Review Article

Impact of climate change in emergency medicine: a narrative review

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Background and Objective: Climate change is an unprecedented global phenomenon with far-reaching implications for every sector, including healthcare. Emergency medicine is uniquely susceptible to the impacts of climate change, and emergency physicians will be increasingly challenged by the increase in attendances and the variation of disease patterns directly due to climate change. This narrative review aims to summarize how climate change is affecting emergency medicine practise through amplification of climate-related disease patterns and epidemiological shifts for conditions treated in the emergency department (ED) and what potential solutions have been explored to address this issue such as clinical practise improvements, disaster preparedness, public health engagement, mitigation and adaptive solutions.

Methods: This narrative review was conducted by the two lead authors through an independent literature review on Scopus, Embase, and PubMed in March 2023. All studies relevant to emergency medicine were included with limitations to English language.

Key Content and Findings: The key themes found were: the association between increase in average temperatures and ED attendances; the impact of increase in pollution and ED attendances for various conditions; the impact of climate-related disasters and adverse weather events to the ED; commentaries and reviews of how ED can be affected by climate change and how potential mitigation strategies can be applied. Increased in daily average temperatures, pollution and frequency of extreme weather events has led to a rise in climate-related health emergencies, for various conditions. Multiple commentaries and reviews called for action on emergency physicians and leaders to become more involved in climate change and look at potential solutions.

Conclusions: Climate change will inevitably play a vital part in provision of emergency care to patients in the coming future. Knowledge of its impact and the potential solutions to this problem can be of help for future clinicians.

Keywords: Emergency department (ED); climate change; emergency medicine; climate crisis

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Introduction

Climate change represents a worldwide health emergency, primarily attributed to human activities such as the combustion of fossil fuels and deforestation. The World Health Organisation (WHO) estimates that between 2030 and 2050, the effects of climate change are projected to cause approximately 250,000 additional deaths each year from heat stress, malnutrition, malaria and diarrhoea (1).

The healthcare industry's average 4% of worldwide net greenhouse gas emissions is a substantial contributor to the global climate crisis; this is equivalent to the annual emissions of 514 coal-fired power plants (2).

Emergency physicians are facing an increasing number of patients with conditions directly attributable to global warming (3,4). Factors such as wildfires, flooding, and heat-related illnesses contribute to the rise in medical emergencies (5). Climate change is anticipated to increase the prevalence of conditions already encountered in emergency departments (EDs), such as cardiovascular diseases (CVDs), respiratory conditions, and gastrointestinal disorders (3).

The implications of climate change for emergency care have been emphasised by medical organisations globally. In 2018, the policy statement issued by the American College of Emergency Physicians (ACEP) underscored the significance of fostering collaboration between emergency medicine and public health in the realm of climate change research (6). The Royal College of Emergency Medicine (RCEM) in the United Kingdom officially declared a climate emergency in 2019, leading to the establishment of Green ED as a means to incorporate environmental sustainability into routine medical procedures (7). The Australasian College of Emergency Medicine (ACEM) has advised governments to pledge to attain a carbon-neutral economy by 2050 and dedicate resources towards renewable energy sources (8).

The WHO has highlighted five global research priorities for protecting human health from the effects of climate change. This includes risk assessment, finding cost-effective solutions, assisting with decisions about adaptation and mitigation that promote health, and improving decision support and cost estimation (9).

Previous studies have looked at the impact of healthcare on greenhouse effect. A systematic review showed how healthcare services impact greenhouse effect by 15% to 50% through direct and indirect carbon emissions and suggested that disposable equipment and pharmaceuticals represented the highest percentage (10). Similar review has also found that, even though the rate of energy consumption and environmental impact per hospital bed is relatively low compared to other industries, it still compounds to a significant figure (11). Both sources agree that the use of energy saving initiatives like the use of renewable energy, thermal insulation for buildings and low-consumption equipment for electricity and rainwater harvesting and wastewater recycling could help significantly reduce the overall carbon footprint of healthcare (11).

A few studies specifically looked at the impact of climate change to emergency medicine (3,12). Hess *et al.* described how climate change could impact the delivery of emergency service in the USA within the next years (3). They argue that climate change will be highly likely to increase the incidence of conditions regularly seen in ED because of the impact of temperature rises, pollutions, pollens and extreme weather events. Also, it is likely that patients living in marginalised area and more socially vulnerable would be more likely to attend as a consequence of heat-related illnesses. They also predict that climate change will likely introduce unfamiliar zoonotic and vector-borne diseases into new geographic areas, as seen in some areas of the USA. Finally, they describe how climate change is due to impact disaster response and management from both a prehospital and intradepartmental point of view and reflect on priorities needed to be addressed to prepare emergency physicians in their role as future leaders.

The only scoping review that could be found on the impact of climate change on emergency care was from Theron *et al.* (12) although they limited their scope to the African continent. They identified three key themes in their review: surges in demands related to climate change, opportunities for health sector engagement and proposed solutions to improve preparedness. In particular, floodings were noted to be the major single hazard for infectious disease spread, but also injuries from mudslides and other extreme weather events and heat-related illnesses due to the rising average temperatures accounted for high emergency care requirement. Challenges specific to the African continent were also mentioned to be the need for a strengthened healthcare infostructure capable of dealing with these weather events and potential solutions identified were action plans aimed at improving capacity during adverse weather events and disaster tools to promote health care facility flood preparedness. In their article they also conclude with various recommendations for leaders to address climate-related health threats in the near future.

Table 1 Research methods

Items	Specification
Date of search	Literature search: 11 March 2023
	Manual search up until April 2024
Database	PubMed, Embase, Scopus
Search items used	("climate change" OR "global warming" OR "heatwave" OR "heat wave" OR "greenhouse effect" OR "wildfire" OR "natural disaster") AND ("Emergency department" OR "emergency medicine" OR "emergency department*" OR "emergency room" OR "emergency physician" OR "emergency physicians") AND (y_5[Filter])
Timeframe	From January 2018 to March 2023
Exclusion criteria	Commentaries, letters, repeated published articles and case reports
Selection process	Independent selection process by two authors C.D.V. and A.S. Discrepancies in study selection were resolved through mutual discussion

The purpose of this narrative review is to provide a concise overview of the impact of climate change on emergency medicine at an international level. Additionally, it highlights responses undertaken by certain countries to address the impact of climate change on ED presentations. This article is written in accordance with the Narrative Review reporting checklist (available at https://jphe.amegroups.com/article/view/10.21037/jphe-23-87/rc).

Methods

C.D.V. and A.S. performed an independent literature review through Embase, Scopus and PubMed in March 2023. The detailed research strategy is outlined in Appendix 1. A 5-year time limit was applied to focus on recent literature updates (*Table 1*).

This search strategy yielded a total of 1,957 studies. Upon removing duplicates, the authors screened titles for relevance to emergency medicine. Irrelevant studies were excluded based on the authors' judgment. Priority was given to international studies offering diverse perspectives from various countries. Discrepancies in study selection were resolved through mutual discussion.

All studies relevant to emergency medicine were included, with limitation to the English language. Additionally, we also consulted the website of major international emergency medicine colleges to identify policies, reports, and position statements relevant to climate change.

A further *ad hoc* literature review was performed by the authors to complement some sections of the article in April 2023.

Results

A total of 70 studies were obtained from the literature review (*Table 2*). These have been categorized by year, country of origin, and relevant results. The majority of the studies were observational, comprising three systematic reviews (13-15); two scoping reviews (12,16) and nine consisting of commentary and review articles (17-25).

Most studies come from high-income countries such as the USA (24), Australia (6) and China (6). Studies from the Asia continent excluding China's mainland were from South Korea (3), India (1), Pakistan (1) and Taiwan region (1). Two studies from the American continent excluding the USA were from Canada and Puerto Rico and the only two European studies were from Italy and France. One study was from South Africa and was a scoping review of the impact of climate change on emergency care in the African continent. The key themes found were: the association between increase in average temperatures and ED attendances; the impact of increase in pollution and ED attendances for various conditions; the impact of climate-related disasters to the ED; commentaries and reviews of how ED can be affected by climate change and how potential mitigation strategies can be applied (19-26).

