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Impact of climate events on emergency departments

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Sustainable emergency care in a changing climate –
assessing impact and implementing adaptation strategies





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Impact of climate events on emergency departments

There is expected to be an increase in the frequency of natural disasters and extreme weather events, which will likely further strain the healthcare system, including emergency departments (EDs). Data analysis was undertaken to assess the impact of several recent climate events on ED presentations in New South Wales (NSW).

Heatwaves

- ▶ January 2019 is the hottest month on record in NSW with the mean daily temperature 5.9°C above average.
- ▶ During the heatwave, there was an increase in the diagnosis of heatstroke-related conditions by 133 per cent and dehydration by 63 per cent in NSW EDs.

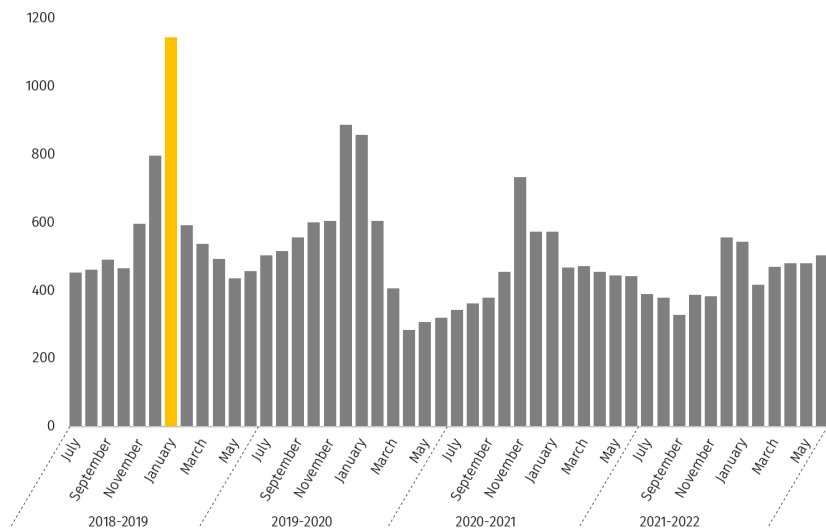


Figure. The number of heatstroke-related and dehydration diagnoses in NSW EDs per month from July 2018 to June 2022. The orange column in January 2019.

Bushfires

- ▶ The Black Summer bushfires resulted in the direct deaths of 33 people, with an estimated 430 dying due to smoke inhalation.
- ▶ All-cause respiratory conditions were increased by 25%, which equated to ~15,000 additional presentations across NSW EDs.
- ▶ Asthma and chronic obstructive pulmonary disease were increased by 42% and 40%, respectively.

Storms and floods

- ▶ In early 2022, northeast NSW experienced its wettest period since 1900, resulting in devastating flooding.
- ▶ ED presentations were increased by 10 per cent in flood affected areas.

ED clinician experiences during flooding from the *YourED* article 'As the Floodwaters Rise'

"Initially the community was relying on the ED for more than medical care. People needed somewhere dry and warm."

"Power and all EMR shutdown so we were on generator power, tracking patients on whiteboards, writing paper notes and paper ordering investigations..."

"The department faced a surge of presentations, staggering to comprehend"

Summary

Health services and EDs must ensure they have adequate disaster preparedness plans and resource allocation in place to handle the demand of future climate events.

1. Introduction	2
2. Heatwaves	2
2.1 Impact of heatwaves on total emergency department presentations.....	2
2.2 Impact of heatwaves on direct and indirect heat-related diagnosis	3
2.3 Impact of heatwaves by remoteness	4
2.4 Impact of heatwaves by sex.....	6
2.5 Impact of heatwaves by age	7
2.6 Impact of heatwaves compared to other jurisdictions in Australia.....	7
2.7 Summary of the impact of heatwaves on emergency department presentations.....	8
3. Bushfires	8
3.1 Impact of the Black Summer bushfires on emergency department presentations.....	9
3.2 Impact of other bushfire seasons on emergency department presentations.....	10
3.3 Summary of the impact of bushfires on emergency departments	11
4. Storms and floods	11
4.1 Impact of storms and floods on emergency department presentations	11
4.2 Summary of the impact of storms and floods on emergency departments	12
5. Impact of climate events on emergency department operations and delivery of services	12
6. References	13

1. Introduction

Emergency departments (EDs) around Australia are often busy and regularly experience overcrowding which causes delays in treatment, increased length of stays and staff burnout (Australasian College for Emergency Medicine (ACEM) 2022). This is expected to worsen due to system-wide issues including an increase in the elderly population, a reduction in the utilisation of primary health care services, an increase in the acuity of presentations, and a worsening of access block (Dinh, Bein et al. 2015, Morley, Unwin et al. 2018). To add further pressure to an already stretched system, there is expected to be an increase in natural disasters and extreme weather events (CSIRO and The Bureau of Meteorology 2022). Many of these natural disasters may lead to an increase in ED presentations and impact the normal operations of EDs (access, supply chains, utilities) (Ghazali, Guericolas et al. 2018, Xu, Yu et al. 2023, Humphrey 2024).

The Australasian College For Emergency Medicine (ACEM) has partnered with the New South Wales (NSW) Environment Protection Authority to assess the impact of climate-related events on NSW EDs and understand the sustainability practices being implemented in EDs and hospitals. This report presents the findings of part 1 of the project, which examines the impact of climate events on EDs in NSW. The report examines relevant published literature and undertakes an analysis of ED presentations in NSW EDs, focusing on the impact of heatwaves, bushfires, and floods.

