Research Square

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Association Between Extreme Air Temperature Variability and Inpatient Psychiatric Hospitalizations: Aggregated Observational Data from 2015–2022

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Abstract

Background

The present study aimed to investigate the association between extreme maximum temperature anomalies (TXa > 5°C) and hospitalization rates for Mood Disorders (MD), Psychotic Spectrum Disorders (PSD), and Personality Disorders (PD).

Study design:

Retrospective observational study.

Methods

Hospital discharge records from the Psychiatric Inpatient Unit of “S. Salvatore” Hospital in L’Aquila, Italy, were examined for the period 2015–2022 (n = 2,967). Monthly hospitalization rates for MD, PSD, and PD were assessed in relation to the frequency of TXa > 5°C, as identified using regional meteorological data.

Results

The analyses indicated a statistically detectable association between the occurrence of TXa > 5°C and hospitalization rates for PD. In contrast, associations for PSD and MD were less pronounced and did not show the same degree of consistency.

Conclusions

The findings suggest that hospital admissions for PD may be more sensitive to short-term extreme temperature variations than those for other psychiatric diagnostic groups. While previous studies have reported associations between climatic factors and MD or PSD, the present results highlight the need for further investigation into disorder-specific responses to acute environmental stressors. In the context of increasing temperature variability associated with climate change, continued research may help inform preventive strategies and mental health service planning for potentially vulnerable populations.

BACKGROUND

The impact of climate variations on human health has gained considerable attention in recent years, with a growing body of evidence highlighting the profound effects of rising temperatures and extreme weather events on both physical and mental health. Global warming, driven by climate change, has been particularly linked to a range of health concerns, including an increased incidence of heat-related

illnesses, respiratory conditions, and the spread of vector-borne diseases (1–3). Notably, studies have shown a higher prevalence of neurological disorders, such as Alzheimer's disease, Parkinson's disease, and motor neuron diseases, in regions experiencing rising temperatures (4). Heat stress has also been associated with life-threatening conditions like heat stroke, which can trigger acute and chronic kidney disease due to electrolyte imbalances, as well as strokes and cardiovascular diseases, including acute myocardial infarction (5–8).

While the physical consequences of climate change, including heat-related illnesses and the spread of infectious diseases, are well documented, its mental health impacts remain less explored but equally critical. Shifts in temperature, precipitation patterns, and the occurrence of extreme weather events have been shown to significantly affect mental well-being. These impacts range from the psychological toll of acute, traumatic events, including wildfires, hurricanes, and floods, to the gradual mental health consequences stemming from chronic environmental changes like long-term heat exposure and social instability. Acute climate events have been associated with increased incidences of post-traumatic stress disorder (PTSD), depression, and suicide, while chronic changes contribute to social disruptions that weaken mental health and individual functioning, leading to job loss, displacement, and conflicts (9–11). Moreover, rapid daily fluctuations in temperature and precipitation, particularly heatwaves, have been linked to exacerbations of psychiatric conditions. Studies have documented a rise in hospitalizations for mood disorders, psychotic disorders, and behavioral disorders during extreme weather conditions, underscoring the growing public health burden of climate change (12–14).

These findings highlight the urgent need for research into the relationship between climate variability and mental health, especially for vulnerable populations. This study seeks to investigate the impact of temperature anomalies on acute psychiatric hospitalizations across three major diagnostic categories: Mood disorders (MD), Psychotic Spectrum Disorders (PSD), and Personality Disorders (PD).

PSD (including schizophrenia and related conditions) are characterized by abnormalities in one or more of the following domains: delusions, hallucinations, disorganized thinking (speech), grossly disorganized or abnormal motor behavior (including catatonia), and negative symptoms. MD (such as depressive and manic/hypomanic episodes and others related conditions) involve pathological alterations in mood, cognition, and psychomotor activity. PD are defined by enduring and inflexible patterns of inner experience and behavior that deviate markedly from sociocultural expectations. Affected individuals often exhibit impaired adaptive functioning in response to stressors, with heightened emotional reactivity and externalizing behaviors. These psychopathological conditions may necessitate hospitalization when symptoms severely compromise an individual's personal, social, or occupational functioning. Admission is indicated when clinical severity leads to acute risks to safety or to substantial impairment in basic self-care, occupational duties, or socially appropriate behavior, especially in cases involving suicidality, aggression, or psychotic decompensation.

By elucidating these connections, we aim to improve our understanding of whether climate fluctuations are associated with mental health outcomes and to inform public health strategies to address potential

emerging risks.