Most studies examined rates of ED attendance for specific medical conditions in association with increases in average temperatures and specifically cardiovascular diseases (16,27,28), respiratory diseases (13,29), renal diseases (30-32), mental health conditions (33-36), neurological disorders (37,38), diabetes (15), and dermatological conditions (39). Most studies found an association between ED attendances and increasing average daily temperatures.

Table 2 List of studies included

Topic	Authors	Year	Country/ region	Methodology	Results
Cardiovascular	Bo Wen *et al.*	2022	Australia	Observational study	10% increase in ED attendances for cardiovascular conditions during bushfires (95% CI: 5–15%)
	Paolo Contiero *et al.*	2019	Italy	Observational study	Increase in presentation to ED during hot days for cardiovascular-related conditions (OR =1.34, 95% CI: 1.05–1.75) and increase in PM (OR =1.23, 95% CI: 1.09–1.37)
	Kendra R. Cicci *et al.*	2022	–	Scoping review	Increase in ED attendance due to cardiovascular disease, HTN, IHD, ischemic stroke with high temperatures
	Wenzhi Zhu *et al.*	2021	China's mainland	Observational study	1% increase in diurnal temperature associated with increase ED attendance for CVD of 1.3% (95% CI: 0.99–1.62%)
	Yuxia Ma *et al.*	2019	China's mainland	Observational study	Increase in CVD attendances to ED associated with extreme temperature changes (both low and high temperatures) (RR =3, 95% CI: 1.6–4.4)
	Joan A. Casey *et al.*	2021	USA	Observational study	High wildfire PM2.5 non-significantly associated with an increase in CVD-related ED visits or mortality
Respiratory	Bo Wen *et al.*	2022	Australia	Observational study	6% increase in ED attendances for cardiovascular conditions during bushfires (95% CI: 1.9–10%)
	Yuxia Ma *et al.*	2019	China's mainland	Observational study	Increase in ED attendances for respiratory condition with increase in temperature (OR =1.36, 95% CI: 0.96–1.92)
	Larry W. Figgs *et al.*	2019	USA	Observational study	Non-significant increase of asthma ED diagnosis 1.23 (95% CI: 0.96–1.57) times higher during heat wave compared to previous year
	Colleen E. Reid *et al.*	2016	USA	Observational study	Increase ED visits for asthma (RR =1.05, 95% CI: 1.02–1.07). Non-significant for hospitalizations
	Nicholas J. Nassikas *et al.*	2021	USA	Observational study	Average excess asthma-related ED visits of 3.2 (95% CI: 1.52–4.75) per 10,000 population due to ozone attributable asthma attacks
	Daniel Kiser *et al.*	2020	USA	Observational study	Daily increase in PM2.5 associated with increase in asthma visits to ED to 6.1% (95% CI: 2.1–10.3%). Presence of wildfire smoke increased ED asthma visit by 5.5% (95% CI: 2.5–8.6%)
	Firdian Makrufardi *et al.*	2023	–	Systematic review	Increase ED asthma visits 1.25 folds (95% CI: 1.14–1.27), hospital admissions 1.10 (95% CI: 1.04–1.17) and mortality 2.10 (95% CI: 1.35–3.27) with extreme weather
	Ryan W Gan *et al.*	2020	USA	Observational study	Increase in PM2.5 associated with increase in asthma ED diagnosis (OR =1.08, 95% CI: 1.04–1.13)

Table 2 (*continued*)

Table 2 (*continued*)

Topic	Authors	Year	Country/ region	Methodology	Results
	Nicholas Nassikas *et al.*	2020	USA	Observational study	Comparison of climate warming mitigation scenario *vs.* "business as usual scenario" to project asthma admissions and healthcare spending. Projected annual average of 3,100 averted asthma ozone-related ED visits translating to 1.7 million USD averted costing
	Francis Thien	2018	Australia	Commentary	Epidemic thunderstorm asthma leading to 3,365 excess asthma-related presentation to ED in Melbourne in one day with 10-fold increase in ICU admissions
	Yuxia Ma *et al.*	2019	China's mainland	Observational study	Association between ED visits for respiratory conditions and extreme temperatures. RR =1.36 (95% CI: 0.96–1.92) with high temperatures; RR =1.96 (95% CI: 1.7–2.26) with extreme cold
	Xuping Song *et al.*	2021	China's mainland	Observational study	Association between ED visits for respiratory conditions and air pollution index associated with moderate cold days (RR =1.006, 95% CI: 1.002–1.009)
	Joan A. Casey *et al.*	2021	USA	Observational study	High wildfire PM2.5 associated with a 14.6% (95% CI: 4.2–24.9%) increase in same-week respiratory disease-related ED visits
	Bowen Cheng *et al.*	2021	China's mainland	Observational study	Increase in ED visits for respiratory conditions associated with increase in PM2.5 and PM10. RR for PM2.5 1.042 (95% CI: 1.036–1.047) and for PM10 1.01 (95% CI: 1.01–1.02)
Mental health	Xinye Qiu *et al.*	2022	USA	Observational	Relative increase in admission for a psychiatric disorder with 5-degree increase in atmospheric temperature. Depression: RR 3.66 (95% CI: 3.06–4.25); schizophrenia: 3.03 (95% CI: 2.04–4.02); bipolar disorder: 3.52 (95% CI: 2.38–4.68)
	Eric Lavigne *et al.*	2023	Canada	Observational study	Cumulative exposure to extreme heat associated with increase attendance to ED for mental and behavioural disorders (personality disorder, schizophrenia, dementia and substance misuse) (OR =0.98, 95% CI: 0.97–0.98)
	Jamie T. Mullins *et al.*	2019	USA	Observational study	For every additional day with temperature >80 °F, there is a 0.3% increase in ED attendances for mental health and a 0.24% increase in suicide rate
	Eun-Hye Yoo *et al.*	2021	USA	Observational study	Positive association between short extreme weather bursts and ED attendances for mental health conditions (RR =1.28, 95% CI: 1.23–1.33)
	Julia Feriato Corvetto *et al.*	2023	–	Systematic review	Suicide (completed or attempted), substance misuse, schizophrenia, mood, organic and neurotic disorders, and mortality were strongly affected by climate change

Table 2 (*continued*)

Table 2 (*continued*)

Topic	Authors	Year	Country/ region	Methodology	Results
	Eun-Hye Yoo *et al.*	2021	USA	Observational study	Positive associations between short-term exposure to extreme ambient temperatures and increased ED visits for mental disorders (RR =1.16, 95% CI: 1.06–1.27)
	Li Niu *et al.*	2023	USA	–	Elevated temperature days were associated with higher risk of mental health-related ED for the 6- to 11-year-olds (OR =1.28, 95% CI: 1.13–1.46), for the 12- to 17-year-olds (OR =1.17, 95% CI: 1.09–1.25) and for the 18- to 25-year-olds (OR =1.09, 95% CI: 1.04–1.15)
Gastrointestinal	Arbor J. L. Quist *et al.*	2022	USA	Observational study	Increase in acute gastrointestinal disease after hurricanes (RR =1.1, 95% CI: 1.0–1.23)
	Jacob E. Simmering *et al.*	2022	USA	Observational study	Increase in incidence of appendicitis with higher-than-expected temperatures *vs.* normal temperatures (3.3% increase incidence, 95% CI: 1–5.7%)
Neurology	Seonjeong Byun *et al.*	2020	South Korea	Observational study	Short-term exposure to wide diurnal temperature ranges immediately increased the risk of ED visits for MS (OR =8.81%, 95% CI: 3.46–14.4%)
	Hyewon Lee *et al.*	2018	South Korea	Observational study	Higher air pollution levels associated with increased ED attendances for migraine (OR =1.031, 95% CI: 1.01–1.05)
	Holly Elser *et al.*	2021	USA	Observational study	Anomalously warm weather was associated with increased risk for ED visits (RR =1.043, 95% CI: 1.025–1.063)
Endocrine	Donghong Gao *et al.*	2022	–	Systematic review	Increase in diabetes-related ED visits with exposures to extreme daily ambient maximum temperature (RR =1.03, 95% CI: 1.01–1.06)
Dermatology	Dharshani Pearson *et al.*	2020	USA	Observational study	Risk of ED visits for HFMD per 1 °F increase in mean temperature during the same week increased 2.00% (95% CI: 1.15–2.86%) and 2.35% (95% CI: 1.38–3.33%) during the warm and cold seasons
	Nai-Tzu Chen *et al.*	2021	Taiwan	Observational study	Increase in attendance to ED from patients with atopic dermatitis during floods (OR =1.14, 95% CI: 1.01–1.128)
Nephrology	Zhiwei Xu *et al.*	2020	Australia	Observational study	Increase in AKI presentation in ED with hourly increase in temperature degree (OR =1.37, 95% CI: 1.10–1.71)
	Satbyul Estella Kim *et al.*	2019	South Korea	Observational study	Increase in AKI presentation to ED with 1-degree increase of temperature (OR =1.01, 95% CI: 1.00–1.02)