The major climate events analysed in this report include the January 2019 heatwave, the Black Summer bushfire season of 2019-2020 and the February/March floods in 2022. Presentation demographics, case mix and performance were analysed using the Australian Institute of Health and Welfare (AIHW) National Non-admitted Patient Emergency Department Care Database (NNAPEDCD). We analysed the number and rate (per 5,000 presentations) of ED presentations by relevant direct and indirect diagnoses and the percentage difference in the rate of presentations compared to equivalent times in other years. Diagnoses were classified using the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification (ICD-10-AM). The ICD-10-AM diagnosis codes included in our analysis of direct heat-related presentations during heatwaves were heatstroke and related conditions (T67) and dehydration (E86). A number of diagnoses codes were used for the analysis of both heatwaves and bushfires; we analysed respiratory conditions (J00-J99) and sub-groups asthma (J45-J46) and chronic obstructive pulmonary diseases (COPD) (J44 and J47), mental health conditions (F00-F99), circulatory conditions (I00-I99) and subgroups ischaemic heart disease (I20-I25) and heart failure (I50), renal conditions (N00-N39), and endocrine conditions (E00-E90).

2. Heatwaves

Extreme heat is the leading cause of climate-related morbidity and mortality in NSW and around Australia (Health and Welfare 2023). Heatwaves are expected to become more frequent and intense and last for a longer duration in the coming years (Steffen, Hughes and Perkins 2014). The primary direct health implications of extreme heat include heatstroke-related diagnoses and dehydration. Vulnerable members of the community including the elderly and those with co-morbidities are at a further risk of secondary complications (Wu, Hutton et al. 2023).

The analysis of extreme heat focuses on January 2019, the hottest month on record (to date) in NSW and around Australia. In NSW, the mean daily temperature was 5.9°C above average (more than 2°C hotter than the previous hottest month) and the mean maximum and minimum temperatures were 6.2°C and 5.6°C above average, respectively (Bureau of Meteorology 2024). Our analysis compared ED presentations in January 2019 to January of the subsequent years (2020, 2021, and 2022). We analysed direct and indirect heat-related diagnoses, with subgroup analysis by the remoteness of EDs, age, gender, and comparisons to other jurisdictions in Australia.

2.1 Impact of heatwaves on total emergency department presentations

A recently published scoping review found an increase in the risk of ED presentations during heatwaves in 18 of 23 studies (Wu, Hutton et al. 2023). A systematic review of studies based in Australia also found that heatwaves increased total ED presentations (Mason, C King et al. 2022). Two studies included in this review were from NSW, one of these studies analysed the impact of extreme heat on ED presentations from 2005 – 2015 and reported that intense heatwaves increased total ED presentations by up to 4% (Jegasothy, McGuire et al. 2017). Another study analysing the impact of a 2011 heatwave on the central NSW coast reported that ED presentations increased by 2% (Schaffer, Muscatello et al. 2012).

In January 2019, 262,730 presentations were recorded by 173 public EDs across NSW, 1.9% more than the average of total ED presentations in January 2020-2022 (Table 1).

Table 1. The number and rate of ED presentations in NSW between January 2019 and 2022.

Year Mean temperature ranking (Anomaly)	Jan 2019 110/110 (+5.9°C)		Jan 2020 107/111 (+3.4°C)		Jan 2021 64/112 (+0.25°C)		Jan 2022 89/113 (+1.5°C)	
Total number of presentations (n)	262,730		262,877		259,859		250,678	
Diagnosis	Number	Rate	Number	Rate	Number	Rate	Number	Rate
Heatstroke-related conditions	184	3.5	130	2.5	55	1.1	46	0.9
Dehydration	960	18.3	726	13.8	517	9.9	496	9.9
Circulatory conditions	8,448	160.8	8,875	168.8	8,394	180.8	7,084	141.3
Respiratory conditions	14,675	279.3	16,554	314.9	12,470	239.9	10,080	201.1
Endocrine conditions	2,780	52.9	2,549	48.5	2,295	44.2	2,108	42.0
Renal conditions	10,677	203.2	10,919	207.7	11,005	211.7	9,809	195.6
Mental health conditions	11,502	218.9	11,346	215.8	10,927	210.2	8,945	178.4

Mean temperature ranking is the rank of the average monthly temperature since records began and the anomaly is the departure from the long-term mean (1961-1990) (Bureau of Meteorology 2024). The rate is per 5,000 ED presentations.

2.2 Impact of heatwaves on direct and indirect heat-related diagnosis

A study analysing the impact of a 2011 heatwave in NSW reported that the number of people with direct heat-related diagnoses (heatstroke-related conditions and dehydration) presenting to EDs increased by 670% and 191%, respectively, over the 8 days of the heatwave compared to the same period in previous years (Schaffer, Muscatello et al. 2012). A study analysing emergency hospital admissions, not ED presentations, in NSW from 1998 to 2006 reported an increase in heatstroke-related diagnoses by up to 590% and dehydration diagnoses by up to 220% (Khalaj, Lloyd et al. 2010). Our analysis identified that the rate of ED presentations for heatstroke-related conditions was 40% to 288.9% (an average of 133.3%) higher in January 2019 than in January 2020-2022. Diagnoses of dehydration were 32.6% to 84.8% (an average of 63.4%) higher in January 2019 compared to the same month in the subsequent years (Figure 1 and Table 1).

In addition to the direct heat-related diagnoses, heatwaves may have contributed to the diagnoses of other conditions in people with underlying co-morbidities. A study (Khalaj, Lloyd et al. 2010) investigated emergency hospital admissions in NSW and found that mental health diagnoses were the only indirect heat-related condition classified as the primary diagnosis to be increased (by 7%) during prolonged heatwaves. Our analysis identified that diagnosis rates of several indirect heat-related conditions were higher in January 2019 compared to January 2020-2022. For instance, diagnoses of endocrine conditions were 9.1% to 26.0% (an average of 17.8%) higher, while respiratory conditions were up to 38.9% (an average of 10.5%) higher and mental health diagnoses were 1.4% to 22.7% (an average of 8.5%) higher in January 2019 compared to subsequent years. Diagnoses of circulatory (an average of 2.2%) and renal (an average of 1.0%) conditions were minimally impacted in January 2019 compared to the subsequent years (Table 1). It is important to note that confounding factors may have influenced the number of secondary diagnoses recorded in our analysis including other climate events that were occurring at the time (bushfires) and COVID-19.

