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ORIGINAL ARTICLE

Heatwaves and mental disorders: A study on national emergency and weather services data

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Abstract
Background and objectives: Heatwaves pose an increasing threat. However, there is a significant gap in understanding the impact of extreme temperatures on mental health. This study aimed to examine the associations between extreme temperatures and emergency visits for psychiatric disorders.
Method: We conducted quasi-Poisson regressions on emergency visits' rate for psychiatric reasons in French hospitals on days exceeding the percentiles 90, 95, 97.5, 99.5, and 99.9, between June 1st and September 15th, from 2015 to 2022, compared to days whose temperatures were below the 50th percentile during the two fortnights before and after our period of interest. We also examined the cumulative effect of three consecutive days exceeding the specified percentiles.
Results: Among the analyzed 1,198,953 psychiatric visits, we found an increased relative risk (RR) for dementia ranging from 5 % to 17 % on days exceeding percentiles 90 (RR=1.05, CI=1.02−1.07), 95 (RR=1.05, CI=1.02−1.08), 97.5 (RR=1.07, CI=1.03−1.11), 99.5 (RR=1.09, CI=1.01−1.17), and 99.9 (RR=1.17, CI=1.03−1.32). The cumulative heat effect also showed an increased risk ranging from 4 % to 44 %. For psychoses, we observed increases from 5 % to 7 % for the cumulative heat effect of percentiles 90 (RR=1.05, CI=1.01−1.08), 95 (RR=1.06, CI=1.02−1.11), and 97.5 (RR=1.07, CI=1.01−1.15). Conversely, mood disorders exhibited a decreased RR from 14 %

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to 7 % for percentiles 90 (RR=0.93, CI=0.91—0.95), 95 (RR=0.92, CI=0.89—0.94), and 97.5 (RR=0.90, CI=0.87—0.93), as well as for the cumulative effects.

Conclusion: This study highlights the associations between weather conditions, extreme temperatures and psychiatric disorders and emphasize the importance of considering mental health management during future heatwaves.

Introduction

Climate change is the challenge of the 21st century. The Intergovernmental Panel on Climate Change (IPCC) alerted in 2021 that global surface temperature increased of 1.1 °C during the last century and revealed with a high level of confidence that this temperature will reach 1.5 °C by approximately 2030. In this context of global warming, heatwaves and droughts are projected to be more and more frequent.[1] Thus, it appears crucial to investigate the impacts of heatwaves on health. Extreme heat is the most studied and is known to induce specific heat related diseases such as hyperthermia, dehydratation[2] and to increase morbidity and mortality often threw deterioration of cardiovascular diseases.[3,4]

Psychiatric disorders are frequent and affect one person out of five.[5] The global burden of mental disorders accounts for 32.4 % of years lived with disability and 13.0 % of disability-adjusted life-years which rank them at the first place of disabling diseases.[6] Psychiatric disorders are multifactorial and highly influenced by the individuals' environment. Few researches have explored the connection between meteorological data, particularly extreme heat, and psychiatric disorders. Identifying key environmental factor associated with emergency departments (ED) visits for psychiatric disorders could significantly contribute to healthcare delivery planning. While numerous studies have investigated the relationship between temperature and mental health, only 17 studies have specifically studied the impact of extreme temperature on psychiatric disorders. These studies, performed in different countries with their own specific climates, used different methods and heatwaves definitions. Despite these differences, their findings consistently favored an exacerbation of ED visits due to psychiatric disorders. For instance, Carlsen et al. found a 22 % increase of ED visits for psychiatric disorders during the warm days of the year.[7] In 2021, Liu et al. performed a meta-analysis of two studies and found a 6 % increase in mental health related ED visits during heatwaves defined as three or more consecutive days whose daily mean temperature reached or exceeded the 95th percentiles.[8] The lack of consensus on the definition of a heatwave further complicates the interpretation of findings, as it varies based on the specific impact of the heat under consideration and the meteorological characteristics of the studied region. In France, the national heatwave alert plan is activated when the three-day means of maximal and minimal temperature reach the 99.5th percentile. This threshold is based on a temperature-mortality study in 14 main French cities and extended to one reference station in each mainland department. However, this threshold does not account the impact of heat on the initiation or exacerbations of diseases.[9] Results regarding the impact of extreme temperatures on specific psychiatric disorders have yielded contradictory outcomes among subgroups. For instance, in Northern Vietnam, overall mental disorders admissions showed a relative risk ratio (RR) of 1.15 (1.005—1.31) during heatwaves, with only organic mental disorders and mental retardation remaining significantly increased in the per-group analysis.[10] As for an Australian study, organic illnesses, including symptomatic mental disorders, dementia, mood (affective) disorders, neurotic, stress related, and somatoform disorders, disorders of psychological development, and senility were significantly more frequent during heatwaves.[11] "

Thus, the objectives of this study are to 1) study relationships between heatwaves and ED visits due to psychiatric disorders, 2) examine different temperature thresholds during the warm period in metropolitan France, as well as other meteorological data.