METHODS

Hospital Data

This retrospective observational study analyzed discharge records from the Inpatient Psychiatric Unit of "San Salvatore" Hospital (L'Aquila, Italy) between 2015 and 2022. Hospital data were extracted from a computerized database maintained by the Hospital Archive Office. This included individual patient discharge records containing sociodemographic information (e.g., gender, date, and place of birth), admission and discharge dates, and primary discharge diagnoses classified according to the International Classification of Diseases, 9th Revision (ICD-9).

The analysis focused on patients with a primary discharge diagnosis within one of three diagnostic groups: PSD, MD, or PD. To ensure privacy, data were anonymized, and patients were identified solely by pre-assigned codes. The anonymized dataset was securely stored in an Excel file accessible exclusively within the hospital's internal network. After data collection, records were manually reviewed for completeness, and missing information was corrected whenever possible.

Meteorological Data

Temperature time series were obtained of maximum and minimum daily values, derived from the nearest available weather stations across the Abruzzo Region. The database was carefully quality-checked and homogenized over time as reported in a study by Curci *et al.* (15).

Since we are focusing on effects of extreme heat, we subtract the monthly mean from each value of maximum temperature, to obtain the so-called "anomalies" (TXa throughout the manuscript).

Data Analysis

Data on hospital admissions for the three diagnostic categories were processed to obtain the monthly admission for PD, PSD and MD. ICD-9 (International Classification of Diseases, Ninth Revision) includes a range of codes for mental, behavioral, and neurodevelopmental disorders, specifically from 290–319. This classification system covers psychoses, intellectual disabilities, and other nonpsychotic mental disorders like neurotic disorders and personality disorders (16).

It was observed that the number of admissions for the three diagnostic categories had a negative trend during the study period (Fig. 1a). This behavior was likely due to an increase in the average hospital stay duration during the study period (Fig. 1b). Indeed, since the number of hospital beds didn't change during the study period, an increase in the average duration of the hospital stay leads to a reduction of the number of monthly admissions. The duration of the hospital stay may be related to many factors which are not dependent on the atmospheric conditions, such as the severity of the psychiatric disorder, the

presence of comorbid medical conditions, the patient's response to pharmacological, availability of post-discharge support or community care services, and institutional policies regarding hospitalization and discharge planning.

Figure 1a *and b. Time series of monthly admissions (a) and monthly mean hospitalization days (b). PD, PSD and MD are shown with blue, orange and green colors respectively.*

Thus, we fitted a linear model to the time series of monthly admissions for PD, PSD and MD and we removed the observed trend. The original time series and the detrended times eries can be seen in Figs. 2a,b,c for PD, PSD and MD respectively, where the black line and dots represent the original data, while the red line and dots represent the detrended data. After the detrending procedure, PD and MD show less inter-annual variability compared to the original data. Instead, the detrended PSD time series still shows a strong inter-annual variability, indeed the original data has a clear non-linear trend, which cannot be removed with the linear model that we applied. However, we decided to not use a different detrending approach for PSD, to apply the same approach to all three diagnostic categories.

For methodological consistency, we decided to apply the same smoothing technique used for the meteorological dataset also to the medical dataset. The time series obtained after the smoothing procedure are shown in Figs. 2d,e,f for PD, PSD and MD respectively, where the black lines represent the detrended data, while the red lines represent the detrended data after the application of the smoothing procedure.

Figure 2. *a), b) and c): the black line represents the original timeseries, while the red line represents the detrended timeseries for PD, PSD and MD respectively. d), e) and f): the black line represents the detrended timeseries, while the red line represents the smoothed timeseries for PD, PSD and MD respectively.*

The removal of the linear trend observed in the monthly admissions has the implication that this dataset cannot be used anymore for the investigation of a correlation with observed trends in the main atmospheric variables (i.e. air temperature, relative humidity, precipitation, etc.). However, this is not a limitation, since the study period is not long enough (8 years) to observe a trend in the main atmospheric variables, which show clear trends on much longer periods (at least 20 to 30 years) (11, 17, 18).

Thus, we decided to investigate whether there was a correlation between the normalized monthly admissions and the number of times, for the same months, the measured maximum air temperature anomaly TXa was larger than a certain threshold. We fixed the threshold to 5°C, and Fig. 3 shows the number of times TXa exceeds the threshold during each month in the study period (TXa > 5°C). The black line in the figure represents the number of times in each month that TXa > 5°C, and it can be noticed that it presents a strong monthly variability. So, we decided to smooth the time series in order to reduce the impact of the noise on our analysis. Our smoothing approach consisted in resampling each time series at a frequency of 3 months, then linearly interpolating the time series to the original 1-month temporal resolution, and then dividing each value by 3, in order to obtain the number of times that TXa > 5°C. The resulting smoothed time series is shown in Fig. 3 as a red line.