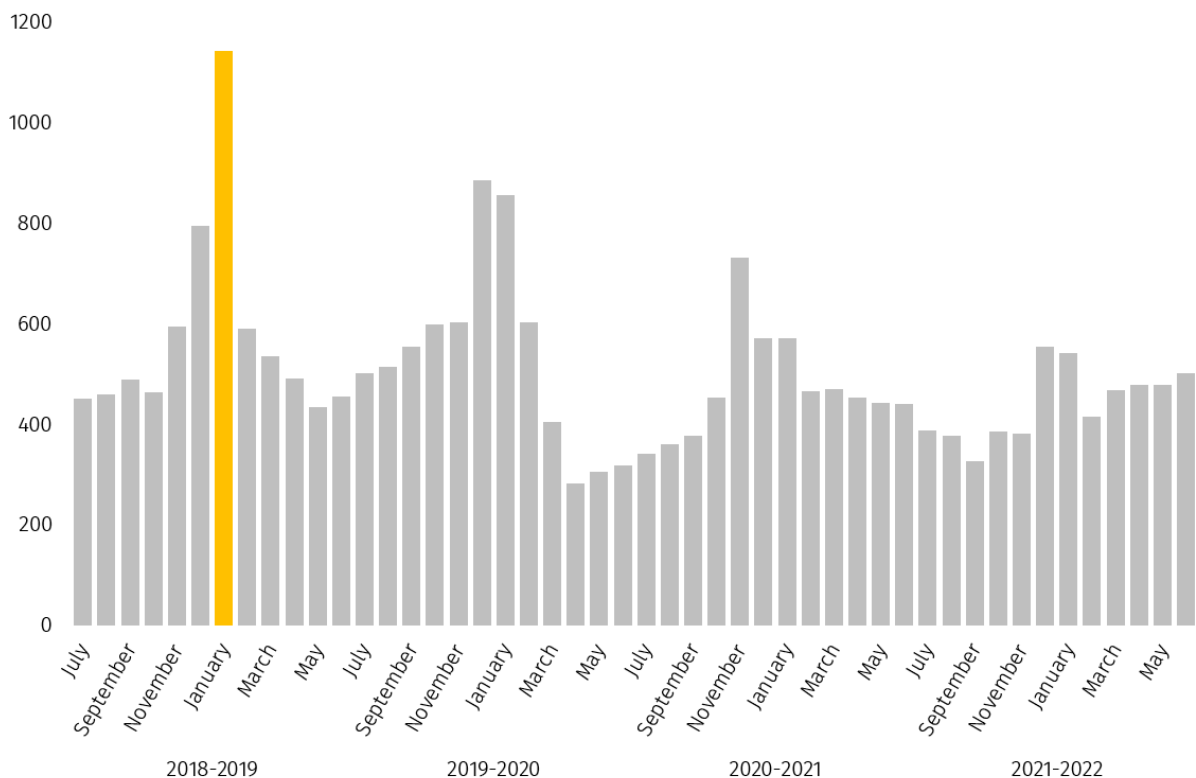


Figure 1. Number of direct heat-related (heatstroke-related and dehydration diagnoses) ED presentations in NSW per month from July 2018 to June 2022. The orange column is January 2019.

2.3 Impact of heatwaves by remoteness

Limited research has analysed the impact of heatwaves on presentations in NSW by the remoteness of the ED. Only one known study has reported on this and found that total ED presentations were more likely to be increased in regional and remote EDs than metropolitan EDs during intense and very intense heatwaves (Jegasothy, McGuire et al. 2017). Our analysis of the extreme heat during January 2019 found that total ED presentations were 1%-2% higher across all remoteness areas compared to January in the subsequent years (2020-2022).

Diagnoses of direct heat-related conditions were higher in January 2019 than in the following years across all remoteness areas, with non-metropolitan EDs experiencing more significant increases than metropolitan EDs. For instance, in regional EDs, the rate of heatstroke-related conditions was 46.7% to 388.9% (an average of 175.0%) higher in January 2019 than in January 2020 – 2022. Whereas in metropolitan EDs diagnoses of heatstroke-related conditions were 31.8% to 262.5% (an average of 107.1%) higher in January 2019 than in subsequent years (Table 2).

Remote EDs were most likely to experience increases in diagnoses of indirect heat-related conditions in January 2019. In particular, the diagnosis rate of circulatory conditions was 2.3% to 138.3% (an average of 55.0%) higher and the diagnosis rate of endocrine conditions was 5.0% to 179.1% (an average of 70.2%) higher in January 2019 compared to the subsequent years (Table 2). However, it is important to consider that the small sample size of presentations to remote EDs may reduce the reliability of the results.

Table 2. The number and rate of ED presentations by ED remoteness in NSW between January 2019 and 2022.

Year Mean temperature ranking (Anomaly)	Jan 2019 110/110 (+5.9°C)		Jan 2020 107/111 (+3.4°C)		Jan 2021 64/112 (+0.25°C)		Jan 2022 89/113 (+1.5°C)	
	Number	Rate	Number	Rate	Number	Rate	Number	Rate
Diagnosis + remoteness								
Total presentations								
<i>Metropolitan</i>	164,660		167,254		158,446		158,117	
<i>Regional</i>	95,567		93,152		98,983		90,049	
<i>Remote</i>	2,503		2,471		2,430		2,512	
Heatstroke-related conditions								
<i>Metropolitan</i>	96	2.9	72	2.2	38	1.2	24	0.8
<i>Regional</i>	84	4.4	56	3.0	17	0.9	18	1.0
<i>Remote</i>	<5	8.0	<5	4.0	<5	N/A	<5	8.0
Dehydration								
<i>Metropolitan</i>	463	14.1	357	10.7	250	7.9	250	7.9
<i>Regional</i>	468	24.5	344	18.5	254	12.8	239	13.3
<i>Remote</i>	29	57.9	25	50.6	13	26.7	7	13.9
Circulatory conditions								
<i>Metropolitan</i>	5,475	166.3	5,894	176.2	5,483	173.0	4,658	147.3
<i>Regional</i>	2,916	152.6	2,926	157.1	2,881	145.5	2,402	133.4
<i>Remote</i>	57	113.9	55	111.3	30	61.7	24	47.8
Respiratory conditions								
<i>Metropolitan</i>	9,366	284.4	10,403	311.0	7,174	226.4	5,850	185.0
<i>Regional</i>	5,200	272.1	6,025	323.4	5,189	262.1	4,134	229.5
<i>Remote</i>	109	217.7	126	255.0	107	220.2	96	191.1
Endocrine conditions								
<i>Metropolitan</i>	1,676	50.9	1,623	48.5	1,440	45.4	1,339	42.3
<i>Regional</i>	1,054	55.1	879	47.2	833	42.1	751	41.7
<i>Remote</i>	50	99.9	47	95.1	22	45.3	18	35.8
Renal conditions								
<i>Metropolitan</i>	4,393	133.4	4,566	136.5	4,131	130.4	3,820	120.8
<i>Regional</i>	2,691	140.8	2,731	146.6	2,880	145.5	2,628	145.9
<i>Remote</i>	57	113.9	40	80.9	42	86.4	49	97.5
Mental health conditions								
<i>Metropolitan</i>	7,301	221.7	7,360	220.0	7,593	239.6	6,146	194.3
<i>Regional</i>	4,092	214.1	3,895	209.1	3,239	163.6	2,731	151.6
<i>Remote</i>	109	217.7	91	184.1	95	195.5	68	135.4