Materials and methods

Meteorological data

Meteorological data were provided by the French national weather services Météo-France. For the purpose of this study, we collected daily minimal and maximal temperatures, humidity and windspeed during the warm period (15th may to 30th September) from the year 2015 to 2022 at the metropolitan department scale. Overseas French departments were excluded from the study because they have currently no heatwave alert system. France is characterized by diverse climates: the Mediterranean climate, the oceanic climate, the altered oceanic climate, the semi-continental climate, the mountainous climate. These climates imply important variations of temperature according to the localisation on the territory. The department level appears as a good compromise between climate homogeneity and sufficient health data.[12] We calculated for each department its temperature percentiles to allow comparisons between them. Days from 15th to 30th May and from 16th to 30th September were chosen as reference if their maximal temperatures were under the 50th percentile. The 50th percentile chosen as reference is usual in weather analyses and in accordance with previous studies.[13,14] Reference days were chosen in the warm period and very close to summer season to prevent a seasonality bias while avoiding the mental health impact of Covid-19 lockdown (15th March-10th May 2020) and the back to school and work of the beginning of September after summer holidays. Days of interest were those reaching the 90th, 95th, 97.5th, 99.5th and 99,9th percentiles of the maximal temperatures distribution between the 1st June and the 15th September, which is the alert system time span. We chose to work on maximal temperatures because they reflect the highest stress due to temperature on individual during the warm period.[4] Furthermore, maximal temperatures are highly correlated to mean temperature and minimal temperatures. If the maximal temperature is high, the global temperature of the day will be too. To look at the heat cumulated effect, we considered three consecutive days average minimal and maximal temperatures, as derived from the French heat and health alert system (HHAS). Indeed, in France, HHAS is launched when the weather services forecast that the mean of the minimal and the mean of the maximal temperatures of the three forthcoming days, will reach the 99,5th temperature percentile. Thus, we calculated the 90th, 95th, 97.5th, 99.5th, 99,9th percentiles for this dual three-day indicator and categorise the alert days as the ones reaching the two thresholds. The choice of the three-day period is coherent with previous studies findings and methodology.[11,13,15]

Emergency visits

Admission data were collected from the Oscour® database of Santé Publique France (https://www.santepubliquefrance.fr/surveillance-syndromique-sursaud-R/reseau-oscour-R). Oscour database collects national emergency patient's visits from more than 600 establishments on the French territory since 2008. A code is attributed to each visit according to the 10th International Classification of Diseases (ICD). We collected visits due to a decompensation of a psychiatric disorder and visits of individuals for another reason highly associated with a psychiatric comorbidity. Psychiatric chronic illnesses are known risk factors for heat-related illnesses and can triple the risk of heat wave-related deaths.[16] Because of the large amount of different psychiatric codes, we used the followed Oscour syndromic clusters: dementia, psychosis, stress, anxious disorders, mood disorders and conduct disorders (more details in supplemental appendix). Admissions were classified according to sex and age (<15 years old, 15−64 years old, >64 years old). Each hospital must report two information: the number of visits and the code of each visits to the database. The quality of the reported information varies. To ensure sufficient coding quality for visits, we have included only those of hospitals that coded for more than 50 % of their patient visits and for more than 50 % of the study period. We summed all relevant visits across the departments of various hospitals.

Statistical analysis

During the overall period (15th May- 30th September), we conducted Pearson's correlations between patient visits and meteorological data. Quasi-Poisson regressions were performed to compare different coding patterns between the days of interest and the reference days. All daily visits attributed to acute psychiatric disorder or other medical conditions highly associated to a psychiatric disorder were adjusted. This adjustment involved dividing their count by the total number of hospital visits for all causes on that the same day. This step was taken to mitigate variations in visit frequency arising from factors such as departmental population or the overall attractiveness of the hospital. 2015. Regressions were adjusted on the department's population, the year and the day of the week. All analyses were conducted using the RStudio® software.

Results

Health data description

For the period between 2015 and 2022, days falling between June 1st and September 15th were considered days of interest. Additionally, days from May 15th to 30th and from September 16th to 30th were chosen as reference points if their maximal temperatures fell below the 50th percentile of temperature. According to our coding quality criteria, 5 departments out of 96 were excluded from the analysis. During our days of interest, healthcare database consisted of 922,840 visits due to/among people with chronic and major psychiatric disorders and 26,853,232 visits for all causes (0.034 %). During our reference days, we collected 222,756 visits due to/among people with chronic and major psychiatric disorders out of 6489,697 visits for all reasons (0.034 %). Descriptive statistics are summarized in Table 1 (means, medians, standard deviations and quantiles by days, months and years).

Concerning the demographic characteristics, females represented 55.8 % of the psychiatric visits and males 44.2 %. The 15−64 years old represented more than 70 % of the visits, followed by people above 64 years old (23 %) and then people under 15 years old (6 %) (Fig. 1a et Fig. 1b).

In terms of diagnosis distribution, anxiety disorders accounted for the majority of visits (36.18 %), followed by mood disorders (19.94 %), conduct disorders (18.18 %), dementia (12.36 %), psychotic disorders (9.24 %), and stress reactions (4.11 %) (Fig. 1).

Among those under 15 years old, females account for 53.75 % of the visits, while males represent 46.25 %. They predominantly sought care at ED for conduct disorders, with a majority of males (54.30 %), followed by anxiety disorders and mood disorders, where females made up a larger portion (63.60 % and 70.91 %, respectively). (Fig. 2a).

Among individuals aged 15−64 years old, females accounted for 54.01 % of the visits, while males represented 45.99 %. They predominantly sought care at ED for anxiety disorders and mood disorders, with a majority of females (61.26 % and 55.32 %, respectively), followed by conduct disorders and psychosis, where males made up a larger portion (53.28 % and 63.01 %, respectively). Subsequently, visits for stress showed a majority of females (58.37 %), while visits for dementia showed a majority of males (58.22 %) (Fig. 2b). Among individuals over 64 years old, the majority of visits was attributed to dementia (42.65 %), followed by anxiety disorders, mood disorders, conduct disorders, psychosis, and reactions to stress factors. Females accounted for a majority of the visits (61.87 %), regardless of the disorder (Fig. 2c).

The mean visit rate per 100,000 inhabitants was calculated for each code and department, as shown in Fig. 3. The South-Est region of France had the global highest prevalence of psychiatric visits.

Meteorological data description

The meteorological data characteristics for the entire study period, May 15th to September 30th from 2015 to 2022, are available in Table 2. Supplemental Table 1 provides the descriptive characteristics of various percentiles, while

Table 1 Descriptive statistics of the number of psychiatric visits at the national level per day, month, and year during our total period.

