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Article

Health effects of Wildfires Reported in Emergency Medical Communication Centres: An Ecological Study in Gironde District, France, during the Summer of 2022

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Abstract: Wildfires are a rising environmental threat which health impact remains poorly documented, in particular beyond the fire period. This ecological study investigates changes in health conditions before, during, and after two consecutive wildfires that occurred in France's Gironde district in the summer 2022. Electronic records from the district's emergency medical communication centre were used to identify calls with respiratory and cardiovascular diseases, and two specific subgroups of those, asthma (all ages and 0-5 years) and cardiac arrest, respectively. Compared to before the fires, respiratory disease cases were fewer during each fire (OR = 0.85, 95% CI: 0.79, 0.90 and OR = 0.62, 95% CI: 0.58, 0.67, respectively), cardiovascular disease cases, more common during the second fire, and asthma cases, higher following the fires (OR_{all ages} = 1.85, 95% CI: 1.56, 2.21 and OR_{children} = 3.52, 95% CI: 2.62, 4.80). Asthma cases also rose during the same calendar time in 2021, but to a lesser extent. In sum, except for asthma, emergency calls data in Gironde reveal few significant potentially smoke-related symptoms around fire periods, apart from post-fire asthma. Whether the effects are smoke- or season-related remains to be determined, preferably using additional data sources.

Keywords: wildfires; smoke; air pollution; climate change; asthma; respiratory diseases; emergency medical services

1. Introduction

The World Health Organization (WHO) estimates that 99% of the global population is exposed to high levels of pollutants in the air, including nitrogen oxides, sulfur dioxide, and fine particles like dust and sand (1, 2). Long-term exposure to poor air quality is projected to reduce global life expectancy by an average of eight months, and in heavily polluted areas, by up to two years (3). Air pollution causes the deaths of seven million people annually, with half a million premature deaths occurring just in Europe (2), one of the regions currently most affected by climate change (4). The smoke of wildfire alone, releasing carbon dioxide, carbon monoxide, and particulate matter into the atmosphere, is one significant contributor to air pollution (1). Fine particulate matter (PM_{2.5}) in particular poses the greatest public health risk due to its ability to enter deeply into the lungs (1, 5, 6). As witnessed in recent years, wildfire smoke can travel distances far beyond a wildfire itself and its impact on air quality persists long after it (7, 8).

Wildfires are a threat on the rise globally, not least in Europe. The year 2022 witnessed the second-worst wildfire season in Europe and marked the second-largest recorded burnt area in history

for the region (4, 9). In the summer of that year, smoke emissions from wildfires were estimated at approximately 6.4 megatons of carbon, marking the highest levels in the past 15 years (10). The year 2023 started with yet new alarming signs whereby the continent witnessed numerous winter and spring fires, spanning from southern Ireland to the Balkan region (4, 9). In Europe, population exposure to wildfire smoke is projected to increase from 10 per 1,000 persons exposed, between 1981 and 2010, to a range of 12 to 20 per 1,000 persons during the years 2071-2100 (11). Globally, future projections indicate that the risk of wildfires will rise by 14% in 2030 and by 50% in 2050 as a result of climate change (12).

Between January and September 2022, wildfires in France consumed over 62,000 hectares of land, six times the average annual figure recorded between 2006 and 2021 (10). The Gironde district in southwestern France, which is the focus of this project, was particularly hard-hit, experiencing the most significant forest loss in the country since 1949, and the smoke emissions from these fires are estimated to have released close to one million metric tons of carbon (13, 14). The effect of those fires on the population has not yet been documented.