Mean temperature ranking is the rank of the average monthly temperature since records began and the anomaly is the departure from the long-term mean (1961-1990) (Bureau of Meteorology 2024). Where the number of presentations is less than 5 it is reported as <5. The rate is per 5,000 ED presentations.

2.4 Impact of heatwaves by sex

A recent systematic review analysed the impact of heatwaves on health service usage in Australia, including ED presentations, and reported no differences between males and females (Mason, C King et al. 2022). Conflictingly, a scoping review reported that males were at a higher risk of presenting to EDs during extreme heat than females. In a NSW context, males over 75 years of age were at an increased risk of emergency hospital admission for heatstroke-related conditions, but ED presentations were not examined in the study (Khalaj, Lloyd et al. 2010).

Our analysis of direct heat-related ED presentations demonstrated that males were more likely than females to present to the ED in January 2019 than in the same month of 2020-2022. The rate of heatstroke-related diagnoses was 57.1% to 388.9% (an average of 158.8%) higher in males while only 23.8% to 188.9% (an average of 100%) higher in females. Diagnoses of dehydration were 33.8% to 95.9% (an average of 68.1%) higher in males and 30.6% to 75.0% (an average of 56.3%) higher in females. Mental health conditions were the only indirect heat-related diagnosis that differed to a larger degree between males and females. The rate of mental health diagnoses was 2.5% to 32.0% (an average of 14.0%) higher in males and up to 13.2% (an average of 2.4%) higher in females in January 2019 compared to the subsequent years (Table 3). Overall, the data suggests that males may be at a slightly increased risk of presenting to an ED during a heatwave compared to females, but further research is needed.

Table 3. The number and rate of ED presentations by patient sex in NSW between January 2019 and 2022.

Year Mean temperature ranking (Anomaly)	Jan 2019 110/110 (+5.9°C)		Jan 2020 107/111 (+3.4°C)		Jan 2021 64/112 (+0.25°C)		Jan 2022 89/113 (+1.5°C)	
Diagnosis + sex	Number	Rate	Number	Rate	Number	Rate	Number	Rate
Total presentations								
<i>Male</i>	132,783		132,627		129,808		124,702	
<i>Female</i>	129,926		130,221		130,006		125,935	
Heatstroke-related conditions								
<i>Male</i>	117	4.4	75	2.8	32	1.2	23	0.9
<i>Female</i>	67	2.6	55	2.1	23	0.9	23	0.9
Dehydration								
<i>Male</i>	504	19.0	376	14.2	253	9.7	244	9.8
<i>Female</i>	456	17.5	350	13.4	264	10.2	252	10.0
Circulatory conditions								
<i>Male</i>	4,465	168.1	4,841	182.5	4,511	173.8	3,929	157.5
<i>Female</i>	3,982	153.2	4,034	154.9	3,882	149.3	3,154	125.2
Respiratory conditions								
<i>Male</i>	7,650	288.1	8,174	308.2	6,369	245.3	5,198	208.4
<i>Female</i>	7,025	270.3	8,379	321.7	6,100	234.6	4,881	193.8
Endocrine conditions								
<i>Male</i>	1,380	52.0	1,251	47.2	1,142	44.0	1,030	41.3
<i>Female</i>	1,400	53.9	1,298	49.8	1,153	44.3	1,078	42.8
Renal conditions								
<i>Male</i>	2,913	109.7	2,958	111.5	2,698	103.9	2,573	103.2
<i>Female</i>	4,228	162.7	4,379	168.1	4,354	167.5	3,924	155.8
Mental health conditions								
<i>Male</i>	6,297	237.1	6,135	231.3	5,482	209.1	4,480	179.6
<i>Female</i>	5,199	200.1	5,204	199.8	5,440	209.2	4,454	176.8

Mean temperature ranking is the rank of the average monthly temperature since records began and the anomaly is the departure from the long-term mean (1961-1990) (Bureau of Meteorology 2024). The rate is per 5,000 ED presentations.

2.5 Impact of heatwaves by age

It is well-accepted that older people are at an increased risk of adverse health outcomes and mortality as a result of heatwaves due to physiological, pathological, and social factors (Cheng, Xu et al. 2018). All-cause ED presentations for this cohort have also shown to be increased due to heatwaves (Mason, C King et al. 2022, Wu, Hutton et al. 2023). In NSW, a 2011 heatwave increased the risk of all-cause ED presentations in those aged 75+ years by 8%, while increasing the risk of presentations of those aged less than 75 years by 1% (Schaffer, Muscatello et al. 2012). Interestingly, our analysis of ED presentations found no major differences in all-cause ED presentations in those aged 65+ (1.5% higher) when comparing January 2019 to January 2020 – 2022.