Table 2 (*continued*)

Table 2 (*continued*)

Topic	Authors	Year	Country/ region	Methodology	Results
	Yanji Qu *et al.*	2023	USA	Observational study	Increase in kidney disease-related conditions (kidney stones, AKI, and urinary tract infections) with extreme heat exposure. 1.7% to 3.5% increased risk of attendance to ED with renal-related conditions
Disaster	Kate R. Weinberger *et al.*	2021	USA	–	Hurricane Sandy associated with a higher rate of ED visits due to injuries and poisoning (RR =1.19, 95% CI: 1.10–1.28), respiratory disease (RR =1.35, 95% CI: 1.21–1.49), cardiovascular disease (RR =1.10, 95% CI: 1.02–1.19), renal disease (RR =1.44, 95% CI: 1.22–1.72), and skin and soft tissue infections (RR =1.20, 95% CI: 1.03–1.39)
	Chitta Ranjan Mohanty *et al.*	2020	India	Observational study	Retrospective study of patients attending ED during a cyclone. Injury primary cause for attendance
	Verónica M. Frasqueri-Quintana *et al.*	2020	Puerto Rico	Observational study	Retrospective study of patients attending ED during a hurricane. Injury primary cause of presentation
	Kevin C. Heslin *et al.*	2021	USA	Observational study	ED utilization rates for weeks during and after hurricanes were compared with pre-hurricane rates. Respiratory disorders exhibited the largest post hurricane increase, particularly 2–3 weeks following the hurricane
	Rachel S.C. Friedman *et al.*	2022	USA	Observational study	Role of telemedicine to reduce attendance to ED in private healthcare during wildfires. Telemedicine familiarity associated with decreased absolute risk in pre- to post-fire inpatient and emergency department utilization
General	Elzarie Theron *et al.*	2022	South Africa	Scoping review	Key themes that were identified: climate-related health impacts that contribute to surges in demand and resource utilization, opportunities for health sector engagement, and solutions to improve emergency preparedness
	Cecilia J. Sorensen *et al.*	2020	USA	Commentary	Key opportunities for emergency medicine to lead the medical response to climate change through 7 key areas: clinical practice improvements, building resilient EDs and health care systems, adaptation and public health engagement, disaster preparedness, mitigation, research, and education
Mitigation strategies	Hanna Linstadt *et al.*	2020	USA	Commentary	To educate and motivate emergency providers to action by providing a guide to sustainable health care and an approach to creating a climate-smart ED

Table 2 (*continued*)

Table 2 (*continued*)

Topic	Authors	Year	Country/ region	Methodology	Results
	Nadeem Ullah Khan *et al.*	2023	Pakistan	Quasi-experimental study	The diagnosis rate of heat-related conditions improved from 3% (n=125/4,181) to 7.5% (n=302/4,022) (P value <0.001)
	Patrice K. Nicholas *et al.*	2021	USA	Commentary	Application of a clinical tool mnemonic to identify climate-related emergencies in ED
	Katelyn Moretti *et al.*	2021	USA	Commentary	Argument to include climate change-related conditions in emergency medicine curriculum
	Amy Dryden *et al.*	2019	Australia	Commentary	Argument that emergency departments cannot make a meaningful impact on climate change
	Joseph Ting *et al.*	2019	Australia	Commentary	Counterargument that ED can make a meaningful impact on climate change
	Daniel Aiham Ghazali *et al.*	2018	France	Review article	Climate change increase demand to ED generally and causes increase in disasters. Mitigation strategies entail capability development, enhance surge capacity, increase in resources and reduction of carbon footprint
	Caitlin Rublee *et al.*	2021	South Africa	Commentary	Commentary on workshop aimed at improving emergency care in Africa with regard to climate change
Heatwaves	Dimpalben Patel *et al.*	2019	Australia	Observational study	Increase in ED attendances due to air pollution during heatwaves compared (77.8/100,000/day) to non-heatwaves days (73.9/100,000/day) in Perth
	Yu Wang *et al.*	2020	China's mainland	Observational study	Increase in ED attendances for each degree of average temperature increase across 18 sites in China. Subgroup analysis showing increase in attendances for injury, digestive, respiratory and endocrine conditions
	Berhanu Yazew Wondmagegn *et al.*	2022	Australia	Observational study	Increase in heat attributable ED attendances with estimated cost of 4.7 million Australian dollars. Expected to grow by 3.5% ED presentations and 5% costs by 2050
	Shahan Waheed *et al.*	2019	Pakistan	Short report	Description of patient presentation during a heatwave in a tertiary hospital. Higher mortality in elderly patients
	Hannah Mason *et al.*	2022	Australia	Systematic review	Increase in hospital admission for CVD, respiratory, renal, mental conditions during heatwaves. Increase in mortality during heatwaves. Most vulnerable children and elderly
	Aaron S. Bernstein *et al.*	2022	USA	Observational study	Increase in ED attendance of children in 47 US children hospital (RR =1.83, 95% CI: 1.12–1.12). Subgroup analysis increase in heat-related illnesses (RR =1.83, 95% CI: 1.31–2.57), gastroenteritis (RR =1.35, 95% CI: 1.02–1.79) and otitis (RR =1.30, 95% CI: 1.11–1.52)

Table 2 (*continued*)

Table 2 (*continued*)

Topic	Authors	Year	Country/ region	Methodology	Results
	Robert E. Davis *et al.*	2018	USA	Observational study	Increase hospital admission during heatwaves compared to non-heatwaves periods
	Sharon L. Campbell *et al.*	2019	Australia	Observational study	Increase of ED presentation of 5% (OR =1.05, 95% CI: 1.01–1.09) and 19% for children <5 years old (OR =1.19, 95% CI: 1.04–1.36)
	Ines Corcuera Hotz *et al.*	2020	UK	Observational study	Increase in ED attendances of 1% (95% CI: 0.8–1.4%) and 1.4% (95% CI: 1.2–1.5%) for children <15 years old. Increase in fracture-related attendances 1.1% (95% CI: 0.7–1.5%) per 1-degree increase
	Jessie Adams *et al.*	2022	Australia	Observational study	Decrease in ED presentation during heat days in rural south-west Victoria compared to non-heat days
	Penelope Dring *et al.*	2022	USA	Observational study	Increase in ED heat-related conditions throughout the years
	Fraser Kegel *et al.*	2021	Canada	Observational study	Increase in ED attendances and patients' length of stay during days with higher average daily temperature
	Nese Colak Oray *et al.*	2018	Turkey	Observational study	Higher ED attendance rate of patients during period of heatwave compared to previous years. Higher in hospital mortality rate. Same ED admission rate. No able to describe direct correlation
	Paul J. Schramm *et al.*	2021	USA	Report	Description of patient presentations during heatwave. Increase in heat-related attendances. Elderly most affected
	Kate R. Weinberger *et al.*	2021	USA	Observational	Estimation of attendances to ED with two projected greenhouse emission scenarios. Results are increase in ED attendances but reduce overall mortality annually
	Piotr Wilk *et al.*	2020	USA	Observational study	Increase in ED attendance of 22% with extreme heat compared to normal temperature days. Subgroup analysis showed increase attendances for infectious diseases (35%) and most pronounced in children
	Richard Skinner *et al.*	2022	–	Systematic review	Mostly studies from Australia and USA. PM considered the primary cause for increase in ED attendances. Increase in attendance of respiratory and CVD during wildfires. Increase risk for children, elderly and patient with comorbidities

ED, emergency department; CI, confidence interval; OR, odds ratio; HTN, hypertension; IHD, ischemic heart disease; CVD, cardiovascular disease; RR, relative risk; PM, particulate matter; USD, US dollar; ICU, intensive care unit; MS, multiple sclerosis; HFMD, hand foot mouth disease; AKI, acute kidney injury.