	Day			Month			Year		
	Number of visits	Number of men visits	Number of women visits	Number of visits	Number of men visits	Number of women visits	Number of visits	Number of men visits	Number of women visits
Min.	778.00	332.00	417.00	30,615	13,391	17,224	127,127	55,927	70,139
1st Qu.	996.50	440.00	552.75	32,110	14,265	17,663	128,081	57,210	71,794
Median	1089.00	481.00	604.00	32,679	14,483	18,343	131,590	58,121	73,421
Mean	1078.20	476.57	601.63	32,856	14,545	18,311	131,426	58,181	73,245
3rd Qu.	1157.25	513.00	646.00	33,677	14,842	18,861	133,645	59,055	74,663
Max.	1388.00	627.00	784.00	35,721	15,692	20,029	136,650	60,163	76,487

**May was excluded from the monthly statistics because it only included 15 days.

Supplemental Table 2 displays the number of days exceeding the different percentiles during the study period.

Fig. 4 illustrates the percentage of days between June 1st and September 30th, categorized by their percentile per year. With the exception of the year 2021, there is a noticeable increasing trend of hot days (exceeding the 90th percentile). In 2022, these days accounted for more than 20 % of the period, with over 10 % of the days surpassing the threshold of the 95th percentile.

Interestingly, the departments with relatively high temperatures in the overall period, indicated by high 90th percentiles, are not the ones experiencing the most extreme peaks of temperature. We observe that the southern departments have high overall temperatures, while the hottest temperature peaks occur in the central, south-west and Île-de-France regions (Fig. 5).

Statistical analysis

The Pearson's correlations showed positive correlations between all psychiatric disorders in general, psychosis, anxiety disorders, mood disorders (all $p<0.001$), and between conduct disorders and humidity ($p = 0.04$). Humidity was also negatively correlated with psychosis ($p<0.001$). The maximal temperature was positively correlated with dementia ($p = 0.01$) and negatively with all psychiatric disorders in general, anxiety and mood disorders ($p<0.001$). The minimal temperature was positively correlated with dementia, psychosis, stress reactions and conduct disorders (all $p<0.001$), and negatively with all psychiatric disorders in general ($p = 0.04$), anxiety and mood disorders (all $p<0.001$). Windspeed was positively correlated with mood disorders ($p = 0.01$) and negatively with all psychiatric disorders in general and anxiety disorders (all $p<0.001$) (Table 3).

The regression analysis revealed no significant results for the overall category of psychiatric disorders. However, significant results were observed within specific subgroups. Notably, the analysis demonstrated a continuous and significant increase in dementia visits as the different temperature thresholds were reached: the incidence rate ratio (IRR) increased from 5 % for the 90th percentile of the temperature distribution to 17 % for the 99.9th percentile. Similarly, the analysis of the cumulated heat effect also exhibited a continuous and significant increase in dementia visits: the relative risk ratio increased from 4 % for the HHAS90 days to 44 % for the HHAS99.9 days. Among visits for psychosis, a significant increase of 3 % of the IRR was observed when the 90th percentile of the temperature distribution was reached, but not for the other percentiles. A significant cumulated heat effect was obtained, with the IRR increasing from 5 % to 6 % and 7 % for the HHAS 90, 95, and 97.5 days, respectively. For visits related to stress, a significant increase of 15 % was associated to the HHAS 90th percentile, but not for other thresholds, both in terms of cumulated (HHAS) and acute (daily temperatures) effects. Regarding mood disorders, except for the acute and cumulated effects of reaching the 99th percentile, which is not significant, all other IRRs indicated a decrease in visits, ranging from 14 % to 7 %. Visits for conduct disorders and anxiety disorders did not show any significant differences between hot days and reference days (Table 4).