A study analysing extreme heat events in NSW reported an increased risk of emergency hospital admissions in older patients with diagnoses of heatstroke, cerebrovascular, and cancer conditions (Khalaj, Lloyd et al. 2010). Another study analysing several heatwaves in Adelaide reported mixed results when reporting on the risk of ED presentations of various diagnoses and age groups (Nitschke, Tucker et al. 2011). Our analysis shows that the rate of heatstroke-related and dehydration diagnoses was higher in all age groups in January 2019 compared to the subsequent years, with the rate of those aged 65+ not increasing more than the other age groups (Table 4). There were no major differences between age groups in the rate of non-heat-related diagnoses between January 2019 and subsequent years (data not shown). Further research is needed to examine if older adults are at an increased risk of ED presentations during heatwaves, particularly the age at which older adults are at an increased risk.

Table 4. The number and rate of ED presentations by patient age group in NSW between January 2019 and 2022.

Year Mean temperature ranking (Anomaly)	Jan 2019 110/110 (+5.9°C)		Jan 2020 107/111 (+3.4°C)		Jan 2021 64/112 (+0.25°C)		Jan 2022 89/113 (+1.5°C)	
Diagnosis + age	Number	Rate	Number	Rate	Number	Rate	Number	Rate
Total presentations								
0-14	47,335		46,365		45,101		41,064	
15-64	153,636		152,709		153,439		152,161	
65+	61,750		63,789		61,304		57,442	
Heatstroke-related conditions								
0-14	15	1.6	6	0.6	8	0.9	6	0.7
15-64	116	3.8	71	2.3	34	1.1	28	0.9
65+	53	4.3	53	4.2	13	1.1	12	1.0
Dehydration								
0-14	108	11.4	89	9.6	83	9.2	94	11.4
15-64	435	14.7	338	11.1	215	7.0	212	7.0
65+	417	33.8	299	23.4	219	17.9	190	16.5

Mean temperature ranking is the rank of the average monthly temperature since records began and the anomaly is the departure from the long-term mean (1961-1990) (Bureau of Meteorology 2024). The rate is per 5,000 ED presentations.

2.6 Impact of heatwaves compared to other jurisdictions in Australia

A number of studies have examined the impact of heatwaves on ED presentations in jurisdictions outside of NSW, most (Williams, Nitschke et al. 2012, Lindstrom, Nagalingam and Newnham 2013, Campbell, Remenyi et al. 2019, Wondmagegn, Xiang et al. 2021) but not all (Adams, Brumby et al. 2022) have shown that total presentations increased during periods of extreme heat. While a study in South Australia reported an increase in total ED presentations during a 2008 heatwave, but not during a 2009 heatwave (Nitschke, Tucker et al. 2011).

In general, nearly all studies in Australia report that direct heat-related diagnoses such as heatstroke and dehydration were increased during periods of extreme heat (Nitschke, Tucker et al. 2011, Williams, Nitschke et al. 2012, Toloo, Yu et al. 2014, Campbell, Remenyi et al. 2019, Wondmagegn, Xiang et al. 2021). In contrast, the reported impact of heatwaves on indirect diagnoses of cardiovascular, renal, respiratory, and mental health diseases was variable (Nitschke, Tucker and Bi 2007, Williams, Nitschke et al. 2012, Williams, Nitschke et al. 2012, Campbell, Remenyi et al. 2019, Wondmagegn, Xiang et al. 2021, Adams, Brumby et al. 2022).

To date, January 2019 is the hottest January on record for Victoria and Queensland, however, the average daily temperature increase was not as high as in NSW. Victoria's average daily temperature was 4.0°C above average, while Queensland's average daily temperature was 2.5°C above average (Bureau of Meteorology 2024). In Victoria, the rate of heatstroke-related diagnoses was 100.0% to 145.5% (an average of 116.0%) higher and diagnoses of dehydration 29.4% – 49.5% (an average of 37.5%) higher in January 2019 compared to January 2020-2022. In Queensland, heatstroke-related diagnoses were up to 36.8% (an average of 18.2%) higher and diagnoses of dehydration were up to 63.8% (an average of 31.9%) higher during January 2019 compared to subsequent years (data not shown). The diagnosis of indirect heat-related conditions in Victoria and Queensland during the extreme heat of January 2019 was comparable to the findings in NSW. In Victoria, diagnoses of indirect heat-related conditions were on average 0-10% higher, while in Queensland, these diagnoses were on average 11.8%-28.1% higher in January 2019 compared to January 2020-2022 (data not shown). These findings support the analysis of the NSW data and the published literature to demonstrate that direct heat-related presentations significantly increase during heatwaves, but changes in indirect heat-related diagnoses are inconclusive.

2.7 Summary of the impact of heatwaves on emergency department presentations

Overall, EDs in NSW experienced an increase in presentations due to extreme heat events. The analysis suggests there is generally a small increase in all-cause ED presentation numbers, with a more noticeable impact seen in the diagnosis of direct heat-related conditions (heatstroke-related and dehydration). Whether the increased presentation rate of these diagnoses would affect the functioning and workload of EDs remains to be studied, as the total number of these presentations was relatively low in comparison to the total ED demand. However, specialised patient care should be emphasised as part of heatwave response protocols, especially for vulnerable populations, to reduce avoidable mortality and morbidity.

Our analysis adds to the existing literature, highlighting areas for further research and advocacy. Patients presenting to EDs outside of metropolitan areas were shown to be affected more by extreme heat than those in metropolitan areas. The impact of heatwaves on ED presentations when compared by sex was variable, with males appearing to be more impacted than females. Further data is needed to examine the impact of heatwaves on ED presentations by age, as our analysis did not find any significant impacts, despite the published literature suggesting older people are at an increased risk of adverse health outcomes.

The conflicting findings on the impact of heatwaves may be due to several factors, including the diverse ways that extreme heat and heatwaves are classified and analysed. For instance, a study that analysed the impact of heatwaves on ED presentations in Brisbane categorised heatwaves in two separate ways and reported significantly different outcomes (Toloo, Yu et al. 2014). Standardised criteria for classifying heatwaves are crucial to ensure consistency across studies and allow more accurate comparisons and a better understanding of their impact. Additionally, confounding factors may have influenced the types of diagnoses that were presented to EDs during the study period, such as the COVID-19 pandemic and other climate events (i.e. bushfires).