During heatwaves in particular, children and in the elderly were shown to be proportionally more affected (40). Only one study showed a decrease in ED attendances associated with elevated temperatures in regional Victoria, Australia (41).

Additionally, some studies compared ED attendances to concerning increases in particulate matter (PM) levels (27,42-44). Most found a positive association between attendance rate and increase in PM (43). Cheng *et al.* found a positive correlation between patients with respiratory conditions visiting ED and PM levels in a city in northwest China (45). They noted that children under 15 years, elderly and male patients were mainly affected with higher attendance recorded in the winter season. Kiser *et al.* looked at the association between asthma visits and PM in Nevada, USA (42). They found that wildfire smokes increase the association between PM levels and asthma visits especially in the immediate phase. They argue that PM from wildfire is more harmful to asthma patients than PM from non-wildfire causes and they hypothesise this to be due to the combination of a different PM composition, elevated temperature and patient behaviour during wildfire. Ozone was also an important factor in asthma attendances with two studies quoting specifically ozone-related asthma attacks (46,47). Nassikas *et al.* estimated the burden of ozone-related asthma attack in New England (47). They estimated an average rate of 3.2 (95% confidence interval: 1.52–4.75) per 10,000 population excess ozone-related asthma ED visits.

Some studies looked at mitigation strategies and tools to aid clinicians in detecting climate change-related conditions. One study from Friedman *et al.* explored a potential mitigation strategy through the use of telemedicine in the aftermath of a disaster to reduce ED attendances in a private hospital in the USA (48). This was a quasi-experimental study on the impact of a wildfire in California on ED admission of patients with conditions that would have been suitable for ambulatory care. They hypothesised on whether pre-existing familiarity with telemedicine could reduce ED attendance and hospital use compared with no familiarity. The study showed an overall reduced ED and hospital utilization. They argue that telemedicine access could keep patients from experiencing ill health and preventable hospitalization following a disaster. An important limitation is patient access to telemedicine and difficult generalisability to other countries where infostructures might be less developed.

Other studies explored clinical tools and mnemonic aids to help clinicians to diagnose and address heat-related emergencies arguing that these could be subtle and becoming more prevalent (20,26). Nicholas *et al.* developed a tool to help triage nurses in ED to identify climate-related conditions. In particular they stressed the importance of considering climate-related conditions such as heat strokes and educating on possible regional variations of extreme weather events to try anticipate ED demand (20). Khan *et al.* similarly did a quasi-experimental study on whether education on heat-related emergencies presenting to an ED in Pakistan could improve diagnosis and management of these conditions. In this study they claimed improvement of diagnosis from 3% to 7% and use of specific management such as external cooling methods from 1.3% to 3.4%, although it suffers from significant risk of bias from lack of blinding and the likely Hawthorne effect of pre- and post-implementation studies (26).

Two studies looked at the economic impact of climate-related conditions presenting to ED. The first from Nassikas *et al.* compared the cost of ED attendances of patients with ozone-related asthma in a scenario where the US government would have lowered their in-house gas emission compared to usual practice. In their study, the projected reduction of asthma cases prevented by reducing the ozone level would save the healthcare up to 1.7 million US dollars annually (46). The second from Wondmagegn *et al.* estimated the healthcare cost of projected increase in attendances due to heat-related conditions to EDs in Adelaide, Australia. It predicted a total spend of 4.5 million Australian dollars with an expected increase of 5% by 2050 (49).

Five studies looked at the aftermath of extreme weather events such as hurricanes (50-52), cyclones (53) and earthquakes (54) to the ED and the service demand that they required. In particular, a study from Mohanty *et al.* described the challenges faced by a tertiary ED in India following cyclone Fani (53). They described how the challenge of dealing with incoming trauma patients was also compounded by the hospital infostructure damage. Electricity blackout following the cyclone caused inability to utilise equipment, laboratory and imaging services, oxygen pipeline malfunction required massive relocation of patients from critical care areas and collapsed ceilings caused physical barriers to mobility within the hospital.

Some studies found in the literature search were categorised as studies that offered mitigation strategies or proposals for solutions. In some cases, these were commentaries made as a call for action required from all emergency physicians to become aware of climate change as

a new challenge (19,25) with one commentary from Moretti *et al.* arguing that climate change should be added to the emergency medicine curriculum for residency in the USA (21). Two commentaries respectively from Ting *et al.* and Dryden *et al.* were an argument/counterargument on whether emergency physicians can make a meaningful impact on climate change (22,23). Suggestion on improvement were sustainable energy use, urban planning to facilitate public transport and healthier sustainable food, while the counterargument was that small adjustments from single individuals would be unlikely to bring to a significant reduction to the carbon footprint that the hospital generates.

Discussion

The narrative review highlighted the impact of specific disease burden due to either temperature increase or pollution and effect of extreme weather events on ED attendances. It also revealed studies focusing on potential solutions and strategies that could be adopted. To the best of our knowledge, this is the only review that analyzes studies on the association between emergency medicine and climate change, which highlights an important gap in the literature that needs to be filled. Not surprisingly, most studies pertained to high-income countries and only a few studies were from developing countries, reducing generalisability of the findings and suggesting the need for further research. Further will be discussed diseases specific effects of climate change and how they affect the provision of emergency medicine care.

Cardiovascular risk

Cardiac diseases are the biggest cause of death in the Western world and a major reason why people seek medical attention in the ED (16). Multiple studies have examined the increased susceptibility to CVD and morbidity linked to extreme heat conditions (16,55,56) with the main causal factor postulated to be the elevated heart rates, blood pressure, blood viscosity, and plasma cholesterol levels, which in turn trigger cardiovascular symptoms (56). Heatwaves have been associated with increase in cardiovascular mortality (55,57), ED attendances (16), and hospital admissions (58). A study from Wen *et al.* demonstrated a 10% increase in attendances to ED following a bushfire season in New South Wales in Australia. They suggest the health effect of bushfire seasons being related to oxidative stress at cellular level, platelet activation, thrombosis, and inflammation of vascular endothelia (58).

In a systematic review from Cicci *et al.*, multiple studies reported statistically significant increase in ischaemic heart disease attendance to ED during heatwaves, an association between patients with myocardial infarction presenting to ED and increase daily temperatures and increase in ED attendance for arrythmia during heatwaves (16). Interestingly, there seem to be no association between heatwaves and increase in patients presenting to ED with decompensated heart failure, although a study found that pre-existing heart failure was a risk factor for patient to present to ED with a heat-related illness (16). Findings were more inconclusive for stroke attendances to ED. A major limitation of the review was the inclusion of only studies from US and Europe.

Pollution-induced rise in PM has also been recognised as a direct factor in the onset of cardiovascular disease (27,44). Short-term exposure to pollution triggers acute exacerbations, while long-term exposure results in decreased life expectancy (27). A study from Rahman *et al.* described how biomass burning in Bangladesh has been responsible for most PM air pollution but fossil fuel combustion PM affected CVD primarily (59). It showed a statistically significant increase in ED visits, hospitalisation, and mortality for seasons with increase in PM concentrations, although lower to effect sizes found in similar studies in developed countries. They argued that the cause of this finding is the lower prevalence of fossil fuel combustion in Bangladesh compared to high-income countries but it could also be explained by the different prevalence of CVD in the respective countries.