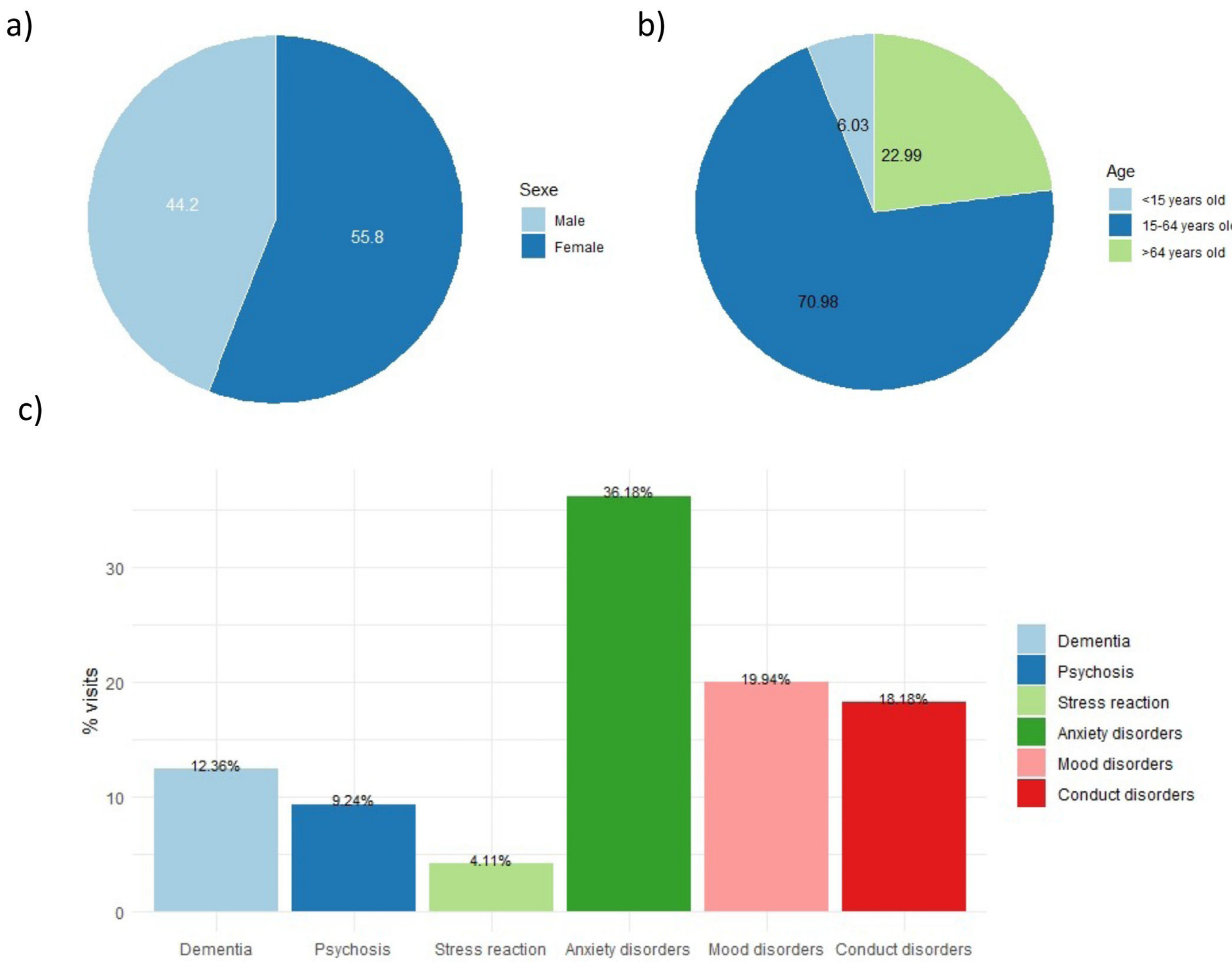

Fig. 1 Descriptions of Psychiatrics Visits percentages according to a) the sex b) the age and c) the diagnosis on the total period.

Discussion

Interpretation and implications

This first study assessing the links between heatwaves and psychiatric disorders found that periods of increased temperatures are associated with a significant increase in ED visits among patients with dementia and psychosis along with a significant decrease in visits by individuals with mood disorders. The visits could have been motivated by an acute psychiatric decompensation or to a disease highly influenced by a psychiatric disorder. The impact on dementia patients shows an increasing and progressive pattern, starting from the 90th percentile, even before reaching the heatwave alert threshold. Interestingly, the cumulative effect of heat seems to play a crucial role in the increase of visits. These findings underscore the importance of psychiatrists vigilance for their patients even prior the initiation of national heat warnings. While an immediate effect on psychosis was not observed, the cumulative impact of heat, commencing from the 90th percentile, emerged as significant. This suggests that individuals with psychosis may be susceptible to heat over prolonged durations. In light of these results, psychiatrists can enhance their patient care practices by intensifying monitoring of these patients during hot days to identify their needs and help them navigating through heat waves.

Patients suffering from psychosis, dementia or severe mood disorders such as melancholia have a noticeable cognitive impairment that could prevent them from adopting the adequate behaviour during extreme heat leading to dehydration, confusion and then emergency visits.[17] Moreover, their communication alterations also impact the early diagnosis of heat related disorders such as cardio-respiratory diseases. These diseases can thus worsen and lead the patient to the emergency room, even though outpatient care could have been possible at an earlier stage. Consequently, discerning the chronic condition from the acute medical event leading to the ED visit becomes challenging

Contribution and congruence with the literature

We found significant and insignificant results according to the psychiatric disorders, the significant results being linked to an increasing (dementia, psychosis, stress reaction) or a decreasing (mood disorders) risk. These different effects of

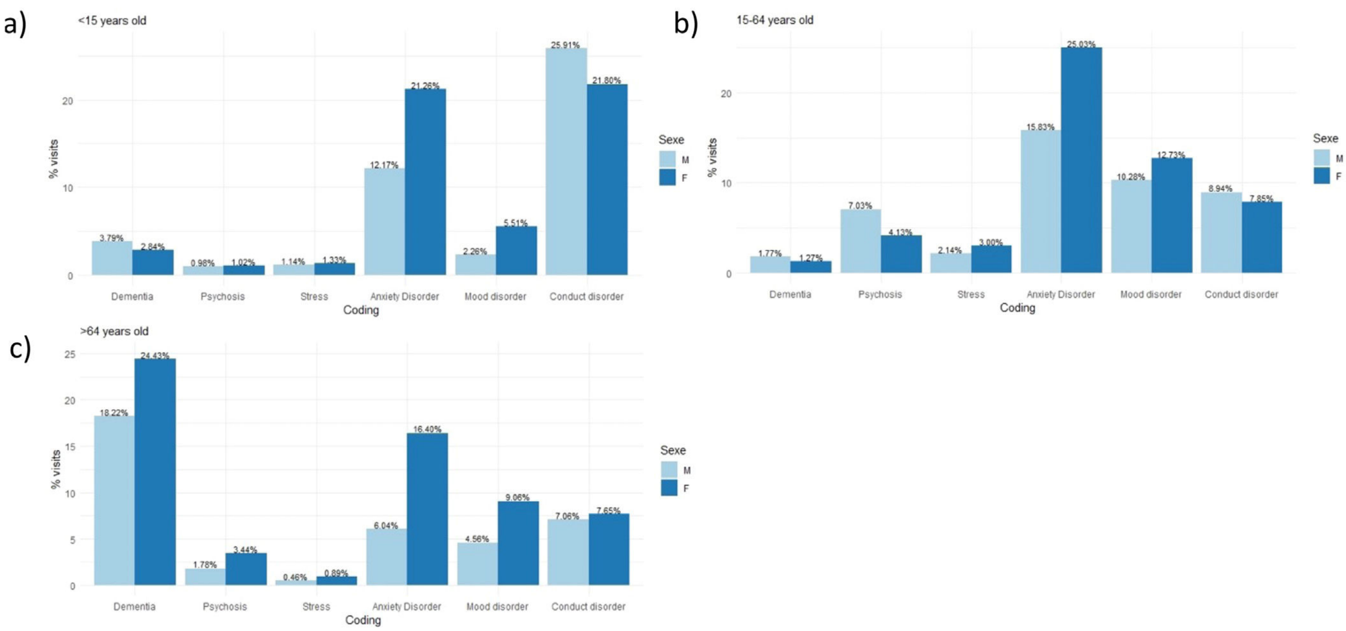

Fig. 2 Distribution of visits among individuals by gender and disorder across all geographic departments and total study duration according to their age a) under 15 years old, b) 15–64 years old, c) >64 years old.

