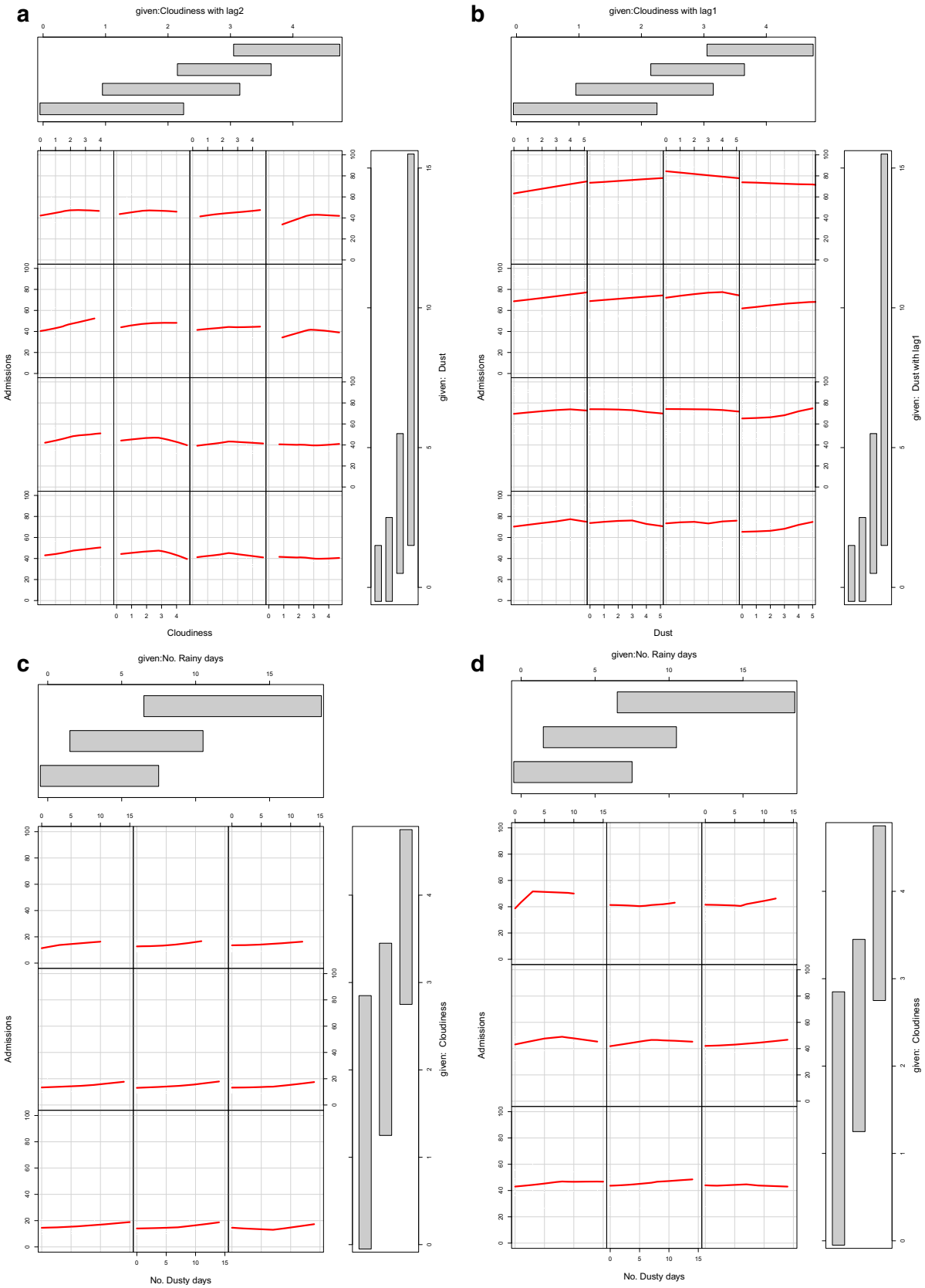

Fig. 2 Predicted number of admissions due to **a** major depressive disorder according, **b** bipolar, **c** schizophrenia, and **d** schizoaffective by four topmost ranked climatic parameters (numbers 1 and 2 stand for lags)