Country-specific responses to the crisis differ. Several countries are developing strategies to reduce the impact of climate change on cardiac health emergencies (60). While some countries place a high priority on public health campaigns that aim to educate the public about the dangers of CVD associated with heat and promote preventative measures, others invest in urban planning and put in place early warning systems for heatwaves to lessen the effects of heat islands. For instance, initiatives in the Netherlands emphasize early warning systems for heatwaves and community education (60). In France, the Plan Canicule reduces ED visits for heat-related CVDs by providing targeted interventions during heatwaves to protect vulnerable populations (61). Similarly, in Australia interventions include improving air quality and increasing access to cardiac care in bushfire-affected communities (61).

Despite efforts, many significant challenges still need to be overcome, such as unequal access to care, a lack of resources, and an inadequate healthcare infrastructure. It is recommended that future interventions prioritise interdisciplinary collaboration, policy advocacy, and public awareness campaigns to effectively address the intricate relationship between cardiac health and climate change (62).

Respiratory risk

Three major aspects of climate change have a significant impact on human respiratory health: the progressive global warming resulting from the greenhouse effect, the increased variability of weather patterns (63) and the increase in pollution (46). Respiratory diseases can be triggered directly or indirectly through the increased exposure to risk factors, the increased amount of allergens and the worsening air quality (63).

PM, ozone, and black carbon are three known air pollutants that are especially harmful to respiratory health (64). Higher pollen concentrations are thought to be caused by increased CO_2 levels, and rising average temperatures have been shown to increase the allergenicity of existing pollens (65). As a result, more people are visiting ED and using healthcare services for allergic diseases. A large study from Liu *et al.* with data from over 600 cities around the world found an independent link between short-term PM exposure and all causes of respiratory mortality (66). Higher temperatures are associated with a greater ozone burden, which in turn increases the prevalence of hospitalisations for chronic obstructive pulmonary disease (67) and asthma exacerbations (68).

Wildfires are also linked to an increase in ED visits for acute dyspnoea caused by airway irritation from fumes and combusted particles in both patients with and without pre-existing respiratory diseases (69). In the USA, areas like California and the Pacific Northwest have been particularly hit by wildfires and various studies have been published on the subject (44). Direct exposure to smoke from wildfires is the main cause for reparatory deterioration (5). In Australia, extreme heat events and bushfires have raised respiratory health concerns, prompting EDs to deploy specialised respiratory care units and community outreach programmes (70). In China, where levels of air pollution are already elevated (71), there has been a number of studies showing increase ED attendance for respiratory conditions (29).

Asthma in particular has been a subject of interest given its direct link with climate-related changes. Seven studies looked at the increase in attendance rate, rate of diagnosis of asthma in ED (13,17,42,43,46,69,72). The increase in ozone levels seems to be a major contributor, with one study showing how a decrease in greenhouse production in the USA would allow for 3,100 averted attendances per year, together with a significant reduction in healthcare spending (46). As extreme weather events become more common with global warming, the risk of asthma epidemics, so called thunderstorm asthma, become more prevalent. In 2016, Melbourne in Australia has seen one of these events where an excess of 3,365 asthma attack in a single day during a storm, leading to overwhelm the major ED, a ten-fold increase in asthma admission and 10 deaths (17).

Governments and healthcare systems are progressively allocating resources towards climate adaptation initiatives, such as the establishment of air quality monitoring networks, implementation of public awareness campaigns, and improvement of respiratory care services in ED. However, to lessen the increasing strain that respiratory illnesses brought on by climate change are placing on emergency medical systems, coordinated worldwide action is required (73).

Gastrointestinal health

Elevated temperatures, extreme weather events, and changes in precipitation patterns all have direct and indirect effects on water quality, food safety, and the spread of infectious agents, exacerbating gastrointestinal illnesses (74). Diarrheal diseases are a leading cause of death worldwide, particularly in low-income countries and among people of extreme ages (75).

Hurricanes and flooding events have been associated with increased pathogen transmission, leading to illnesses when contaminated water is ingested (76). As ocean temperatures rise as a result of the greenhouse effect, the probability of extreme weather events such as storms and hurricanes is anticipated to increase (77). Arbour J. L. Quist conducted a study on the link between acute gastrointestinal illnesses (AGI) and two hurricanes that hit the country in 2016 and 2018. A 15% and 9% rise in AGI-related ED visit rates was documented in the flooded regions throughout the corresponding hurricane periods (76).

A scoping review by Theron *et al.* looking at the impact of climate change on emergency care in the African continent has identified flooding as a significant risk factor for outbreaks of infectious diseases, including cholera,

malaria, leptospirosis, hepatitis A and E, schistosomiasis, and typhoid fever (12). Furthermore, elevated sea temperatures have contributed to a proliferation of waterborne pathogens, including *Vibrio parahaemolyticus* and ciguatera poisoning, both of which are prevalent contributors to seafood-associated AGI (18).

Another good example can be seen in Bangladesh where climate change has resulted in a heightened frequency of flooding which subsequently compromises the safety of drinking water sources and contributes to an outbreak of waterborne illnesses, including cholera and gastroenteritis (78). Similarly, rising temperatures in Australia promote the spread of foodborne pathogens such as *Salmonella* and *Campylobacter*, resulting in an increase in ED visits for gastrointestinal infections (79).

Three studies were found in our review regarding gastrointestinal pathologies. One study showed an association of gastrointestinal diseases after hurricanes (76), while another described an increase in the presentation to ED of patients with acute appendicitis (80). The third study from multiple paediatric hospitals in the USA showed an increase in gastroenteritis-related attendances (81).

Different nations have implemented diverse strategies in response to these challenges. Bangladesh has undertaken initiatives to develop community education on safe water practices in addition to infrastructure improvements related to water and sanitation (82). Australia has prioritised the improvement of surveillance systems and food safety regulations to reduce the incidence of foodborne illnesses (83).

Vector borne diseases

Infectious disease transmission is dependent on the interaction of host, agent, and environment, all of which are influenced by climate change (18,84).

The proliferation of vectors such as mosquitoes and ticks is facilitated by rising temperatures and altered precipitation patterns. As a result, the transmission of diseases including malaria, dengue fever, Zika virus, and Lyme disease has significantly increased (84).

Climate change has the potential to expose populations to a greater risk of mosquito and tick-borne diseases, leading to the emergence of novel diseases not typically endemic to specific regions (18). According to the Intergovernmental Panel on Climate Change, over the next 80 years, it is projected to be a rise in the prevalence of diseases such as malaria, Lyme disease, West Nile virus, and dengue fever (85). For instance, Aedes mosquitoes are increasingly being found in temperate regions such as North America and Europe, while Lyme disease and other tick-borne illnesses are rising in Canada (86).

Malaria, one of the most lethal and well-studied vector-borne diseases sensitive to climate, accounted for over 600,000 deaths in 2020 (87). Its spread has been observed to increase with rising temperatures, even reaching higher altitudes in regions like Ethiopia where it was not previously common (87).

Heatwaves have been associated with the proliferation of West Nile virus infections, as seen during an extreme summer heatwave in Europe in 2010, which led to a notable surge in cases (88). The nonspecific clinical manifestations of some vector-borne diseases pose challenges for diagnosis, underscoring the importance of emergency medicine physicians being cognizant of local shifts in disease rates driven by climate change.

A coordinated efforts from healthcare systems and governments to adapt and respond effectively to the evolving threat of vector-borne diseases is urgently needed. In Brazil, for example, the government took proactive steps to reduce mosquito breeding sites and increase public awareness about disease prevention due to the rising incidence of dengue fever (89). These measures included intensified mosquito control programmes and community engagement campaigns. Similar efforts have been made by the Indian government to distribute insecticide-treated bed nets to vulnerable populations and promote early detection and treatment of malaria, which is endemic there (90).

Healthcare professionals in the USA are increasing surveillance efforts due to the spread of Lyme disease and educating the public about preventive measures like donning protective gear and applying insect repellents (18). Additionally, research into innovative vector control methods, such as genetically modified mosquitoes, is underway in various countries to combat the spread of diseases (18).