Figure 3. *The number of times TXa exceeds the threshold during each month in the study period. The black line represents the original time series, while the red line represents the smoothed time series.*

In order to reduce even further the noise of the dataset due to the interannual variability of PD, PSD and MD admissions and frequency of particularly hot days, we calculated for each month within the study period, the median of the admissions for each disorder, and the median of the times TXa > 5°C. We ended up with four time series, three for PD, PSD and MD, and one for TXa > 5°C, each with twelve elements, one for each month of the year, where the first element represents January, and the last represents December.

Finding a correlation between the PD, PSD and MD admissions and the frequency of particularly hot days, provides indirect information on how the number of admissions for PSD, PD and MD will change in the next future, which will be likely characterized by more frequent heat waves and extreme temperature (2, 9, 10, 13, 14). Thus, even if the study period covers just 8 years, and we had the necessity of detrending the time series of PD, PSD and MD, our approach is still capable of providing information for the three disorders categories in a climate change scenario.

RESULTS

A total of 2967 discharge records regarding the time period 2015–2022 were collected and analyzed: 1076 for MD, 1472 for PSD and 419 for PD (Table 1.)

Table 1
Discharge records details for the study period.

Total admissions 2015–2022	**Psychotic Spectrum Disorders**	**Mood Disorders**	**Personality Disorders**
	1472	**1076**	**419**
2015	195	213	70
2016	234	170	73
2017	226	127	67
2018	212	134	56
2019	195	124	45
2020	155	115	34
2021	140	112	35
2022	115	81	39
Population data			
Mean Age (SD)	42.36 (13.51)	49.33 (14.48)	32.91 (11.10)
Median Age (IQR)	42 (19)	50 (21.25)	32 (18)
Female number (%)	542 (36.79)	634 (58.86)	175 (41.76)
Mean Hospitalization days (SD)	12.99 (16.63)	10.77 (9.02)	7.22 (9.07)
Median Hospitalization days (IQR)	9 (9)	8 (9)	5 (5)

The multi-annual monthly median values of the time series are summarized in Table 2.

Table 2
Multi annual monthly median timeseries.

Month	Multiannual monthly median			
	PD	PSD	MD	TXa > 5°C
1	4.97	9.94	11.98	2.17
2	5.47	10.71	13.16	4.16
3	5.80	11.59	14.51	6.11
4	5.82	12.83	15.19	6.67
5	5.57	12.17	15.86	5.56
6	5.40	12.30	15.31	4.22
7	5.30	12.84	15.34	3.00
8	5.34	12.04	16.26	4.33
9	5.32	10.82	16.15	3.67
10	5.63	9.59	16.01	3.00
11	5.38	10.06	14.95	3.33
12	5.36	10.12	13.36	3.22

The relationship between hospital admissions for PD, PSD, and MD and the number of times TXa > 5°C was explored using scatterplots for each diagnostic category. Scatterplots illustrating monthly admissions for PD, PSD, and MD are shown in Figs. 4a-c, while multiannual monthly median admissions are drawn in Figs. 4d-f. *E*ach plot shows a simple linear fit of the data (red line) and the resulting Pearson correlation coefficient (R).

Figures 4a-c show a positive association between extreme temperature fluctuations and hospitalization for PD. In contrast, no significant associations were observed between hospitalizations for PSD and the number of times the TXa > 5°C.

Figure 4. *Scatterplots of PD, PSD, and MD monthly admissions against TXa > 5°C monthly frequencies. Smoothed data are shown in a), b) and c) for PD, MD and PSD respectively. Smoothed data processed with the multiannual monthly median approach are shown in d), e) and f) for PD, MD and PSD respectively. Each plot shows a linear fit of the data (red line) and the resulting Pearson correlation coefficient (R).*

When the same scatterplots were constructed using the data reported in Table 2 and processed according to the multi-annual monthly median approach described in the previous section, stronger correlations were observed across all three diagnostic categories (Figs. 4d–f). In particular, the correlation coefficient between PD admissions and the frequency of TXa > 5°C increased from 0.63 to

0.83. For MD and PSD, the corresponding coefficients changed from − 0.01 to 0.62 and from − 0.01 to 0.31, respectively. These results suggest that the application of the multi-annual monthly median approach is associated with higher estimated correlations, particularly for MD, while remaining more moderate for PSD.