hospitalizations due to depressive disorder. In the cloudy and rainy days, sensitive people feel more depressed, while when the weather is sunny, sunlight diminishes the severity of depressive disorder. One study has shown that people who live in areas with higher amounts of rainfall per month show greater depressive symptoms (O'Hare et al. 2016). On the other hand in a study, it has been shown that there is a negative relationship between snowfall and depressive disorder (Yang et al. 2015). However, there was no study investigating the relationship between the number of snowy days in a month and depressive disorder. Precipitation and reduced daytime in the cold months of the year can cause major depressive disorder. Our findings confirm this fact, as the number of rainy and snowy days and the number of days with horizontal visibility (vision less than 2 km) as well as cloudiness increase the number of admissions due to depressive disorder increases. Moreover, it was indicated that the dust phenomenon had a direct and significant role on the number of admissions due to depressive disorder. Considering that the study area (Hamadan) is located in the western part of Iran, in this area because of the sub-tropical high pressure center, the rainfall level is very low in summer. Therefore, the number of admissions is less than that in winter. In winter, the arrival of westerlies to the study area and the arrival of the short waves and sub-tropical cyclones increase the rainy and snowy days as well as the foggy days in the region. Therefore, it can be said that the main climatic factor affecting the number of admissions due to depressive disorder in the western region of Iran is the number of rainy, snowy, and foggy days with high sustainability. It is obvious that happiness is often felt on sunny days. In rainy days, emotional disturbances become more intense with diminishing sunlight.

With investigating the effect of climatic phenomena and meteorological parameters on bipolar disorder, it has been determined that the phenomenon of dust has an increasing impact on the number of hospitalization. So, with the increase in the number of dusty days, bipolar disorder is intensified. While several climatic parameters were not significantly associated with the admissions due to bipolar disorder, the cloudiness parameters had a positive significant effect. This finding was in disagreement with the results of the study conducted by Margrethe Christensen et al. (2008) as they did not find evidences about the relationship between cloudiness and the HAM-D17 (Hamilton Depression Scale) scores of bipolar patients. On the other hand, the number of rainy days was negatively associated with the number of admissions due to bipolar disorder. As it is confirmed by other studies, more sunshine is associated with higher admission rates of bipolar disorder (Medici et al. 2016). As the study area is located in a semi-arid climate and the number of rainy days in this area is less than that a humid climate, so the number of arid and sunny days is greater compared with that of rainy days. Consequently, the rain phenomenon in this area delicate the spirit of people. In the mentioned study, the admission was also associated with less snow, while in our study this variable did not show a significant effect.

The results of this study indicated that increasing the number of dusty days is associated with the increase in the number of admission due to schizophrenia, schizoaffective, bipolar, and major depression disorders. This effect lasts up to the next two months. Reducing vision, unpleasant health problems, environmental contamination, and respiratory diseases such as asthma and infectious diseases are among the most adverse events of dust phenomenon that can cause tensions involving human mind. Moreover, dust has an adverse effect on economic and social activities that might reduce the threshold of tolerance. Other negative mental effects of dust include feelings of danger among people, anger and blame, inability to concentrate, and stress. Although dust affects mainly the human body, due to the mutual interacting of the body and mind, the diseases related to the dust phenomenon, such as cardiovascular, pulmonary, and dermatological, can in turn have a negative effect on the mental health of humans. Also, long-term respiration of magnesium compounds in dust particles can cause depression and dizziness (Al-Hurban and Al-Ostad 2010).

We also conducted a RF analysis to see interactions between variables. According to the results, it was revealed that some parameters, identified as important variables, affect the number of admissions due to four studied disorders simultaneously and there were interactions between them. From these findings, it can be concluded that the simultaneous influence of these parameters is escalated that causes other environmental phenomena. For instance, increasing the number of dusty days along with increasing the amount of cloudiness may lead to decreasing sunlight exposure and reducing the horizontal visibility and consequently intensifying the influence of dust on human spirit and mind. Moreover, dust can also limit physical activities such as outdoor sports, hiking, social interactions, and cross-country trips that enforce people stay home. This might point out to the fact that if dust phenomenon happens in a clear sky, its influence will be less compared with a cloudy sky. Considering that in the study area the advent of cloudiness in the sky in winter is accompanied by the entrance of westerlies and Mediterranean low-pressure systems, simultaneous entrance of low-pressure systems and dust reduces the oxygen in the air (which has a destructive effect on the respiratory system and blood circulation) and sunshine radiation. Therefore, the number of admissions increases with simultaneous increase in these parameters.

Limitations

There were some limitations in the present study. The study area was limited geographically. In order to achieve more

reliable results, the data corresponds that a wider area is required. The study period was also short and the data related to a longer period was not available. There might be differences in the impact of the investigated parameters in men and women as well as in different age groups. It is recommended to consider these variables in the future studies.