Several measures can be conceived to characterize wildfires when measuring their health impact, including data from satellite measurements, air pollution monitoring, and the number and duration of wildfires (15). However, few studies have distinguished pollutants from wildfires only from air pollutants that consist of the same components (15), and studies considering what happens beyond the fire period itself are uncommon (16-24) albeit well motivated as highlighted above. Over the years, focus has also been placed on fires that took place in North America (from the US (18-20, 22, 24-30) and Canada (31-33)) and Australia (23, 34-41), in particular ones that took place in California, US (in 2003, 2007, 2008), Victoria, Australia (in 2002-2003 and 2006-2007), and British Columbia, Canada (in 2003). The literature focuses on short-term effects with a few studies on long-term ones and there are limited studies that examine health outcomes from recent wildfire events (8, 11, 21, 26, 42, 43). The evidence accumulated thus far shows that wildfire smoke affects primarily the respiratory system. This is obvious from studies based on emergency visits and hospital admissions (16, 17, 22-25, 27, 44) as well as from those from outpatient data (28, 31). Emergency care is most often sought for conditions like asthma, bronchitis, dyspnea, and chronic obstructive pulmonary disease (8, 20, 24, 29, 30, 34, 45, 46). There is limited and mixed evidence regarding the effect of wildfire smoke on the cardiovascular system (8, 47), with some studies showing no increase in emergency department visits or hospital admissions (30, 31, 35-38), one reporting a protective effect on hospital care seeking for circulatory conditions, including coronary artery disease (19) and yet other ones an excess risk of out-of-hospital cardiac arrest and outpatient cardiovascular visits (20, 39, 40). Groups at risk have been defined as children (e.g., for asthma), the elderly (e.g., for higher rates of mortality and respiratory hospitalizations), and individuals with underlying respiratory and cardiovascular conditions (8, 25, 48).

The mortality of wildfire smoke is not easy to disentangle from that of air pollutants other than wildfire smoke (16). Yet, albeit some studies found increased particulate matter from wildfires to an increase in overall mortality (38, 41, 49, 50), and others on respiratory and cardiovascular mortality (7, 16), one study indicates that the observed mortality rate during wildfires aligns with the increase in mortality from increased air pollution, regardless of the source, making it challenging to ascertain if increased mortality is specifically attributable to wildfire smoke (51).

This study, focused on the wildfire in the Gironde district in 2022, investigates changes in smoke-related health conditions associated with the fires, when they occur, and shortly after. It considers respiratory and cardiovascular diseases, asthma, and cardiac arrest. It also compares the occurrence of those symptoms for similar calendar period the year prior to the fires.

2. Materials and Methods

2.1. Design

We implemented an ecological study design, utilizing a longitudinal approach to analyze medical records, and focusing on the periods before, during, and after the wildfires.

2.2. Setting

This study was conducted in Gironde, the largest district in the Nouvelle-Aquitaine region of southwestern France, with an area of 10,000 square kilometers and a population of 1,623,749 (52). Within the broader Nouvelle-Aquitaine region, which spans approximately one million hectares, forest areas account for 75% of the land, primarily consisting of maritime pine trees (53). Gironde is characterised by an oceanic climate and, in recent years, it has faced exceptionally warm summers with unprecedented high temperatures (54, 55). In 2022, the frequency of fires in the district was higher than during the past 10 years, leading to the highest recorded forest loss in the country since 1949 (14, 56). Two wildfires erupted on July 12th (in the La Teste-de-Buch) and August 10th (Landiras area) and destroyed a total of 27,000 hectares of forest (10, 57). The former fire occurred in a touristic and peri-urban zone, with large campsites, while the latter one primarily affected a rural area dominated by a forested landscape (53). In total, 46,000 individuals were evacuated, including thousands of tourists (58, 59).

The Gironde district has an Emergency Medical Call Centre (EMCC), called the SAMU33 (Service d'Aide Médicale Urgente de la Gironde), which answers medical emergency calls 24/7. Each day, medical assistants, emergency physicians, and general practitioners provide emergency pre-hospital response and care to local inhabitants and tourists (31, 36).

Air quality assessments made during the summer 2022 wildfires revealed alarming levels of suspended particulate matter that surpassed the region's alert threshold (60). In response, local health authorities implemented a series of health recommendations (61), including the use of protective filtering masks, limiting traveling and time spent outdoors, and keeping doors and windows closed (61). At-risk individuals with pre-existing respiratory conditions like asthma, chronic respiratory insufficiency, or other respiratory diseases were recommended to seek medical care in the case of exacerbations of symptoms, and, in the case of severe symptoms, to call SAMU33 for immediate assistance (61).

2.3. Data Source and Outcome Definition

Data were retrieved from the EMCC information system. For all emergency calls received, a clinical report is made by a computerised free-text note and updated by medical staff throughout the telephone interactions concerning the case (62). The clinical report informs about the circumstances of the case and indicates the condition for which the call was made. The coding of conditions was based on a combination of the International Classification of Primary Care, version 2, and the International Classification of Diseases, version 10. The structure of the new dictionary also underwent changes during the period of interest. For these reasons, we utilized the plainly expressed call motifs in relation to each code to proceed with the creation of two groups of conditions of interest for our study: respiratory diseases on one hand, within which we isolated a subcategory for asthma, and cardiovascular diseases on the other hand, within which we isolated a subcategory for cardiac arrests. For each outcome, we considered all ages, and for asthma, also for children aged 0-5 years.