3. Bushfires

Australia is one of the most bushfire-prone regions on earth. In eastern Australia, including NSW, the bushfire season is increasing in length and the number and severity of fires are expected to worsen (Commonwealth of Australia 2020). This was highlighted by the catastrophic 2019-2020 Black Summer bushfire season, which caused the death and displacement of almost three billion animals, the destruction of thousands of houses and the direct deaths of 33 people (Commonwealth of Australia 2020), 26 of whom died in NSW (NSW Rural Fire Service 2020). Whilst the Black Summer bushfires impacted much of the east coast of Australia, NSW was the most affected, with nearly 7% of the state burnt (NSW Rural Fire Service 2020). Bushfires are detrimental to human health not only from the direct effects of heat and fire but also from the indirect effects of smoke and

noxious substances within smoke, in particular, the minute particulate matter of less than 2.5 microns (PM_{2.5}) and less than 10 microns (PM₁₀) (World Health Organization 2013, Ranse, Luther et al. 2022). It is estimated that 430 people died due to smoke inhalation as a result of the Black Summer bushfires (Commonwealth of Australia 2020).

Our analysis on the impact of bushfires on EDs in NSW focussed on the Black Summer bushfire season from November 2019 to February 2020 and compared this data to presentations from November to February of 2018 – 2019, 2020 – 2021, and 2021 – 2022, which were all minor bushfire seasons in comparison. We analysed diagnoses of respiratory and circulatory conditions as these were the diagnoses most discussed in other published studies.

3.1 Impact of the Black Summer bushfires on emergency department presentations

Due to the catastrophic nature of the Black Summer bushfires in 2019-2020, there has been an abundance of research examining their impact on human health. The amount of PM_{2.5} that occurred during the Black Summer fires was well above average and exceeded the national air quality standard for much of the fire season (Borchers Arriagada, Palmer et al. 2020). The Royal Commission that occurred following the Black Summer bushfires estimated that over 1,500 people presented to EDs with asthma symptoms as a result of the bushfires (Commonwealth of Australia 2020, Johnston, Borchers-Arriagada et al. 2021), with around half of those (~700) estimated to have presented to NSW EDs (Borchers Arriagada, Palmer et al. 2020). A separate study assessed the rate of respiratory and cardiovascular-related ED presentations during the 2019-2020 bushfires and reported that respiratory conditions were increased by 6% and cardiovascular conditions were increased by 10% (Wen, Wu et al. 2022). Another study analysed ED presentations at Bathurst Base Hospital in regional NSW and reported that presentations with a respiratory diagnosis were 12% higher during the Black Summer fire season than during the 2018/2019 fire season (Mowbray, Peterson and Bailey 2022). A further study conducted at a hospital in Canberra reported that diagnoses of respiratory conditions increased by 45%, injury-related presentations decreased by 7%, and presentations related to cardiovascular conditions were unchanged compared to the previous year (Ranse, Luther et al. 2022). They also analysed ED performance and case mix for respiratory-related presentations and found no difference in the proportion of presentations by the mode of arrival, triage category, proportion discharged/admitted, and length of stay between the 2018/2019 bushfire season and the 2019/2020 Black Summer bushfire season (Ranse, Luther et al. 2022).

Our analysis of ED presentations during the Black Summer bushfire season found that the rate of all-cause respiratory conditions presenting to EDs in NSW was between 8% and 56% (average of 24.9%) higher than in the 2018-19, 2020-21, and 2021-2022 fire seasons (Table 5 and Figure 2). The proportion of people diagnosed with asthma and COPD was 8.6% – 79.2% (average of 41.9%) and 16.2% – 57.3% (average of 39.5%) higher, respectively, during the Black Summer season compared to the same season in other years (Table 5). Analysis of respiratory presentations by age, sex, Indigenous status, and remoteness of ED showed no major differences between fire seasons (data not shown). Those diagnosed with respiratory conditions during the black summer bushfires had a similar waiting time and length of stay compared to the other years analysed (data not shown). This suggests that no cohort of patients was impacted more than others by the smoke from the bushfires. The presentation rates of all-cause circulatory conditions increased by between 3% and 20% (average of 9.2%) during the Black Summer bushfires compared to the surrounding years. Ischaemic heart disease increased by between 1.2% and 18.5% (average of 7.8%) and heart failure diagnoses increased by between 6.7% and 33.3% (average of 18.5%) during the Black Summer bushfire period compared to the other years (Table 5). Despite these results, confounding factors must be taken into consideration, including other climate events and the COVID-19 pandemic which affected ED presentations from March 2020.

Table 5. The number and rate of ED presentations during the Black Summer bushfire season (Nov 2019 – Feb 2020) in NSW, with comparisons to the same period of time in surrounding years.

Diagnosis	Nov 2018 – Feb 2019 (n = 1,002,876)		Nov 2019 – Feb 2020 (n = 1,027,602)		Nov 2020 – Feb 2021 (n = 1,039,857)		Nov 2021 – Feb 2022 (n = 986,983)	
	Number	Rate	Number	Rate	Number	Rate	Number	Rate
Respiratory conditions	63,833	318.2	70,828	344.6	59,749	287.3	43,620	221.0
Asthma	7,935	39.6	8,831	43.0	5,701	27.4	4,736	24.0
COPD	5,727	28.6	6,833	33.2	4,550	21.9	4,171	21.1
Circulatory conditions	8,448	42.1	8,875	43.2	8,394	40.4	7,084	35.9
Ischaemic heart disease	1,646	8.2	1,701	8.3	1,673	8.0	1,372	7.0
Heart failure	609	3.0	649	3.2	495	2.4	540	2.7

The rate is per 5,000 ED presentations.