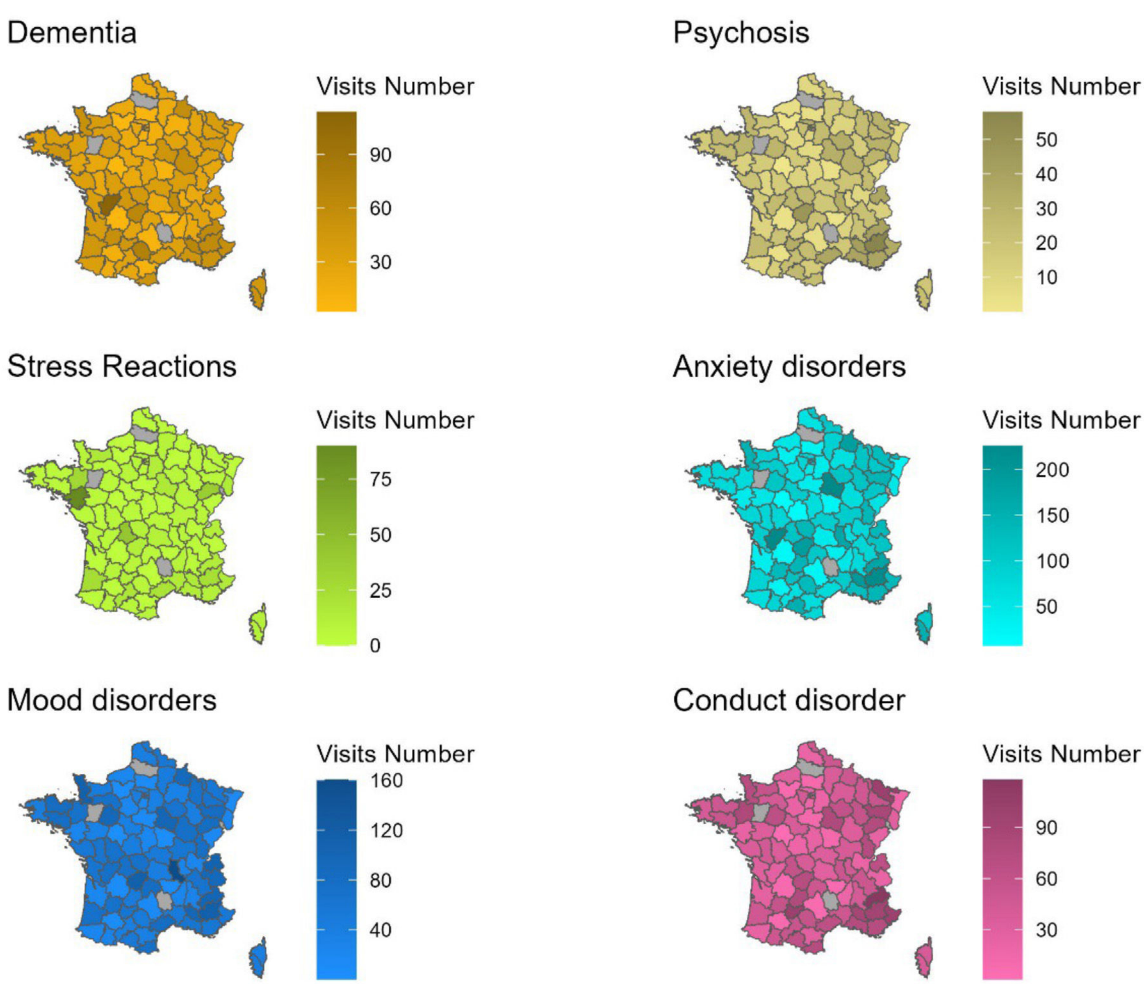

Fig. 3 Mean emergency visit rate per year and 100,000 inhabitants between the 15th May and the 30th September by psychiatric disorder and department.

Table 2 Description of different climatic variables, at a daily time step, across the entire duration and departments of the study.

	Humidity	Tmax	Tmin	Wind speed	TAmpli	HHASmax	HHASmin
Min	25.00	5.90	−3.40	0	0.40	6.77	−0.90
1st Qu	60.00	21.60	11	20	8.40	21.97	11.33
Median	69.00	25.20	13.80	27	11.5	25.4	13.73
Mean	68.25	25.41	13.69	29.10	11.75	25.43	13.69
3rd Qu	77.00	29.10	16.5	36	15	28.8	16.1
Max	100.00	44.40	30.30	146	28.20	41.60	28.43
NA's	211.00	38.00	38	357	39	42	40

*Tmax=maximal temperature, Tmin=minimal temperature, TAmpli)=temperature amplitude (Tmax-Tmin), HHAS= days for which the average of respectively maximal and minimal temperatures on three consecutive days are simultaneously above a specific threshold.

the meteorological data may have offset each other, which would explain the lack of significant findings for the all-cause category that we can find in other studies.[11,14] As far as it concerns heat cumulated impact on psychosis, our results are in line with previous studies at the city level, in New York[18], in three subtropical cities in China[19], in Toronto[13] and at the national level in the USA.[14] Similarly, results for dementia were congruent with previous studies performed in Korea[20], in Hanoï, Vietnam[10], and in Madrid, Spain.[21] As far as it concerns the absence of significant results for anxiety disorders, and our significant results for a decrease of mood disorders during extreme heat, it is congruent with a study in Toronto.[22] Nevertheless, the majority of the previous studies found a significant increase of mood disorders during extreme heat.[13,14,20] These discrepancies are worth examining closely, with several factors that could explain these differences, primarily related to variations in methods. One key factor is the absence of a standardized definition for heatwaves. Different studies employ varying approaches, such as calculating percentiles based on the entire year[20,13], or on the warm period.[14] These choices lead to subsequent different thresholds, for example: a threshold at percentile 97.5th with a mean around 27.07 °C in New York[18] and a threshold at percentile 95th with a mean around 35 °C in the USA.[14] Some studies chose to avoid this difficulty by choosing an arbitrary temperature as threshold instead of percentiles[11,21] but this is possible only for small studies at a local scale. Furthermore, it is important to take into account the study period which is crucial for the analysis interpretation because of the seasonal effect. Indeed, psychiatric disorders and especially mood disorders have seasonal characteristics. Depression is more frequent in winter, and when it is recurrent, it can be considered as a seasonal disorder: the seasonal affective disorder (SAD).[23] Suicides and suicide attempts show a recurrent seasonal pattern.[12] In our study we chose to focus on the warm period to get rid of this seasonal impact. Our percentiles were calculated on the whole warm period, which resulted in a panel of high thresholds. Also, the country's climate plays a significant role in the perceived temperature, as well as the environment. Most of the mentioned studies look at the heat impact in cities[11,15,20] whereas in our study we look at the entire territory including rural and urban environments. Heat impact is often stronger in urban environments compared to rural ones.[24,25] A study in Hong Kong showed IRRs of mortality associated with mental disorders at 1.033