Disaster management

Catastrophic events such as cyclones, storms, hurricanes, flooding, earthquakes, and landslides are predicted to increase as a direct effect of global warming (91). EDs are at the forefront of reception, management, and treatment of patients affected by natural disasters, and preparedness for these events will become increasingly important over time. The WHO projects that between 2030 and 2050, these phenomena will be accountable for over 250,000 annual

fatalities in Europe alone (75). Consequently, ED are likely to witness a surge in patients with minor or serious injuries. The massive influx of patients in a short period during a major incident disrupts the regular service in EDs. Therefore, hospitals worldwide need to be prepared for major incidents by planning and simulating the response to these critical events (24). Natural disasters can also lead to infrastructural collapse, causing damage to electrical systems, mobile network breakdowns, and water supply failures that can impact both patients and hospitals (53).

In the aftermath of Hurricane Katrina, the USA experienced overcrowded EDs, impeding the timely delivery of medical care (92). Similar to this, Bangladesh faces increased flooding and cyclone risks, which increases the need for emergency medical care as well as for evacuation activities (78).

We found five studies in our review with the key theme being the cause of attendance to ED following hurricanes (50-52) and cyclones (53) with most studies describing trauma and orthopaedic injuries being the most common reasons.

In response to disasters, countries worldwide are implementing various strategies to enhance disaster preparedness and response in emergency medicine (93). For example, the Netherlands has invested in flood prevention infrastructure and early warning systems to reduce the health risks associated with flooding (94).

Mental health

Climate change has a profound impact on mental health, manifesting through various direct and indirect ways, which in turn escalate the demand for emergency mental health services. Direct pathways encompass exposure to traumatic events such as bushfires, flooding, droughts, and other extreme weather occurrences. Indirect pathways involve climate-related disasters like forced displacements and loss of livelihoods, culminating in poverty, unemployment, and housing instability (95). Moreover, climate change exacerbates the vulnerabilities of marginalized populations, including those grappling with pre-existing mental health conditions and economic hardships, thus heightening the risk of mental health disorders (96).

The spectrum of mental health effects spans from mild stress and distress symptoms to clinical disorders, encompassing anxiety, sleep disturbances, depression, post-traumatic stress disorder (PTSD), and suicidal ideation. Particularly vulnerable are individuals and communities in low-income countries, expected to bear the brunt of climate change impacts. Responses to extreme events involving disruption of life, such as loss of life, property, social support, or extensive relocation, often lead to PTSD, depression, and anxiety, contributing to increased substance abuse, higher rates of sexual assault, and domestic violence (97,98).

Seven studies were found in our review that investigated the impact of climate change on mental health illnesses in the ED. The majority of these studies showed a direct relationship between rising climate temperatures and increase in ED attendances for conditions such as schizophrenia, depression, bipolar disorder, substance misuse and personality disorders (33,36). Additionally, a study done in the USA showed a direct correlation between pollutants (ozone and PM) and increased hospital admission for psychiatric disorders (99). Furthermore, a systematic review reported an elevated rate of suicide (both completed or attempted) as a direct consequence of climate change (14).

Trauma and environmental diseases

Rising temperatures and extreme weather events may lead to an increase in ED trauma admissions. Traumatic injuries comprise a significant portion of direct mortality during extreme weather occurrences, notably in incidents such as car and motorcycle accidents (98).

The increase in average temperatures has been associated with the increase in attendances to ED related to fractures and injuries in the UK (40) and a large study from 18 sites in China had a similar result (93).

Environmental shifts, including alterations in temperature, humidity, sun exposure, and land surface temperature, are linked to heightened heat vulnerability, particularly in urban locales. A recent study conducted in China utilized land surface temperatures to gauge exposure, severity, and adaptability, thereby determining heat vulnerability among the population (100). Heat-related illnesses disproportionately affect individuals affected by homelessness due to their social circumstances, reduced access to care, and the intricate interplay of substance misuse and mental health disorders (101).

Renal and urological disorders

Heat has been linked to increased ED visits for patients with acute kidney injuries (30,31). Elevated temperatures can result in dehydration, blood hyperosmolality, and

rhabdomyolysis. Moreover, chronic kidney disease is speculated to be more prevalent in regions with extreme heat exposure, primarily among workers (102). Kidney stone incidence demonstrates a correlation with ambient temperature, with higher temperatures in geographical areas associated with increased kidney stone formation, indicating an expected rise in patient admissions for urolithiasis (103).

Neurological conditions

Rising temperatures have been associated with heightened ED attendance among patients with multiple sclerosis (MS), attributed to relapse and acute exacerbation of their condition (37,38). The increase in body temperature, whether due to pyrexia from infection or from environmental factors is known to cause relapse in MS patients, condition called Uhthoff phenomenon. One study correlated increase pollution with additional ED attendances for patients with migraines (104). Experimental studies have linked air pollution with neurological damage and the combination of increase in temperatures and PM have been associated with migraines but the exact causation is still not clear (104).

Endocrine and dermatological disorders

A study investigated the correlation between an increase in daily high temperatures and a rise in ED attendance among patients with diabetes-related complications (15). Patients with DM are particularly prone to complications related to heatwaves because of their impaired autonomous nervous system response and also because of the overall increase in risk for CVD and renal diseases associated with pollution and increase in average daily temperatures. Two separate studies looked at dermatological conditions. A study from Pearson *et al.* observed the association of rising daily temperatures and increased ED visits due to hands foot and mouth disease in California (39) likely explained by coxsackie and enteroviruses thriving in humid and warm temperatures. They saw a 2% increase in ED attendances during the warm season per 1 °F increase in daily temperatures (39). A study from Chen *et al.* looked at the impact of flooding on ED attendances for atopic dermatitis flareup in children in the Taiwan region (105) with an odds ratio of 1.14 comparing case weeks with typhoons and control weeks. This is explained by an average rise in relative humidity, increasing the environmental dampness, an important risk factor for atopic dermatitis.

Mitigation strategies

Various options have been proposed to address the climate crisis in EDs worldwide. In the UK and Ireland, the RCEM has introduced the Green ED initiative to measure and reduce the environmental impact of EDs and to develop sustainable practices within the specialty (106). Their framework outlines different actions divided into bronze, silver, and gold levels that each ED should achieve to improve sustainability. Examples of actions include exclusive use of recycled paper, reduced use of Entonox, effective waste recycling, provision of reusable sharp bins, and minimization of electricity usage.

The concept of climate-smart healthcare was defined in 2017 by the World Bank Group and Health Care Without Harm as strategies to reduce carbon footprint and increase the resilience of healthcare systems (107). In the USA, the Climate Smart ED initiative suggests three major approaches to minimize contributions to climate change: addressing hospital operations, implementing departmental initiatives, and encouraging individual actions (19). Hospital operations may involve tracking wastage and implementing waste reduction or environmentally preferred purchasing options. At the departmental level, efforts may focus on increasing energy and water efficiency, reducing wastage, and minimizing the use of non-recyclable products. On an individual level, actions may include advocating for low-emission transportation and making lifestyle changes.

In Australia, a study on the impact of climate-related disasters on the health and well-being of healthcare workers (HCWs) has led to the development of the 'HCWs Resilience Toolkit'. This toolkit, developed through interviews with staff affected by natural disasters at work, encourages policymakers to support HCW needs such as wellness, education, resources, and communication (108).

In our review of the literature, we also found initiatives to raise awareness and inform emergency physicians about climate-related emergency conditions. In Karachi, Pakistan, an educational intervention focused on heat emergency awareness and treatment improved the approach to heat-related emergencies in four hospitals, leading to increased rates of diagnosis and accurate treatment post-intervention (26). Another tool developed in Boston, known as A CLIMATE, helped providers recognize, diagnose, and treat conditions commonly associated with climate change (20).

Historically, the climate crisis has been framed as an environmental challenge, with health impacts often

receiving little attention. As the climate crisis threatens to disrupt healthcare delivery, emergency medicine has the opportunity to mitigate exposures and improve health outcomes by applying climate-aware clinical decisions and behavioural interventions to care plans (109). Physicians continue to serve as trusted public health communicators and policy drivers. However, a workforce of clinicians with specific skills to address the climate crisis remains absent, despite the intersecting roles of climate and health policy. This gap is influenced by factors beyond healthcare, necessitating a broad, cross-sectoral approach to health policy (110).