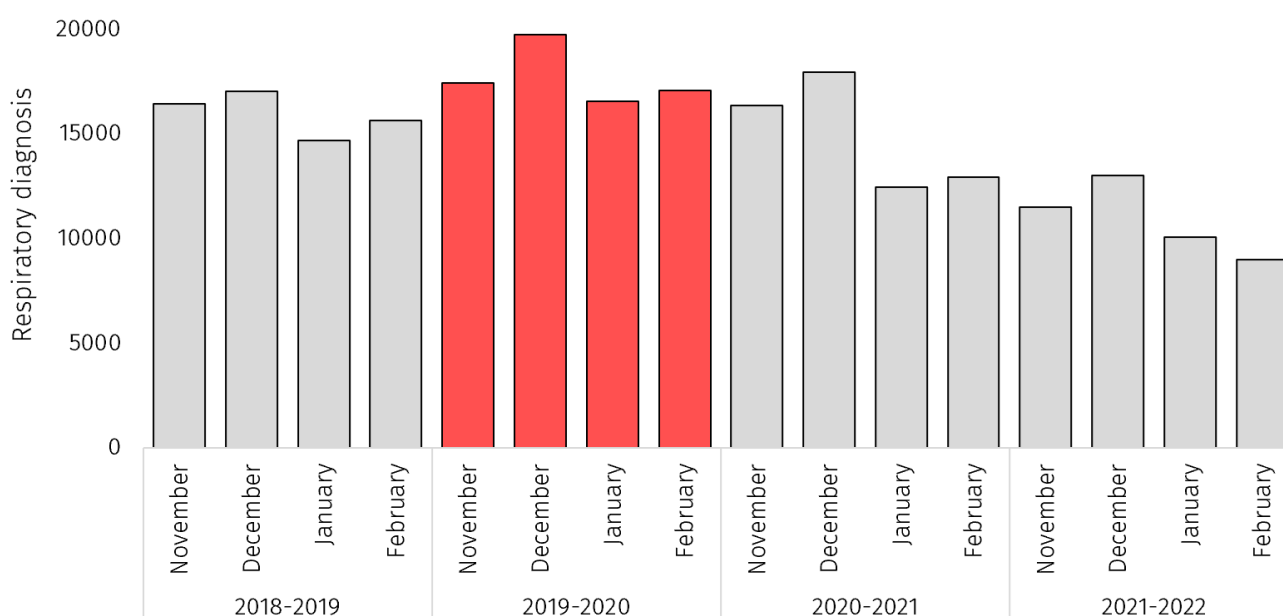


Figure 2. ED presentations in NSW diagnosed with a respiratory condition from November to February 2018 – 2019 to 2021 – 2022. The red columns represent the Black Summer season in 2019 – 2020.

3.2 Impact of other bushfire seasons on emergency department presentations

The results of studies analysing the impact of other bushfire events on ED presentations were consistent with the findings reported from the Black Summer analysis. A review article analysing studies from Australia reported that ED presentations with a diagnosis of asthma increased by up to 23% and COPD by up to 21%, but mixed effects were seen for diagnoses of cardiovascular disease (Walter, Schneider-Futschik et al. 2020). A meta-analysis reported that the relative risk of ED presentations with an asthma diagnosis was increased by 7% for all presentations and 15% for older adults following bushfires (Arriagada, Horsley et al. 2019). A systematic review reported that presentations of all-cause respiratory conditions increased by 10-30%, with increases in asthma presentations by up to 100% compared to non-bushfire periods (Skinner, Luther et al. 2022). They also found that a higher prevalence of women and children presented to EDs during bushfire periods (Skinner, Luther et al. 2022).

3.3 Summary of the impact of bushfires on emergency departments

Bushfires cause immense devastation, yet the poor air quality caused by bushfire smoke can impact human health well beyond the path of a fire. Most of the research into the effects of bushfires on ED presentations focussed on the health implications of smoke on cardiorespiratory conditions, in particular asthma. Based on the published literature and our analysis it is estimated that ED presentations for all-cause respiratory conditions increased by around 25% during the Black Summer bushfires, with presentations of asthma likely increasing by around 42%. These findings are supported by several review articles that report similar increases in respiratory conditions during bushfires. Therefore, in addition to the approximately 430 people who died because of poor air quality during the Black Summer bushfires, hundreds and possibly even thousands of people presented to EDs with respiratory symptoms due to the smoke from the fires. In addition, there are likely small increases in the percentage of people presenting to EDs with circulatory conditions during bushfires, but this has not been explored as extensively.

4. Storms and floods

Storms and floods are devastating natural disasters that often cause severe property damage and force the displacement of large amounts of people. During late February and early March 2022, the north-east of NSW experienced its wettest period since 1900 (NSW Independent Flood Inquiry 2022). It is estimated that over \$2.5 billion of damage occurred due to flooding, with almost 15,000 homes damaged, over 5,000 homes made uninhabitable, and nearly 8,000 people in emergency accommodation. Nine people also died because of the floods. Whilst it is unclear if extreme flood events will increase due to climate change, evidence suggests that NSW is experiencing increased extreme rainfall events and greater climate variability over the coming years (NSW Independent Flood Inquiry 2022).

The Richmond, Wilsons and Tweed River catchments were severely affected during the 2022 flood events, therefore we analysed presentations to five EDs in Northern NSW that may have been impacted by the flooding. The analysis compared these EDs to the EDs in the rest of NSW in March 2022 and to non-flood affected years (March 2019, 2020, and 2021).

4.1 Impact of storms and floods on emergency department presentations

To date, limited research has been conducted into the impact of storms and floods on EDs in Australia. One study analysed the impact of Cyclone Yasi on Townsville ED in 2011 and found that the total number of presentations increased, in particular in those aged 65+ years and in lower urgency triage categories (Aitken, Franklin et al. 2015). Many studies have analysed ED presentations following hurricanes and flooding events in the USA, with most reporting an increase in total ED presentations (Platz, Cooper et al. 2007, Stryckman, Walsh et al. 2017, Chambers, Husain et al. 2020), and increases in specific diagnoses such as gastrointestinal illness (Wade, Lin et al. 2014, Quist, Fliss et al. 2022). It has also been reported that an increased proportion of patients are discharged, and a subsequent reduction in the proportion of patients admitted to hospitals following the storm events (Stryckman, Walsh et al. 2017). This may be because people may have attended the ED to seek shelter as they were displaced by the weather event, rather than directly needing emergency medical attention (Chambers, Husain et al. 2020).