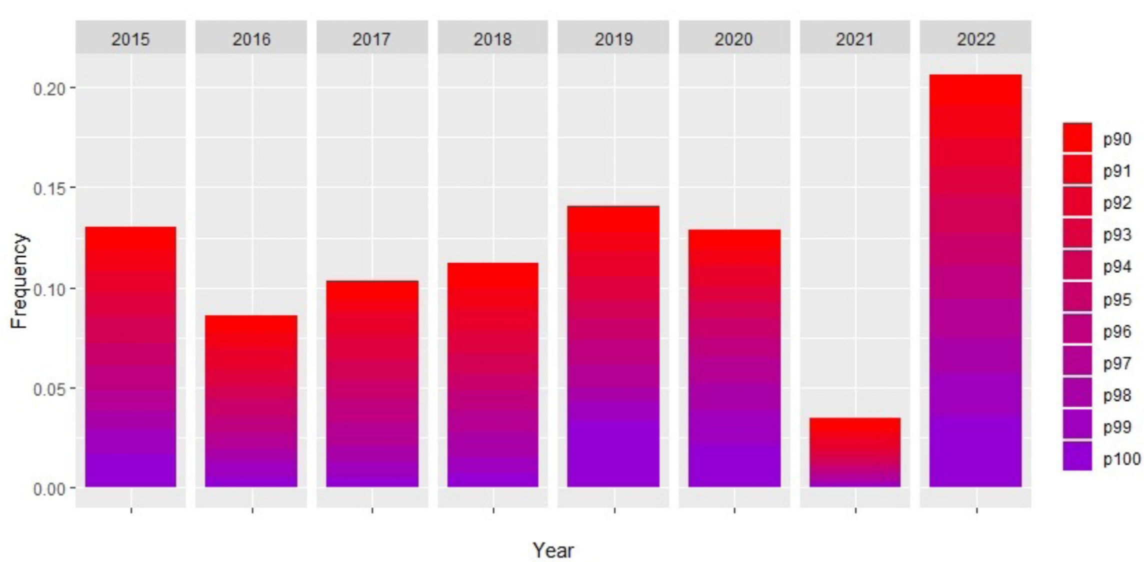

Fig. 4 Distribution of days exceeding the thresholds of percentiles greater than 90, per year, between June 1st and September 15th.

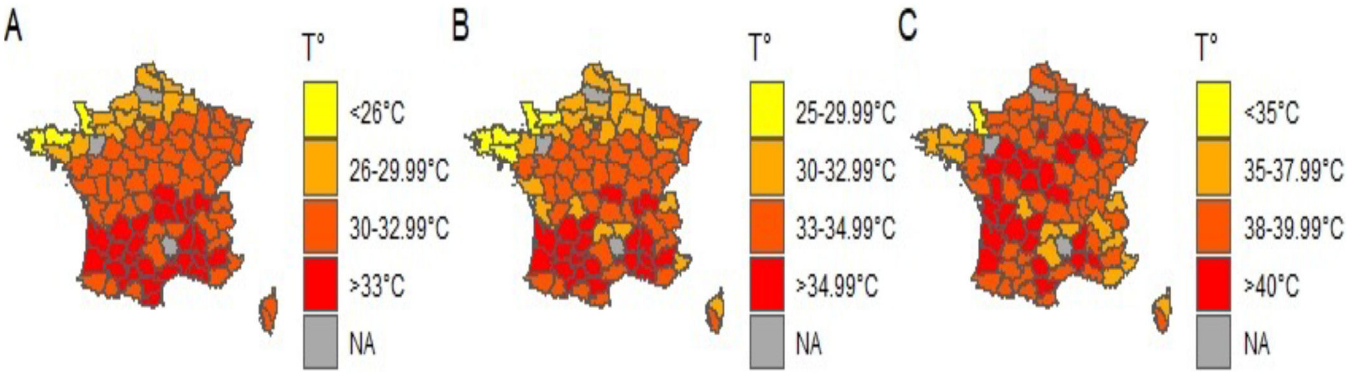

Fig. 5 France's maps representing the temperatures of the different thresholds for A) the 90th percentile B) the 95th percentile, C) the 99.9th percentile.

Table 3 Pearson's correlations between meteorological indicators and disorders.