DISCUSSION

As for the association between PD and short-term weather fluctuations, the correlation may be explained by the heterogeneous emotional and behavioral responses across PD subtypes. Borderline Personality Disorder (BPD), one of the major contributors to hospitalization rates within the PD category, is particularly characterized by heightened emotional reactivity and affective instability (19–21). Individuals with BPD often exhibit externalizing behaviors, such as impulsivity, irritability, and aggression, following a circadian pattern, and potentially exacerbated by environmental stressors like sudden weather changes. The rapid shifts in temperature could act as acute stressors, triggering these externalizing behaviors and leading to an increased need for psychiatric intervention. Moreover, other PD subtypes, such as Avoidant Personality Disorder and Obsessive-Compulsive Personality Disorder, tend to manifest more internalizing behaviors, including anxiety, withdrawal, and excessive self-control (22–24). While these disorders may still be sensitive to environmental changes, their response to sudden weather fluctuations might not immediately translate into impulsive or aggressive behavior that necessitates hospitalization. Instead, internalized distress might contribute to worsening psychiatric symptoms over a longer period, requiring different forms of clinical intervention. This variation highlights the importance of considering the internal differences within Personality Disorders when interpreting the link between weather changes and psychiatric hospitalizations.

A possible explanation for the weaker correlations observed for MD and PSD compared with PD is that these disorders may be more sensitive to longer-term seasonal patterns, such as photoperiod (daylight length) and average seasonal temperatures, rather than to short-term, acute heat anomalies. The pathophysiology of Major Depressive Disorder with seasonal pattern (formerly Seasonal Affective Disorder) and some psychotic disorders is linked to these broader circadian and seasonal rhythms, which develop over weeks or months (25–27). Overall, our findings are consistent with the existing literature, including the study by Zhao et al. (28), which reported a positive correlation between weather fluctuations and hospitalizations for schizophrenia. Similarly, a study by Aguglia and colleagues found an increase in hospital admissions for Bipolar Disorder associated with maximum temperatures and solar radiation, indicating that MDs may respond to environmental changes (29).

Findings of the present study should be taken in light of some limitations. First, the relatively short time span, which may not fully capture long-term trends or the potential delayed effects of climate on psychiatric disorders. Furthermore, findings may have been confounded by the COVID pandemic, both in terms of limitations in healthcare access and/or hospitalization capacity during lockdown, and due to the impact of the pandemic per se on mental health (30–32).

Another important aspect to discuss is the grouping of diagnoses using the ICD-9 classification system. This choice was made to enhance diagnostic consistency across the study, ensuring that the categorization of psychiatric conditions followed standardized criteria. By organizing disorders into diagnostic groups, we aimed to increase inter-diagnostic agreement and facilitate comparisons across related disorders, such as grouping PDs, MDs, and PSDs into broader categories. This approach helped to avoid potential misclassification that could arise from relying on individual diagnoses, which can sometimes vary due to subjective clinical assessments or diagnostic overlap. Furthermore, using diagnostic groupings also allowed us to increase the sample size for each category, enhancing the statistical power of our analyses.

Moreover, observational design precludes causal inference, and unmeasured confounding variables, including pharmacological treatment, socioeconomic status, and seasonal behavioral changes, may have influenced the observed associations.

CONCLUSIONS

The aim of this study was to evaluate the potential association between short-term weather fluctuations, particularly extreme temperature variations, and psychiatric hospitalizations in patients with PSD, MD, or PD.

While seasonal patterns of Mood Disorders have been well-documented, research investigating the impact of rapid, short-term weather changes on PD and PSD remains limited. Given the growing concern over climate change and its potential psychological effects, future studies should investigate these relationships further.

As extreme weather events become more frequent due to climate change, understanding the distinct impacts on various psychiatric disorders will be essential for tailoring mental health interventions and public health strategies accordingly. This study underscores the need for clinicians to be aware of the significant impact that heat waves, and possibly other extreme weather events, can have on individuals with Personality Disorders. To mitigate this risk, public health and mental health services should develop targeted interventions during periods of extreme heat, such as proactive outreach to high-risk patients, providing psychoeducation for patients and their families on managing emotional dysregulation, and strengthening community and peer support networks to foster emotional resilience. Implementing such strategies could help reduce acute crises and the need for hospitalization in this vulnerable population. In conclusion, our findings, in line with the existing scientific literature, suggest that the public health sector may benefit from considering marked temperature variability and heat peaks when monitoring and preventing the onset of PSD and MD.