The US Department of Health and Climate Resilient Health Services developed the Sustainable and Resilient Climate Healthcare Facilities Toolkit, in response to hospitals being forced to close and evacuate during hurricane disasters, resulting in devastating losses in infrastructure assets. Building resilient EDs and healthcare systems can minimize morbidity and mortality during such critical times (111).

Limitations and need for further research

There are various limitations inherent in this study. The search strategy was limited to publications written in the English language, which may have resulted in the exclusion of studies conducted in low-income or non-English speaking countries that lacked access to English publications.

In addition, we limited the study's scope to the last five years as we wanted to highlight current research and we believed that recent studies would be more specific to the current climate situation.

We noticed a gap in research pertaining to climate change and its impact to emergency medicine as most studies would have looked at single conditions and not how attendances and patterns of presentations are changing in view of the global warming. Some published studies called for action for physicians to become aware of climate change but there were no systematic reviews or metanalysis on the subject. We hope that this article adds to the growing literature on the effect of climate change on emergency medicine and encourages further research on the topic.

Conclusions

Climate change will inevitably play a vital part in provision of emergency care to patients in the coming future. Knowledge of its impact and the potential solutions to this problem can be of help for future clinicians. By recognising the challenges, emergency physicians can continue provide care to individuals affected by climate-related emergencies, while also contributing to the broader effort of building a resilient and sustainable healthcare system.

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Footnote

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References

1. World Health Organization. World Health Organization. Available online: https://www.who.int/health-topics/climate-change#tab=tab_1
2. Healthcare Without Harm. Health care's climate footprint. 2015. Available online: https://noharm-global.org/sites/default/files/documents-files/5961/HealthCaresClimateFo

otprint_092319.pdf
3. Hess JJ, Heilpern KL, Davis TE, et al. Climate change and emergency medicine: impacts and opportunities. Acad Emerg Med 2009;16:782-94.
4. Calleja-Agius J, England K, Calleja N. The effect of global warming on mortality. Early Hum Dev 2021;155:105222.
5. Stawovy L, Bathmaprya B. The Threat of Wildfires and Pulmonary Complications: A Narrative. Environmental and Occupational Health 2022;11:105.
6. Impact of Climate Change on Public Health and Implications for Emergency Medicine. Ann Emerg Med 2018;72:e49.
7. Royal College of Emergency Physicians. rcem.ac.uk. 2019. Available online: https://rcem.ac.uk/greened/
8. Australasian College of Emergency Medicine. ACEM.org.au. 2019. Available online: https://acem.org.au/getmedia/d37965ca-42ee-4a65-a979-ae1a13bcbf31/S68-Position-Statement-on-Climate-Change_R2
9. World Health Organization. Protecting Health from Climate Change. Switzerland; 2009.
10. Rodríguez-Jiménez L, Romero-Martín M, Spruell T, et al. The carbon footprint of healthcare settings: A systematic review. J Adv Nurs 2023;79:2830-44.
11. Brown LH, Buettner PG, Canyon DV. The energy burden and environmental impact of health services. Am J Public Health 2012;102:e76-82.
12. Theron E, Bills CB, Calvello Hynes EJ, et al. Climate change and emergency care in Africa: A scoping review. Afr J Emerg Med 2022;12:121-8.
13. Makrufardi F, Manullang A, Rusmawatiningtyas D, et al. Extreme weather and asthma: a systematic review and meta-analysis. Eur Respir Rev 2023;32:230019.
14. Corvetto JF, Helou AY, Dambach P, et al. A Systematic Literature Review of the Impact of Climate Change on the Global Demand for Psychiatric Services. Int J Environ Res Public Health 2023;20:1190.
15. Gao D, Friedman S, Hosler A, et al. Association between extreme ambient heat exposure and diabetes-related hospital admissions and emergency department visits: A systematic review. Hyg Environ Health Adv 2022;4:100031.
16. Cicci KR, Maltby A, Clemens KK, et al. High Temperatures and Cardiovascular-Related Morbidity: A Scoping Review. Int J Environ Res Public Health 2022;19:11243.
17. Thien F. Melbourne epidemic thunderstorm asthma event 2016: Lessons learnt from the perfect storm. Respirology 2018;23:976-7.
18. Sorensen CJ, Salas RN, Rublee C, et al. Clinical Implications of Climate Change on US Emergency Medicine: Challenges and Opportunities. Ann Emerg Med 2020;76:168-78.
19. Linstadt H, Collins A, Slutzman JE, et al. The Climate-Smart Emergency Department: A Primer. Ann Emerg Med 2020;76:155-67.
20. Nicholas PK, Breakey S, McKinnon S, et al. A CLIMATE: A Tool for Assessment of Climate-Change-Related Health Consequences in the Emergency Department. J Emerg Nurs 2021;47:532-542.e1.
21. Moretti K. An Education Imperative: Integrating Climate Change Into the Emergency Medicine Curriculum. AEM Educ Train 2021;5:e10546.
22. Dryden A, Tran V. Is it possible to make a meaningful environmental difference in the emergency department? No. Emerg Med Australas 2019;31:278-9.
23. Ting J. Is it possible to make a meaningful environmental difference in the emergency department? Yes. Emerg Med Australas 2019;31:276-7.
24. Ghazali DA, Guericolas M, Thys F, et al. Climate Change Impacts on Disaster and Emergency Medicine Focusing on Mitigation Disruptive Effects: an International Perspective. Int J Environ Res Public Health 2018;15:1379.
25. Rublee C, Bills C, Theron E, et al. Outcomes of a Climate Change Workshop at the 2020 African Conference on Emergency Medicine. Afr J Emerg Med 2021;11:372-7.
26. Khan NU, Khan UR, Ahmed N, et al. Improvement in the diagnosis and practices of emergency healthcare providers for heat emergencies after HEAT (heat emergency awareness & treatment) an educational intervention: a multicenter quasi-experimental study. BMC Emerg Med 2023;23:12.
27. Contiero P, Boffi R, Tagliabue G, et al. A Case-Crossover Study to Investigate the Effects of Atmospheric Particulate Matter Concentrations, Season, and Air Temperature on Accident and Emergency Presentations for Cardiovascular Events in Northern Italy. Int J Environ Res Public Health 2019;16:4627.
28. Zhu W, Wei X, Zhang L, et al. The effect and prediction of diurnal temperature range in high altitude area on outpatient and emergency room admissions for cardiovascular diseases. Int Arch Occup Environ Health 2021;94:1783-95.
29. Ma Y, Zhou J, Yang S, et al. Effects of extreme temperatures on hospital emergency room visits for respiratory diseases in Beijing, China. Environ Sci Pollut Res Int 2019;26:3055-64.