Meteorological Indicators	Codes	R	*p*-value
Tmax	All psychiatric disorders	−0.03	p<0.001
Tmax	Dementia	0.01	0.01
Tmax	Psychosis	0.01	0.1
Tmax	Stress reactions	0.00	0.3
Tmax	Anxiety disorders	−0.03	p<0.001
Tmax	Mood disorders	−0.05	p<0.001
Tmax	Conduct disorders	0.00	0.2
Tmin	All psychiatric disorders	−0.01	0.04
Tmin	Dementia	0.01	p<0.001
Tmin	Psychosis	0.03	p<0.001
Tmin	Stress reactions	0.02	p<0.001
Tmin	Anxiety disorders	−0.03	p<0.001
Tmin	Mood disorders	−0.04	p<0.001
Tmin	Conduct disorders	0.02	p<0.001
Wind speed	All psychiatric disorders	−0.01	p<0.001
Wind speed	Dementia	0.00	0.6
Wind speed	Psychosis	0.00	0.5
Wind speed	Stress reactions	0.00	0.3
Wind speed	Anxiety disorders	−0.03	p<0.001
Wind speed	Mood disorders	0.01	0.01
Wind speed	Conduct disorders	0.00	0.76
Humidity	All psychiatric disorders	0.04	p<0.001
Humidity	Dementia	0.01	0.07
Humidity	Psychosis	−0.03	p<0.001
Humidity	Stress reactions	0.00	0.8
Humidity	Anxiety disorders	0.04	p<0.001
Humidity	Mood disorders	0.05	p<0.001
Humidity	Conduct disorders	0.01	0.04

for 1 °C increase in average temperature on days with temperature ≥ 24.51 °C. These mortality data were correlated to the city air pollution, the percentage of sky view and vegetation.[26] We chose to focus on the entire territory and on the warm period, usually associated to depression remission[27], this could have highlighted the positive impact of summer outside big urban cities empirically observed by psychiatrists, and thus explain our decrease risk of mood disorders during extreme heat. An other important key point to explain the studies different results could be the sample size differences. Most of the quoted cities include around 150,000 admissions whereas in our study we gathered more than one million visits for psychiatric disorders. Furthermore, each country has its own health care system and France has a good general practitioners network that can handle light to moderate distress, as well as a good chargeability of the costs of town medicine, two factors that can help avoiding part of the emergency visits.[28] Concerning our secondary analysis on the impact of meteorological variables on mental health, it appears that correlations exist as we showed in this study for temperature, wind speed and humidity. However, literature is really scarce. We find no study examining the impact of windspeed on psychiatric disorders. As far as it concerns humidity, our significant results are in line with previous results which showed significant negative correlations with alcohol use disorders[29], and manic admissions[30], and significant positive correlations for humidity and high self-reported distress.[31] We found a positive correlation between humidity and mood disorders, with our sample which includes manic and depressive episodes. Concerning psychosis, we found a negative correlation with humidity, which has been replicated only once according to the systematic review of Jahan et al.[32]

Possible biological explanations

Patients suffering from psychosis often exhibit impaired thermoregulatory system, through their pathological neurotransmitters transmissions, their dysfunctional circadian clock, and through the impact of psychotropic drugs.[33–35] This manifests as dysregulation of body temperature, abnormal daily range of temperatures and diurnal variations, and a disability to compensate to heat stress.[17] Dehydration further complicates matters by altering the bioavailability and efficacy of psychotropic drugs, potentially explaining the onset of psychiatric decompensation and emergency admissions for heat-related diseases. Another etiological mechanism contributing to emergency visits could be the sleep alterations due to high ambient temperatures.[36] These disturbances interfere with heat transfer between the two regulatory compartments: the heat-producing homeothermic core and the heat-loss regulating poikilothermic shell.[36] This

Table 4 Multivariate regression of visits risks for the different disorders according to the different maximal temperature / HHAS thresholds.

Temperature/ HHAS percentiles	All psychiatric disorders			Dementia			Psychosis			Stress Reaction			Anxiety Disorders			Mood Disorders			Conduct Disorders		
	IRR[1,2]	95 % CI2	p-value	IRR[1,2]	95 % CI2	p-value	IRR[1,2]	95 % CI2	p-value	IRR[1,2]	95 % CI2	p-value	IRR[1,2]	95 % CI2	p-value	IRR[1,2]	95 % CI2	p-value	IRR[1,2]	95 % CI2	p- value
>p90	1.00	0.99, 1.01	0.4	1.05***	1.02, 1.07	<0.001	1.03*	1.01, 1.06	0.016	1.04	0.97, 1.11	0.2	1.00	0.98, 1.01	0.6	0.93***	0.91, 0.95	<0.001	1.01	0.99, 1.03	0.5
>p95	0.99	0.98, 1.00	0.081	1.05***	1.02, 1.08	<0.001	1.00	0.96, 1.03	>0.9	1.03	0.94, 1.12	0.5	0.99	0.97, 1.01	0.5	0.92***	0.89, 0.94	<0.001	1.00	0.97, 1.02	>0.9
>p97.5	0.98	0.97, 1.00	0.093	1.07***	1.03, 1.11	<0.001	1.02	0.98, 1.07	0.4	1.06	0.94, 1.18	0.3	0.98	0.96, 1.01	0.2	0.90***	0.87, 0.93	<0.001	1.00	0.96, 1.03	0.8
>p99.5	0.98	0.94, 1.01	0.2	1.09*	1.01, 1.17	0.032	0.98	0.89, 1.08	0.7	1.02	0.81, 1.28	0.8	0.96	0.91, 1.02	0.2	0.89**	0.83, 0.96	0.003	1.00	0.94, 1.07	>0.9
>p99.9	1.01	0.95, 1.08	0.7	1.17*	1.03, 1.32	0.017	0.92	0.78, 1.08	0.3	1.18	0.80, 1.67	0.4	0.98	0.90, 1.07	0.7	0.95	0.83, 1.07	0.4	1.05	0.94, 1.17	0.4
HHAS90	1.00	0.99, 1.02	0.5	1.04**	1.01, 1.07	0.004	1.05**	1.01, 1.08	0.006	1.15***	1.06, 1.25	<0.001	1.01	0.99, 1.03	0.3	0.92***	0.90, 0.95	<0.001	1.00	0.98, 1.03	0.8
HHAS95	1.0	0.98, 1.01	0.6	1.05**	1.01, 1.10	0.009	1.06**	1.02, 1.11	0.007	1.02	0.90, 1.14	0.8	1.00	0.98, 1.03	0.7	0.90***	0.87, 0.94	<0.001	1.00	0.97, 1.04	>0.9
HHAS97.5	1.00	0.97, 1.03	>0.9	1.09**	1.03, 1.15	0.003	1.07*	1.01, 1.15	0.030	1.05	0.88, 1.25	0.5	1.01	0.97, 1.05	0.7	0.90***	0.85, 0.95	<0.001	0.99	0.94, 1.04	0.8
HHAS99,5	1.00	0.94, 1.06	>0.9	1.16*	1.02, 1.32	0.022	1.09	0.93, 1.26	0.3	1.08	0.70, 1.58	0.7	1.02	0.93, 1.11	0.7	0.86*	0.75, 0.98	0.022	0.96	0.85, 1.08	0.5
HHAS99,9	0.97	0.84, 1.12	0.7	1.44**	1.09, 1.87	0.008	0.69	0.43, 1.05	0.11	0.64	0.13, 1.81	0.5	1.08	0.88, 1.31	0.4	0.81	0.58, 1.09	0.2	0.82	0.60, 1.09	0.2