Abbreviations

ICD-9: International Classification of Diseases, Ninth Revision

MD: Mood Disorders

PD: Personality Disorders

BPD: Borderline Personality Disorder

PSD: Psychotic Spectrum Disorders

TXa: Maximum Temperature Anomaly

PTSD: Post-Traumatic Stress Disorder

Declarations

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study adhered to International Ethical Standards (Declaration of Helsinki), as well as National regulations such as Legislative Decree 196/2003 (Personal Data Protection Code), amended by Legislative Decree 101/2018, and the General Data Protection Regulation (GDPR 679/2016). The study protocol was approved by the Local Ethics Committee, Comitato Etico Territoriale Regione Abruzzo (C.Et.R.A.), on April 3, 2025 (approval number 45/2025). In accordance with applicable national regulations, informed consent to participate was not required for this study because it was based solely on aggregated, anonymized data and did not involve the collection or processing of identifiable personal information.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

COMPETING INTERESTS

The authors declare that they have no competing interests.

FUNDING

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AUTHORS' CONTRIBUTIONS

A.Ro. and L.F. conceived the study. A.Ra., E.R., and R.D.S. developed the theoretical framework, performed the statistical analysis, and drafted the manuscript. G.C. and E.R. gathered and managed the meteorological data. C.L. contributed to the analysis and handled the ethics committee procedures.

A.Ro., L.F., and G.C. supervised the project. R.M., F.P., T.B., and W.D.C. critically reviewed the manuscript. All authors discussed the results and contributed to the final version of the manuscript.