2.4. Data Treatment

In this study, two EMCC datasets were extracted corresponding to the years 2021 and 2022 for the period June 1st and October 31st. Extracted information from these datasets included reported smoke-related health complaints, age, and date (day, month, and year). We grouped the count of calls for each condition by date and then manually coded four time intervals: pre-fire, first wildfire, second wildfire, and post-fire. For asthma, age was dichotomized into two categories: children aged 0-5 years and individuals over the age of 5 years.

2.5. Statistical Analyses

We included in the analyses four main periods: pre-fire, first wildfire, second wildfire, and post-fire, using the pre-fire period as the reference one. The same time periods were used for 2022 (the year of the wildfires) and for 2021 (the previous year) to assess whether the patterns observed in 2022

were unique to this particular year. For each period, we compiled the total and daily average numbers of calls and the proportions of calls.

The strength of the association between time period and condition (all ages or age-specific) was measured using odds ratios (ORs) using the pre-fire period as a comparison and their corresponding 95% confidence intervals (CIs) computed with Fisher test. Data analysis was performed with Python version 3.9.7 using SciPy 1.10.

2.6. Ethical Approval

No personal data were needed for this study and all reporting is at the population level. All reports were de-identified which helped prevent breaches in confidentiality, and all data handling and analysis took place in one of the few physical environments authorised by the local authorities to use the data, in the vicinity of the Bordeaux Population Health Research Centre.

This work adheres to the guidelines outlined in Article 65-2 of the amended French Data Protection Act and the General Regulation on the protection of personal data, ensuring the safeguarding of personal health data and privacy. It was approved by the Bordeaux Teaching Hospital committee for ethics and data protection.

3. Results

A total of 353,576 call reports were included in the analysis. It corresponded to 184,020 and 169,556 call reports which were recorded during the selected time periods in 2021 and 2022, respectively. Table 1 presents the distribution of EMCC calls by health complaint for June to October 2022 and 2021. The table provides descriptive statistics for each health outcome of interest, including the total number of health complaint calls and the proportion of calls during each time period.

In 2022, 15,709 call reports were related to respiratory and cardiovascular diseases, asthma, and cardiac arrest (9.3%). Of the total call records, 48,245 (28.5%) calls occurred before the fires, 33,452 (19.7%) during the first fire, 38,142 (22.5%) in the second fire, and 49,717 (29.3%) following the fires. The proportion of calls related to respiratory and cardiovascular diseases, asthma, and cardiac arrest represented 9.6% of calls in the pre-fire period, 8.8% and 8.2% during each of the fires, respectively, and 10.1% in the post-fire period (Table 2). For pediatric asthma, a total of 331 call records were scrutinized, of which 58 (0.1%) calls occurred pre-fire, 26 (0.08%) during the first fire, 37 (0.1%) in the second fire, and 210 (0.4%) post-fire.

We recorded fewer calls related to respiratory diseases during the fires than before, while the number of calls for asthma remained comparable. Following the fires, the proportion of calls for respiratory diseases continued to be lower, while that of calls for asthma slightly rose (0.4%). For cardiovascular diseases, including cardiac arrest, the proportion of calls remained consistent during the first fire and was slightly higher in the second fire and after the fires, compared to the pre-fire period. In 2021, the number of calls related to respiratory diseases was consistently higher throughout similar calendar periods when compared to the pre-fire period in 2022. For asthma and cardiovascular diseases, including cardiac arrest, a similar pattern to the year of the fires persisted.

Table 1. Distribution of the EMCC calls by health complaint and periods before, during, and after the wildfires in 2022 and during these time periods in 2021.

EMCC Calls	Pre-Fire Period		Fire Period I		Fire Period II		Post-fire Period	
	1/6 - 11/7		12/7 - 9/8		10/8 - 15/9		16/9 - 31/10	
	n	%	n	%	n	%	n	%