1 *p<0.05; **p<0.01; ***p<0.001.
2 IRR = Incidence Rate Ratio, CI = Confidence Interval.

can lead to dysregulation in the sleep/wake cycle notably through elevated dopamine levels. Sleep alterations are highly implicated in distress and psychosis decompensation[33], possibly eluciding the positive correlations found between minimal temperature and psychosis or dementia, since minimal temperature is the night temperature's reflection.

Regarding the decrease in emergency visits for acute mood disorders or diseases highly influenced by mood disorders, several explanations can be proposed. First, it is true that working with ratio might have artificially decrease the risk of visits since the all causes visit increases during extreme hot days. Nevertheless, depression can be alleviated by summer, notably through the sunlight impact and very hot days usually have large insolation time. Serotonergic function plays a major component in depressive disorders, and it is known to fluctuate with light and temperature.[37–39] Serotonin availability increases with the duration of daily sunshine.[40] Although literature presents contradictory results, more and more evidence growth to the efficiency of light therapy notably through the regulation of the circadian clock and catecholamine regulation.[41] In addition, major depressive disorders are associated with increased inflammation, and anti-inflammatory agents show interesting results in this indication. Some studies have tested whole body hyperthermia for the treatment of major depressive disorder with good results, notably via anti-inflammatory interleukine-6 secretion.[42,43] Therefore, it's plausible that extreme heat could induce mild hyperthermia, alleviating depressive symptoms and, consequently, reducing emergency visits. This hypothesis aligns with the negative correlations we identified between both minimal and maximal temperatures and mood and anxiety disorders.
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Limits of the study

This study also has several limitations. Due to conflicting findings in the literature and a lack of data at the department scale over our study period, we chose not to include other meteorological variables such as humidity, atmospheric pressure, insolation duration, and air pollution in our regression analysis. Furthermore, we did not perform a time series analysis that would have allowed us to study the lag effect, although we examined the cumulative impact of heat based on a validated three-day time frame. Regarding meteorological data, the trend of temperature impact often reaches a plateau around the 99.5th percentile, likely due to the scarcity of extremely hot days in our study period, despite strong heatwaves and temperature records. However, extending the study period would have compromised the quality of data collection on medical records, whose quality strongly improved in a lot of hospital from 2015. It is essential to note that combining visits for psychiatric disorders with those for illnesses strongly influenced by psychiatric disorders could introduce bias in assessing the impact of extreme temperatures on the pathophysiology of psychiatric disorders.. Nevertheless, it is challenging to work on a pathology-by-pathology basis when individuals suffer from chronic illnesses that impact the entire organism. Additionally, psychiatric patients, often highly vulnerable, place psychiatrists at the forefront of medical guidance, necessitating an approach that addresses the individual comprehensively. Furthermore, working with ratios may have led to an underestimation of the incidence of visits for acute psychiatric disorders, given the increase in visits for heat-related diseases The impact for disorders strongly influenced by psychiatric disorders also exists but is comparatively weaker. Lastly, while daily temperatures may not precisely reflect individual temperature exposure (that depends on occupation, housing, air-conditioning, etc.), they still provide a reasonable approximation given the large sample size.

Strengths of the study

This study possesses several notable strengths. Firstly, the sample size is substantial, ensuring the reliability and robustness of the results. Secondly, the study's geographical scale is noteworthy. By analyzing data across various departments throughout the entire metropolitan territory, we were able to precisely aggregate meteorological data with emergency visits and examine the overall impact of high temperatures at a national level, including rural, urban seaside or mainland populations. The utilization of visit rates and the adjustment based on the department's population allowed us to account for the influence of population density and variations in hospital attendance throughout the warm period. We conducted an extensive analysis considering a wide range of temperature thresholds, enabling accurate identification of the onset of heat effects. By focusing our analysis on the warm period and excluding the seasonal impact, we could specifically examine the extreme heat effect by calculating percentiles during this period. Additionally, by selecting reference days within the warm period but not within the study period, we avoided the potential delayed lag effect of heatwave days.

Conclusion

Extreme heat appears to have a significant impact on mental health, particularly on dementia and psychosis. These findings are of significant relevance, considering the context of global warming and the projected rise in heatwave occurrences. They highlight the need to provide guidance for psychiatric practices during extreme hot weather. Further research is essential to gain a more comprehensive understanding of these phenomena, and exploring the impact of other meteorological factors hold promise as a potential avenue for exploration.

Ethical considerations

The work has been carried out in accordance with The Code of Ethics of the World Medical Association.

Conflicts of interest

The authors have no conflict of interest to declare.

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Authors contribution statements: N. CHRISTODOULOU contributed to the submitted work in the conception and design, in the acquisition and analysis of data and by drafting of the article. P. GEOFFROY and K. LAAIDI contributed to the submitted work in the conception and design, in the acquisition and analysis of data and by revising it critically for important intellectual content. G. FIFRE contributed to the acquisition of data and by revisiting the article. M. AMBAR AKAOUI contributed to the analysis of data and by revisiting the article. P. LEJOYEUX contributed by revisiting the article.

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Supplementary materials

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