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Figures

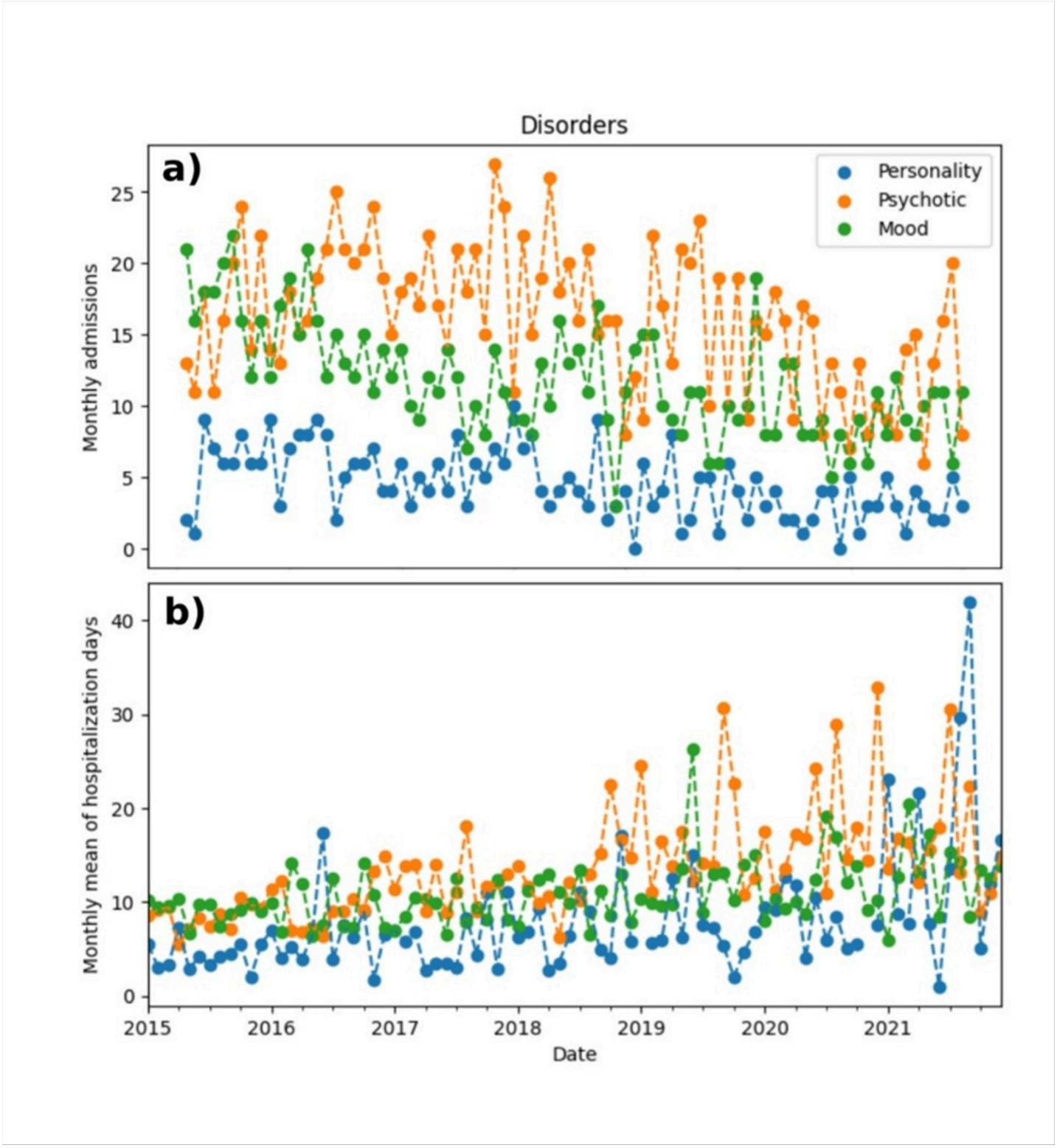


Figure 1

a and b. Time series of monthly admissions (a) and monthly mean hospitalization days (b). PD, PSD and MD are shown with blue, orange and green colors respectively.