2022

Respiratory diseases	2,457	5.1	1,453	4.3	1,233	3.2	2,413	4.9
<i>Asthma all ages (0-5 yrs)</i>	197 (58)	0.4 (0.1)	127 (26)	0.4 (0.08)	148 (37)	0.4 (0.1)	375 (210)	0.8 (0.4)
Cardiovascular diseases	1,684	3.5	1,141	3.4	1,478	3.9	1,833	3.7
<i>Cardiac arrests</i>	309	0.6	214	0.6	268	0.7	368	0.7
Other	43,598	90.4	30,517	91.2	35,015	91.8	44,728	89.9
Total	48,245	100.0	33,452	100.0	38,142	100.0	49,717	100.0
2021								
Respiratory diseases	1,484	3.0	1,599	4.2	1,675	3.8	2,069	3.9
<i>Asthma all ages (0-5 yrs)</i>	208 (98)	0.4 (0.2)	180 (50)	0.5 (0.1)	158 (43)	0.4 (0.1)	372 (165)	0.7 (0.3)
Cardiovascular diseases	1,814	3.7	1,401	3.7	1,820	4.2	2,015	3.8
<i>Cardiac arrests</i>	159	0.3	125	0.3	156	0.4	289	0.5
Other	45,860	92.6	34,562	91.3	39,619	91.2	48,455	91.1
Total	49,525	100.0	37,867	100.0	43,428	100.0	53,200	100.0

3.1. Outcome-Specific Associations between Time Periods in 2022 and 2021

Figure 1 presents the outcome-specific associations between the number of calls and fire-related periods in 2022 and 2021, respectively, measured using ORs with their corresponding 95% CIs.

During the year of the fires, there were a 15% and 38% lower number of cases of respiratory diseases during the first fire period (OR = 0.85, 95% CI: 0.79-0.90) and the second one (OR = 0.62, 95% CI: 0.58, 0.67) when compared to the period before the fires, an 11% higher number of cardiovascular cases during the second fire (OR = 1.11, 95% CI: 1.04, 1.20), and an 85% higher number of asthma cases post-fire, all ages aggregated (OR = 1.85, 95% CI: 1.56, 2.21) (Figure 1). For pediatric asthma, children faced significantly higher odds of asthma compared to all ages aggregated after the fires, with more than triple the odds (OR = 3.52, 95% CI: 2.62, 4.80) compared to the pre-fire period.

In 2021, the main difference compared to the year of the fires was the significantly higher number of respiratory disease cases observed across the time periods. Specifically, compared to the reference period, there were 43% and 30% higher numbers of respiratory disease cases during what corresponds to the first fire period in 2022 (OR = 1.43, 95% CI: 1.33, 1.53) and the second one (OR = 1.30, 95% CI: 1.21, 1.40), as well as a 31% higher number of cases in the fall (OR 1.31, 95% CI: 1.22, 1.40). For pediatric asthma, children faced a 57% higher number of cases in the fall (OR = 1.57, 95% CI: 1.21, 2.04), and there was a significantly lower number of asthma cases during the summer of 2021, which was not observed during the year of the fires.