Our analysis showed that ED presentations were 5.8% – 15.4% (an average of 9.6%) higher in the storm and flood-affected EDs in March 2022 compared to March of the previous years. In comparison, the rest of NSW ED presentations were 2.3% to 3.6% (an average of 3.0%) higher in March 2022 compared to the earlier years. A higher proportion of annual presentations was seen in March 2022 (9.5%) than in March of the previous years (8.2% – 8.9%) in the storm and flood-affected areas, whilst more comparable proportions were seen in the non-storm and flood-affected areas (Table 6).

The proportion of patients that arrived by ambulance was lower in storm and flood-affected EDs (18.1% – 19.2%) than in non-storm and flood-affected EDs (21.5% – 23.1%), with no noticeable effect of the storms and floods occurring in 2022. Concerning patient acuity, there were no apparent differences in the proportion of presentations triaged into the more urgent triage categories (ATS 1-3) in March 2022 compared to the previous years. A smaller proportion of patients were admitted to hospital in March 2022 from the storm and flood-affected EDs (19.9%) compared to previous years (ranging from 22.7% – 23.4%) and compared to the non-storm and flood-affected EDs (22.9%) (Table 6).

Perspectives from clinicians working in flood-affected EDs support the suggestions that there was an increase in people attending EDs that did not need emergency medical care;

- “Initially the community was relying on the ED for more than medical care. People needed somewhere dry and warm.”
- “The department faced a surge of presentations, staggering to comprehend”
- “An entire nursing home was being evacuated to our emergency department. All our beds and waiting room were full.” (YourED 2022)

Table 6. The impact of storms and floods on affected and non-affected EDs in NSW in March 2019 to 2022.

	March 2019		March 2020		March 2021		March 2022	
	Affected EDs	Non-affected EDs	Affected EDs	Non-affected EDs	Affected EDs	Non-affected EDs	Affected EDs	Non-affected EDs
<i>Number of presentations</i>	12,102	247,149	11,344	246,290	12,375	249,370	13,092	255,089
<i>Proportion of annual presentations occurring in March</i>	8.6%	8.7%	8.2%	8.9%	8.9%	8.5%	9.5%	8.9%
<i>Proportion arrived by ambulance</i>	18.5%	22.8%	19.2%	21.5%	19.0%	23.1%	18.1%	22.4%
<i>Proportion ATS 1-3</i>	48.3%	48.3%	49.3%	43.1%	51.4%	49.2%	48.7%	51.6%
<i>Proportion admitted to hospital</i>	23.3%	25.7%	22.7%	21.5%	23.4%	25.0%	19.9%	22.9%
<i>Proportion discharged from ED</i>	70.0%	63.6%	70.4%	68.9%	69.3%	64.7%	70.8%	64.5%

Abbreviations – ATS: Australasian triage scale.

4.2 Summary of the impact of storms and floods on emergency departments

There has been limited published literature analysing the impact of storms and floods on ED presentations in Australia. Based on our analysis and the published research, it is likely that there is an increase in the number of people attending EDs in the aftermath of storms and floods, either to seek shelter or medical care. Some research also suggests delayed impacts on mental health, cardiovascular health, and non-communicable diseases that contribute to ED presentations in the long term following flood and storm events (Du, FitzGerald et al. 2010, Alderman, Turner and Tong 2012, Magdy, Adikari et al. 2023). Further research is needed to further understand the impacts of storms and floods on ED presentations, workload and function, particularly in an Australian and NSW context.

5. Impact of climate events on emergency department operations and delivery of services

Climate change and the increasing number of major climate events are likely to impact the ability of health services, including EDs, to deliver adequate patient care. For instance, in the acute aftermath of a major storm and flooding event, hospitals and EDs may become inaccessible, impacting the supply chain and the ability of staff to access their workplace (Al-Marwani 2023). This sentiment was supported in an article published by ACEM with the perspectives of ED staff working on the ground during a major flooding event. The clinicians highlighted the importance of being prepared for the loss of power and communications and having a well-outlined disaster plan;

- “Prepare for the failure of all electronic communication and have a backup. Review the disaster plan – again.”

- “Power and all EMR shut down, so we were on generator power, tracking patients on whiteboards, writing paper notes and paper ordering investigations – a real throwback to the past!”
- “Over the next three hours, we had to evacuate the hospital’s 60 patients all the while juggling the ongoing care of our existing sick ED patients and the increasing stream of new patients arriving at our doors. At the same time, we had to gather and transport enough equipment, medication, and supplies to create a fully functioning field hospital and ED in a nearby school.” (YourED 2022)

Several articles from the USA have described how hospitals and EDs became inaccessible due to flood waters or damage following hurricanes (Greenstein, Chacko et al. 2016, Chambers, Husain et al. 2020). One study reported that a hospital was cut off for five days, meaning no staff could access the ED and supplies of food and linens were at risk of running out. In addition, several ED beds were reallocated as inpatient beds due to flooding in the rest of the hospital, so the ED was at a reduced capacity (Chambers, Husain et al. 2020). Another study highlighted the importance of having ample staff onsite before the storm event so that inaccessibility issues would not leave the ED short-staffed. This study also reported a change in primary diagnosis that occurred following the storm event, with large increases in the proportion of people presenting with lacerations, cold exposure, and the need for medication refills (Greenstein, Chacko et al. 2016). Several systematic reviews have discussed the importance of disaster preparedness plans following major climate events and have highlighted the need to consider many aspects including staffing, resources and equipment, facilities and command and control protocols (Nekoie-Moghadam, Kurland et al. 2016, Sheikhbardsiri, Raeisi et al. 2017). These plans could then be implemented before future climate events to ensure minimal impact on the delivery of hospital and ED services.

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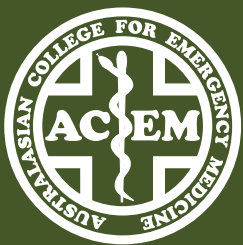
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