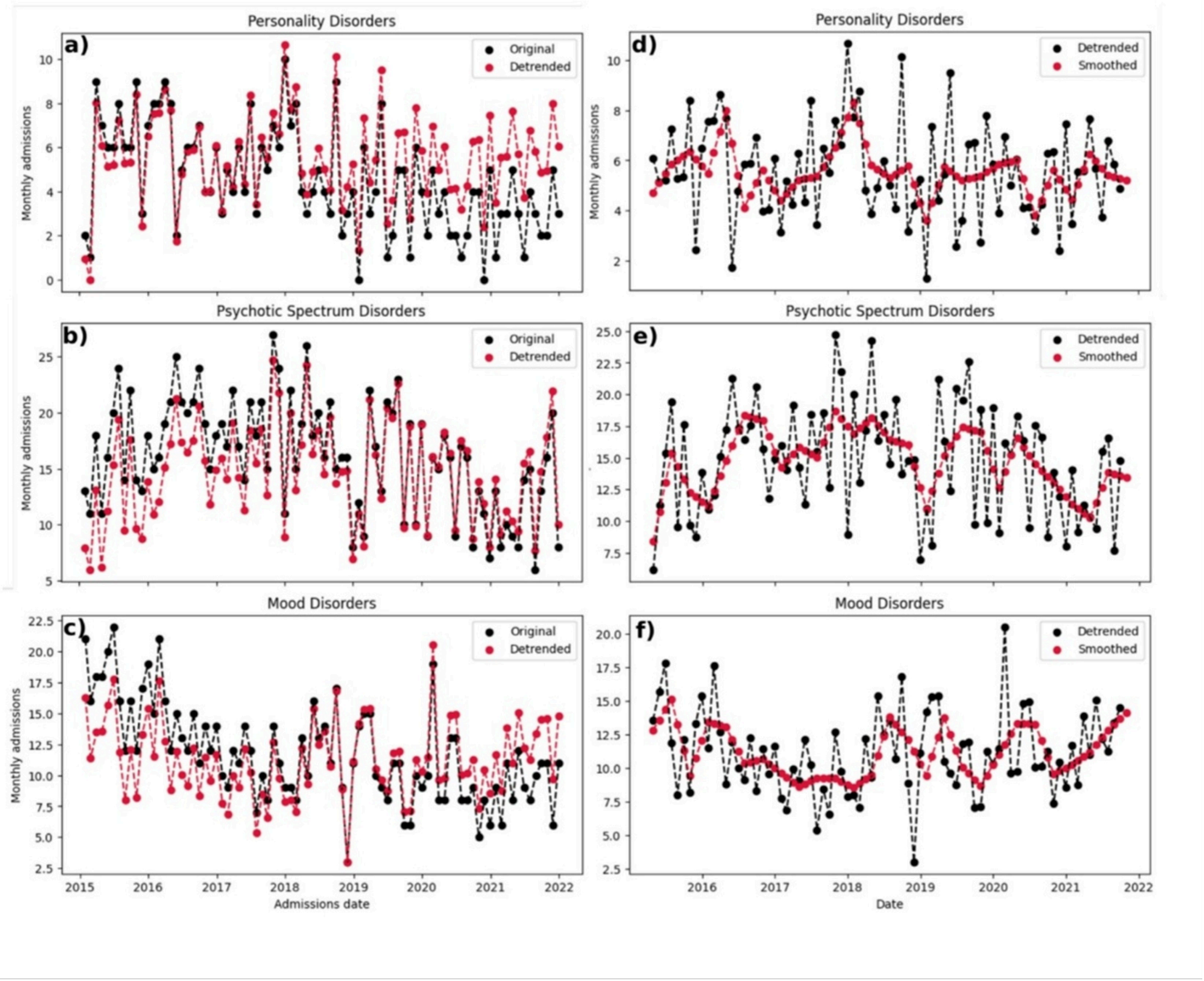


Figure 2

a), b) and c): the black line represents the original timeseries, while the red line represents the detrended timeseries for PD, PSD and MD respectively. d), e) and f): the black line represents the detrended timeseries, while the red line represents the smoothed timeseries for PD, PSD and MD respectively.

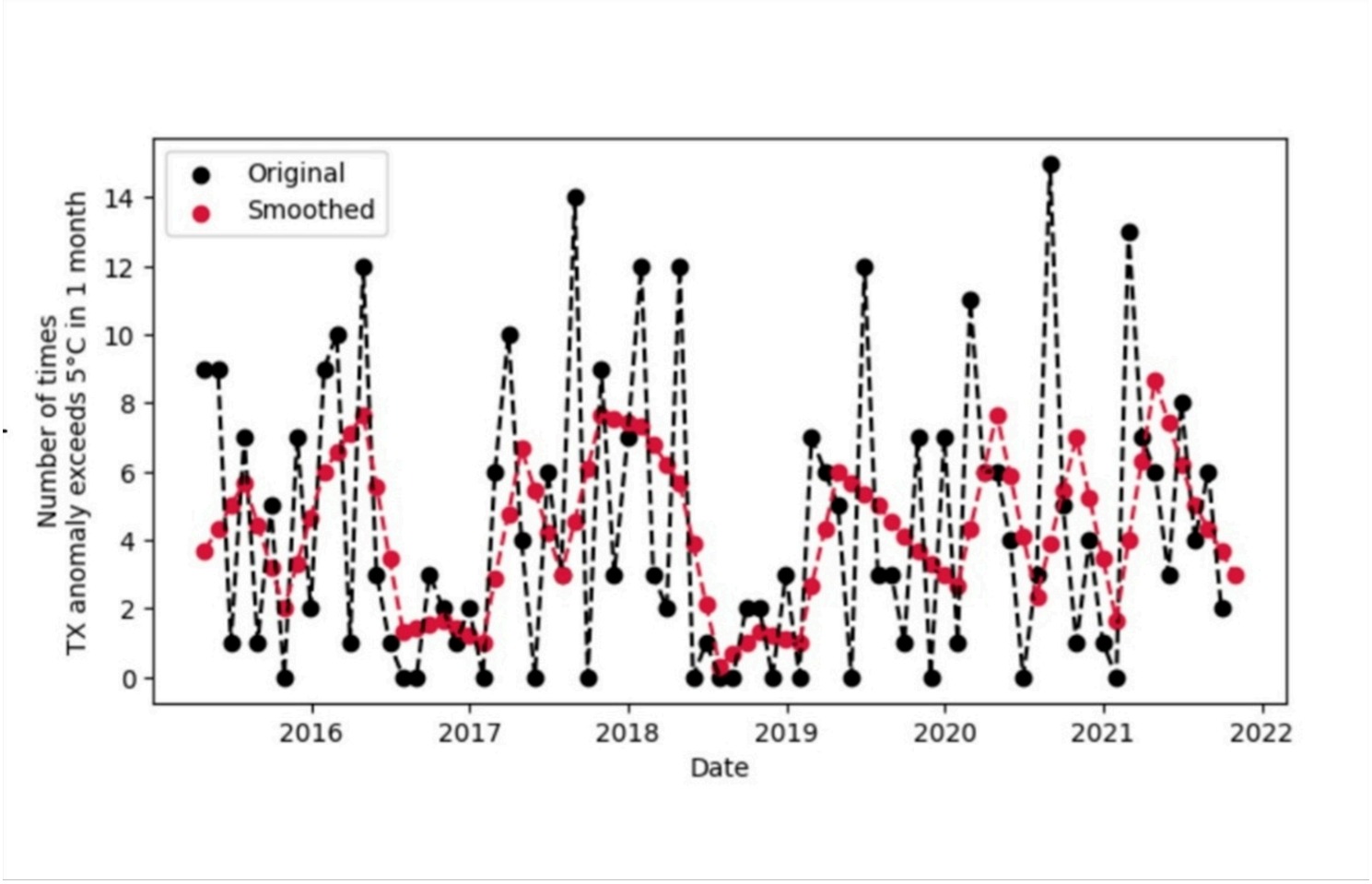


Figure 3

The number of times TXa exceeds the threshold during each month in the study period. The black line represents the original time series, while the red line represents the smoothed time series.