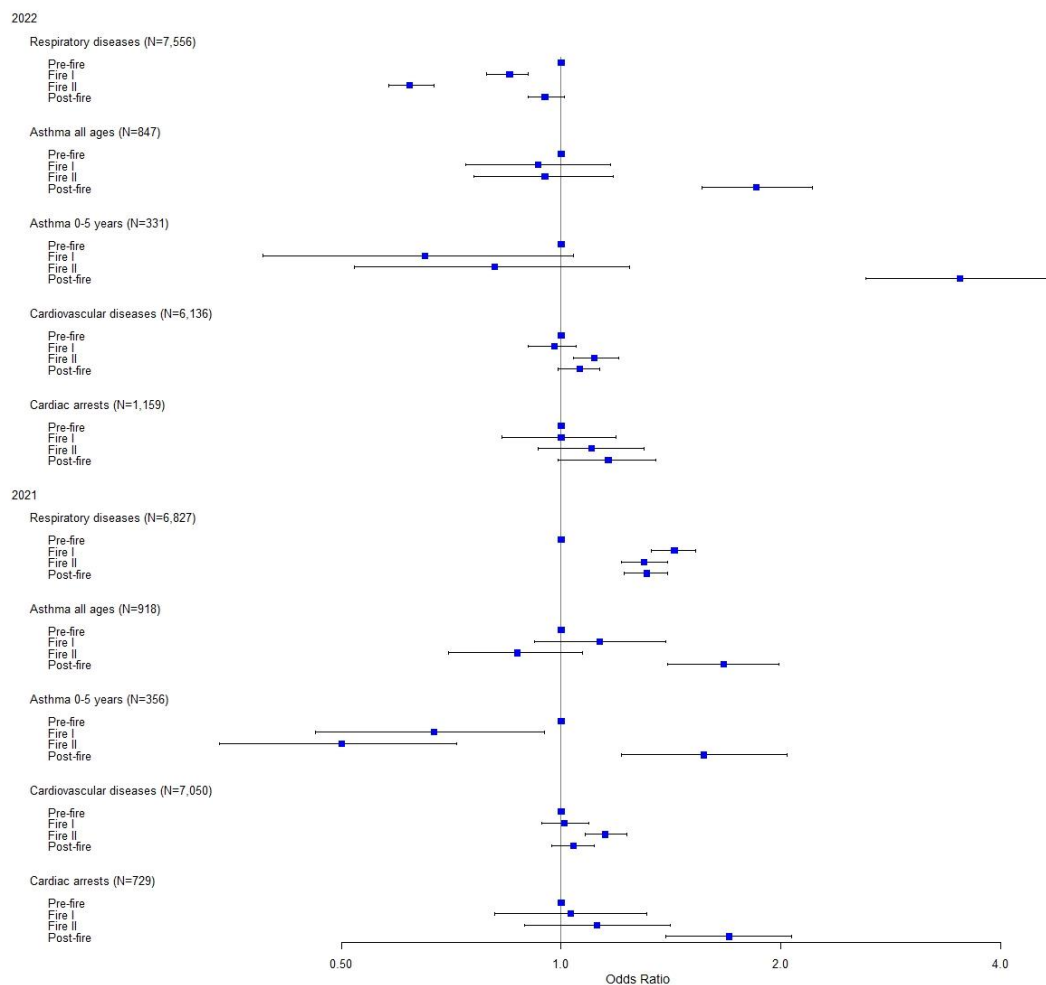


Figure 1. Outcome-specific associations between periods during and after the wildfires with the pre-fire period as the reference, in 2022 and 2021.

4. Discussion

4.1. Main Findings

In this study, we paid attention to two smoke-related sets of symptoms, pertaining in turn to respiratory conditions, far more reported in the literature at hand, and cardiovascular conditions. We found that, when comparing fire and post-fire periods with the pre-fire one, the number of EMCC calls does not change remarkably as regards respiratory and cardiovascular diseases in general and asthma and cardiac arrest in particular. There are however a few exceptions, including lower numbers of calls for respiratory symptoms during each active fire period (15% and 38% respectively), an 11% higher number of calls for cardiovascular symptoms during the second fire, and an 85% higher number of asthma cases in the post-fire period all ages aggregated (85% increase) and for children (an odds that tripled). Compared to the previous year, the single most noteworthy difference was the excess number of asthma-related cases post-fires.

As opposed to our study, significant excess risks of respiratory diseases were observed during at least three previous wildfires that took place about 15-20 years ago, including two in California, in 2003 (20, 24) and in 2007 (22, 30), and one in Victoria (Australia) in 2002-2003 (23). In addition, asthma cases stood out as the most prevalent respiratory condition in excess during the fires in California

(20, 22, 24, 30) and in another one in North Carolina in 2008 (29), let alone in the pediatric populations (25, 63). In fact, considering a time window of a five-day exposure period pertaining to the fires in California in 2007, emergency department visits for asthma increased by 112% all ages aggregated but as much as by 243% among children aged 0-1 years and by 136% among those aged 0-4 years (25). Similar to our study, consideration of the post-fire period in California (in 2003) revealed that the increase in respiratory outcomes, not least asthma, was greater post than during the fire (20).

When it comes to cardiovascular diseases, the literature at hand remains scarce and also relatively dated. Similar to our study, the 2003 California fire revealed a slight rise in admission rates for overall cardiovascular outcomes during and after the fires (4.4% and 6.1%, respectively) (20). For cardiac arrest in particular, two Australian studies from fires in Victoria in 2006-2007 found elevated numbers of out-of-hospital cardiac arrests during both a 12-day exposure period (23.9%), a rise that was attributed to increased PM_{2.5} emissions (39), and a 2-day exposure period (7.0%) (40). For their part, investigations of other fires did not reveal any increase in hospital admissions or emergency department visits for cardiovascular outcomes in Australia during fire seasons in Darwin (in 1996-2005, 2000, 2004, and 2005), Sydney (in 1994-2007 and 2001), Newcastle and Wollongong (in 1994-2007) (35-38), British Columbia (Canada) in 2003 (31), and California (the US) in 2007 (30).