There was no information from areas that are not mountainous to compare our results with them. Despite these limitations, we used a powerful statistical method that is robust to the small sample size of this study.

Acknowledgements We would like to thank the Vice-Chancellor of Research and Technology, Hamadan University of Medical Sciences, for the approval and support of the study.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Al-Hurban AE, Al-Ostad AN (2010) Textural characteristics of dust fallout and potential effect on public health in Kuwait City and suburbs. Environ Earth Sci 60:169–181

Anderson CA (2012) Climate change and violence. The encyclopedia of peace psychology. Wiley-Blackwell, Hoboken

Bauer M, Glenn T, Grof P, Rasgon NL, Marsh W, Sagduyu K, Alda M, Murray G, Quiroz D, Malliaris Y (2009) Relationship among latitude, climate, season and self-reported mood in bipolar disorder. J Affect Disord 116:152–157

Breiman L (2001) Random forests. Mach Learn 45:5–32

De Messias EL, Cordeiro NF, Sampaio JJC, Bartko JJ, Kirkpatrick B (2001) Schizophrenia and season of birth in a tropical region: relationship to rainfall. Schizophr Res 48:227–234

Dominiak M, Swiecicki L, Rybakowski J (2015) Psychiatric hospitalizations for affective disorders in Warsaw, Poland: effect of season and intensity of sunlight. Psychiatry Res 229:287–294

Ishwaran H, Kogalur UB, Blackstone EH, Lauer MS (2008) Random survival forests. Ann Appl Stat 2:841–860

Lee H-C, Tsai S-Y, Lin H-C (2007) Seasonal variations in bipolar disorder admissions and the association with climate: a population-based study. J Affect Disord 97:61–69

Liaw A, Wiener M (2002) Classification and regression by randomForest. R News 2:18–22

Liboschik T, Fokianos K, Fried R (2015) tscount: an R package for analysis of count time series following generalized linear models, Universitätsbibliothek Dortmund

Margrethe Christensen E, Knud Larsen J, Gjerris A, Peacock L, Jacobi M, Hassenbalch E (2008) Climatic factors and bipolar affective disorder. Nord J Psychiatry 62:55–58

Mcwilliams S, Kinsella A, O'Callaghan E (2013) The effects of daily weather variables on psychosis admissions to psychiatric hospitals. Int J Biometeorol 57:497–508

Medici CR, Vestergaard CH, Hadzi-Pavlovic D, Munk-Jorgensen P, Parker G (2016) Seasonal variations in hospital admissions for mania: examining for associations with weather variables over time. J Affect Disord 205:81–86

Messias E, Mourao C, Maia J, Campos JPM, Ribeiro K, Ribeiro L, Kirkpatrick B (2006) Season of birth and schizophrenia in Northeast Brazil: relationship to rainfall. J Nerv Ment Dis 194: 870–873

O'Hare C, O'Sullivan V, Flood S, Kenny RA (2016) Seasonal and meteorological associations with depressive symptoms in older adults: a geo-epidemiological study. J Affect Disord 191:172–179

QUALITY, I. O. M. C. O. T. E. O. C. C. O. I. A. & HEALTH P (2011) Climate change, the indoor environment, and health. National Academies Press

Sarran C, Albers C, Sachon P, Meesters Y (2017) Meteorological analysis of symptom data for people with seasonal affective disorder. Psychiatry Res 257:501–505

Shiloh R, Shapira A, Potchter O, Hermesh H, Popper M, Weizman A (2005) Effects of climate on admission rates of schizophrenia patients to psychiatric hospitals. Eur Psychiatry 20:61–64

Talaei A, Hedjazi A, Rezaei Ardani A, Fayyazi Bordbar MR, Talaei A (2014) The relationship between meteorological conditions and homicide, suicide, rage, and psychiatric hospitalization. J Forensic Sci 59:1397–1402

Wang S, Zhang X, Xie M, Zhao D, Zhang H, Zhang Y, Cheng Q, Bai L, Su H (2018) Effect of increasing temperature on daily hospital admissions for schizophrenia in Hefei, China: a time-series analysis. Public Health 159:70–77

Welham J, Davies G, Auliciems A, McGrath J (2000) Climate, geography, and the search for candidate, nongenetic, risk factors for schizophrenia. Int J Ment Health 29:79–100

WHO (2018) Available: http://www.who.int/whr/2001/media_centre/press_release/en/ [Accessed]

Yang W, Mu L, Shen Y (2015) How we can use twitter data to better understand weather-related depression. USApp–American politics and policy blog