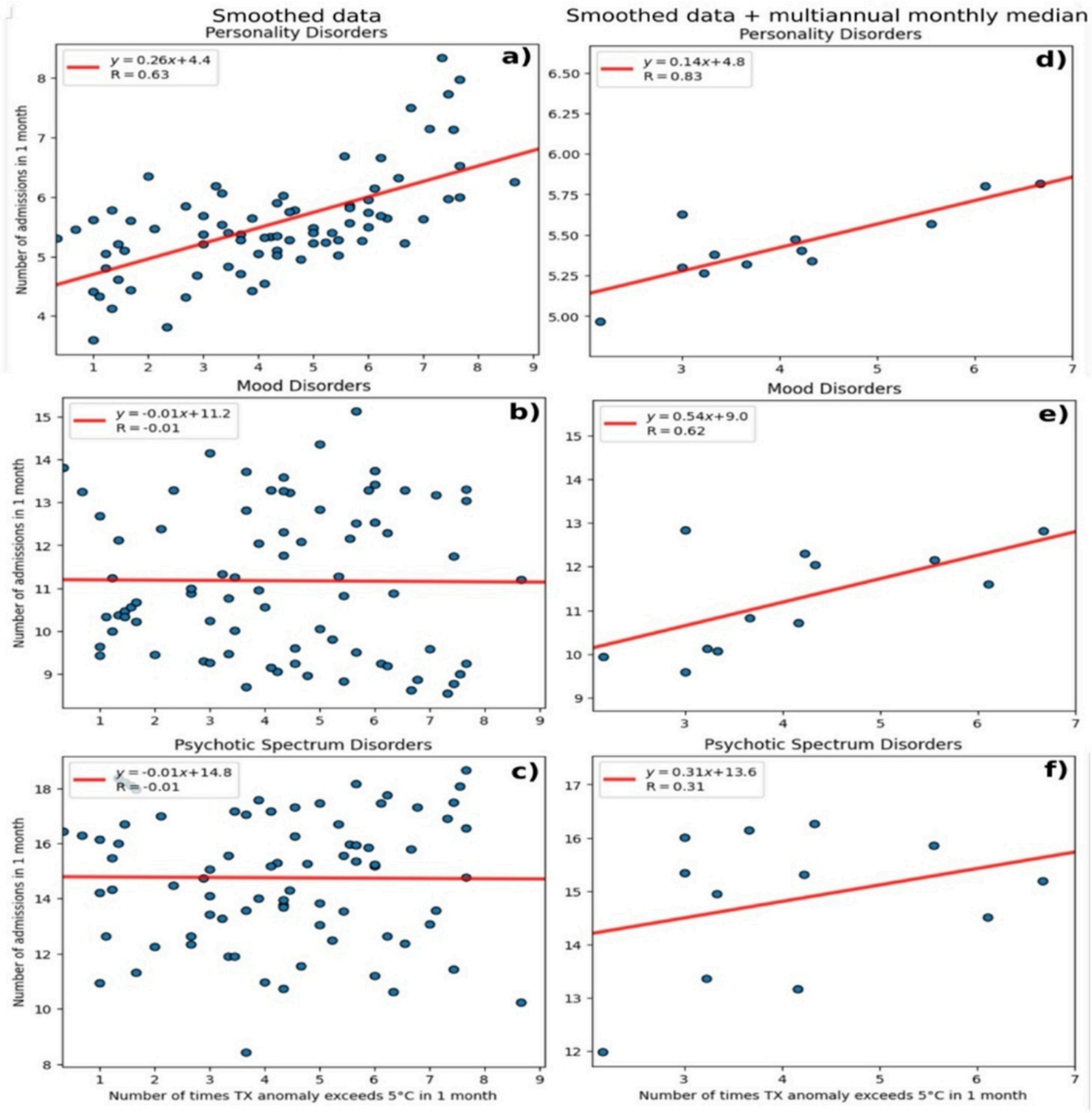


Figure 4

a-c show a positive association between extreme temperature fluctuations and hospitalization for PD. In contrast, no significant associations were observed between hospitalizations for PSD and the number of times the TXa> 5°C.