4.2. Strengths and Limitations

This study is the first one investigating the health effects of the 2022 Gironde fires. Based on data from the EMCC, which ensures full population coverage and is an integral part of the healthcare system while operating on well-established routines and protocols for coordinating emergency medical services, the study provides a comprehensive picture of reported health complaints at the population level. The inclusion of a post-fire period in the design enhanced our ability to detect health effects that may arise in the aftermath of wildfires or over a longer term, which has received less attention in current studies.

Compared to on-site clinical diagnoses, the use of emergency call data most likely decreases the level of certainty and imprecise categorisation and classification of health symptoms may occur as information about each case is collected over the phone. Further, observed associations may be underestimated as individuals with smoke-sensitivity symptoms may seek care from a general practitioner, potentially resulting in missing cases of interest. Additional methodological limitations pertain to the absence of robust methods to quantify smoke exposure during and after the fires, and the use of smoke exposure measures could potentially have provided more precise health effects of exposure to poor air quality caused by wildfires. As our focus was on over-the-phone emergency assistance data, our results do not lend themselves well to total morbidity and mortality assessments. Earlier studies show an association between wildfires and increased risk of mortality (7), attributable supposedly to air pollution during a fire. We also present the effect of the fire on the population that resides in the Gironde district itself, not in neighbouring municipalities, which may also underestimate some of the potential effects of the fires, during and after. Further, given that many factors come into play to determine the magnitude and nature of the impact of a fire on health (15), the results of this study may also be specific to the situation that prevailed in place and time, i.e., the Gironde district in 2022. Indeed attributes of the fire itself (e.g., size, intensity, and duration), and those of the environment may, in combination play a role in the level of exposure.

4.3. Implications for Research and Practice

The few significant differences in the outcome-specific number of calls observed during the fires in this study may be explained by implemented wildfire prevention and management strategies, such as the evacuation of populations in affected areas, staying indoors, keeping doors and windows closed, and wearing protective face masks. These practices are particularly important from a public health perspective and highlight the need for continued efforts to develop and implement effective interventions to mitigate potential health effects during wildfires. Further, combining multiple data sources, such as emergency call data, hospital visits, and admissions, could provide a more complete understanding of the impact of wildfire smoke exposure on health.

It is also of note to investigate the impact of elevated particulate matter resulting from wildfires on mortality, something that could not be investigated using the emergency data at hand. Several studies on mortality have found different associations with fires from different parts of the world. In Sydney, Australia, smoke events between the years 1994-2007 were associated with a 5% increase in non-accidental mortality and a 10% increase in cardiovascular mortality (41). Further, during two major fire events in 1994 and 2001, also in Sydney, wildfire air pollution was associated with a small increase in all-cause mortality but no associations were found with cardiovascular or respiratory mortality (38). A study on different European regions in 2005 and 2008 revealed that exposure to PM_{2.5} from wildfires caused tens of hundred of premature deaths with the highest impacts in southern and eastern Europe (49). In Southeast Asia, increases in particulate matter from fires in 1997 were associated with a relative risk of 1.07 in total mortality (50). In contrast to these findings, a study investigating population exposure to smoke from East European fires in Finland in 2002 found no significant associations in daily all cause-mortality (51).

Wildfire smoke exposures are becoming increasingly acknowledged as a significant public health concern and have been a long-standing issue in public policy (16). Numerous challenges need to be addressed to fully comprehend the impact of wildfire smoke on human health, including comprehensive exposure assessments to assess potential increases in morbidity and mortality during wildfire smoke exposure (16). Enhancing health outcomes at the population level during and after wildfire events is a crucial priority and could identify valuable implemented prevention practices that effectively address health concerns, while also shedding light on critical areas for improvement (16, 21). The level of exposure, depending on the unique characteristics of each fire, should be taken into consideration both in surrounding areas and at a regional scale (64).

The findings of this study make a useful contribution to understanding the variation in emergency call volume and characteristics before, during, and shortly after wildfires and the use of emergency call data could serve as a sensitive outcome indicator to reflect certain acute health effects.

5. Conclusions

This study highlights that the number of emergency calls for smoke-related symptoms appears to vary by time period, with different symptoms exhibiting varying risks during and following the two executive fires in 2022. Noteworthy, a higher number of asthma cases was found after the fires, with the highest increase observed in pediatric cases, compared to the period before the fires. Comparable associations in the number of emergency calls for the same smoke-related symptoms were identified across the calendar periods in 2022 and 2021. Whether the effects are smoke- or seasonal-related remains to be determined. Thus, further research is warranted to better understand these findings.

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