30. Xu Z, Hu X, Tong S, et al. Heat and risk of acute kidney injury: An hourly-level case-crossover study in Queensland, Australia. Environ Res 2020;182:109058.
31. Kim SE, Lee H, Kim J, et al. Temperature as a risk factor of emergency department visits for acute kidney injury: a case-crossover study in Seoul, South Korea. Environ Health 2019;18:55.
32. Qu Y, Zhang W, Boutelle AM, et al. Associations Between Ambient Extreme Heat Exposure and Emergency Department Visits Related to Kidney Disease. Am J Kidney Dis 2023;81:507-516.e1.
33. Lavigne E, Maltby A, Côté JN, et al. The effect modification of extreme temperatures on mental and behavior disorders by environmental factors and individual-level characteristics in Canada. Environ Res 2023;219:114999.
34. Mullins JT, White C. Temperature and mental health: Evidence from the spectrum of mental health outcomes. J Health Econ 2019;68:102240.
35. Yoo EH, Eum Y, Roberts JE, et al. Association between extreme temperatures and emergency room visits related to mental disorders: A multi-region time-series study in New York, USA. Sci Total Environ 2021;792:148246.
36. Niu L, Girma B, Liu B, et al. Temperature and mental health-related emergency department and hospital encounters among children, adolescents and young adults. Epidemiol Psychiatr Sci 2023;32:e22.
37. Byun S, Myung W, Kim H, et al. Association between diurnal temperature range and emergency department visits for multiple sclerosis: A time-stratified case-crossover study. Sci Total Environ 2020;720:137565.
38. Elser H, Parks RM, Moghavem N, et al. Anomalously warm weather and acute care visits in patients with multiple sclerosis: A retrospective study of privately insured individuals in the US. PLoS Med 2021;18:e1003580.
39. Pearson D, Basu R, Wu XM, et al. Temperature and hand, foot and mouth disease in California: An exploratory analysis of emergency department visits by season, 2005-2013. Environ Res 2020;185:109461.
40. Corcuera Hotz I, Hajat S. The Effects of Temperature on Accident and Emergency Department Attendances in London: A Time-Series Regression Analysis. Int J Environ Res Public Health 2020;17:1957.
41. Adams J, Brumby S, Kloot K, et al. High-Heat Days and Presentations to Emergency Departments in Regional Victoria, Australia. Int J Environ Res Public Health 2022;19:2131.
42. Kiser D, Metcalf WJ, Elhanan G, et al. Particulate matter and emergency visits for asthma: a time-series study of their association in the presence and absence of wildfire smoke in Reno, Nevada, 2013-2018. Environ Health 2020;19:92.
43. Gan RW, Liu J, Ford B, et al. The association between wildfire smoke exposure and asthma-specific medical care utilization in Oregon during the 2013 wildfire season. J Expo Sci Environ Epidemiol 2020;30:618-28.
44. Casey JA, Kioumourtzoglou MA, Elser H, et al. Wildfire particulate matter in Shasta County, California and respiratory and circulatory disease-related emergency department visits and mortality, 2013-2018. Environ Epidemiol 2021;5:e124.
45. Cheng B, Ma Y, Wang H, et al. Particulate matter pollution and emergency room visits for respiratory diseases in a valley Basin city of Northwest China. Environ Geochem Health 2021;43:3457-68.
46. Nassikas N, Spangler K, Fann N, et al. Ozone-related asthma emergency department visits in the US in a warming climate. Environ Res 2020;183:109206.
47. Nassikas NJ, Spangler K, Wellenius GA. Asthma Exacerbations Attributable to Ozone Air Pollution in New England. R I Med J (2013) 2021;104:20-3.
48. Friedman RSC, Carpenter DM, Shaver JM, et al. Telemedicine Familiarity and Post-Disaster Utilization of Emergency and Hospital Services for Ambulatory Care Sensitive Conditions. Am J Prev Med 2022;63:e1-9.
49. Wondmagegn BY, Xiang J, Dear K, et al. Understanding current and projected emergency department presentations and associated healthcare costs in a changing thermal climate in Adelaide, South Australia. Occup Environ Med 2022;79:421-6.
50. Weinberger KR, Kulick ER, Boehme AK, et al. Association Between Hurricane Sandy and Emergency Department Visits in New York City by Age and Cause. Am J Epidemiol 2021;190:2138-47.
51. Frasqueri-Quintana VM, Oliveras García CA, Adams LE, et al. Injury-Related Emergency Department Visits After Hurricane Maria in a Southern Puerto Rico Hospital. Disaster Med Public Health Prep 2020;14:63-70.
52. Heslin KC, Barrett ML, Hensche M, et al. Effects of Hurricanes on Emergency Department Utilization: An Analysis Across 7 US Storms. Disaster Med Public Health Prep 2021;15:762-9.
53. Mohanty CR, Jain M, Radhakrishnan RV, et al. Tropical

cyclone Fani-perspective from the trauma and emergency department of an affected tertiary hospital. Chin J Traumatol 2020;23:243-8.
54. Uz İ, Çetin M, Songur Kodik M, et al. Emergency department management after the 2020 Aegean Sea - Izmir earthquake. Ulus Travma Acil Cerrahi Derg 2022;28:361-8.
55. Cheng J, Xu Z, Bambrick H, et al. Cardiorespiratory effects of heatwaves: A systematic review and meta-analysis of global epidemiological evidence. Environ Res 2019;177:108610.
56. Basu R. High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. Environ Health 2009;8:40.
57. Mason H, C King J, E Peden A, et al. Systematic review of the impact of heatwaves on health service demand in Australia. BMC Health Serv Res 2022;22:960.
58. Wen B, Wu Y, Xu R, et al. Excess emergency department visits for cardiovascular and respiratory diseases during the 2019-20 bushfire period in Australia: A two-stage interrupted time-series analysis. Sci Total Environ 2022;809:152226.
59. Rahman MM, Garcia E, Lim CC, et al. Temperature variability associations with cardiovascular and respiratory emergency department visits in Dhaka, Bangladesh. Environ Int 2022;164:107267.
60. Sitati A, Joe E, Pentz B, et al. Climate change adaptation in conflict-affected countries: A systematic assessment of evidence. Discov Sustain 2021;2:42.
61. Faurie C, Varghese BM, Liu J, et al. Association between high temperature and heatwaves with heat-related illnesses: A systematic review and meta-analysis. Sci Total Environ 2022;852:158332.
62. Xu R, Shi C, Wei J, et al. Cause-specific cardiovascular disease mortality attributable to ambient temperature: A time-stratified case-crossover study in Jiangsu province, China. Ecotoxicol Environ Saf 2022;236:113498.
63. Joshi M, Goraya H, Joshi A, et al. Climate change and respiratory diseases: a 2020 perspective. Curr Opin Pulm Med 2020;26:119-27.
64. Manisalidis I, Stavropoulou E, Stavropoulos A, et al. Environmental and Health Impacts of Air Pollution: A Review. Front Public Health 2020;8:14.
65. Beggs PJ. Impacts of climate change on aeroallergens: past and future. Clin Exp Allergy 2004;34:1507-13.
66. Liu C, Chen R, Sera F, et al. Ambient Particulate Air Pollution and Daily Mortality in 652 Cities. N Engl J Med 2019;381:705-15.
67. Medina-Ramón M, Zanobetti A, Schwartz J. The effect of ozone and PM10 on hospital admissions for pneumonia and chronic obstructive pulmonary disease: a national multicity study. Am J Epidemiol 2006;163:579-88.
68. McConnell R, Berhane K, Gilliland F, et al. Asthma in exercising children exposed to ozone: a cohort study. Lancet 2002;359:386-91.
69. Reid CE, Brauer M, Johnston FH, et al. Critical Review of Health Impacts of Wildfire Smoke Exposure. Environ Health Perspect 2016;124:1334-43.
70. Borchers Arriagada N, Bowman DMJS, Palmer AJ, et al. Climate Change, Wildfires, Heatwaves and Health Impacts in Australia. In: Akhtar R. editor. Extreme Weather Events and Human Health. Springer, Cham; 2020:99-116.
71. Song X, Jiang L, Wang S, et al. The impact of main air pollutants on respiratory emergency department visits and the modification effects of temperature in Beijing, China. Environ Sci Pollut Res Int 2021;28:6990-7000.
72. Figgs LW. Emergency department asthma diagnosis risk associated with the 2012 heat wave and drought in Douglas County NE, USA. Heart Lung 2019;48:250-7.
73. Fox M, Zuidema C, Bauman B, et al. Integrating Public Health into Climate Change Policy and Planning: State of Practice Update. Int J Environ Res Public Health 2019;16:3232.
74. Ebi KL, Vanos J, Baldwin JW, et al. Extreme Weather and Climate Change: Population Health and Health System Implications. Annu Rev Public Health 2021;42:293-315.
75. World Health Organization. 2017. Available online: https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease
76. Quist AJL, Fliss MD, Wade TJ, et al. Hurricane flooding and acute gastrointestinal illness in North Carolina. Sci Total Environ 2022;809:151108.
77. Reed KA, Wehner MF, Zarzycki CM. Attribution of 2020 hurricane season extreme rainfall to human-induced climate change. Nat Commun 2022;13:1905. Erratum in: Nat Commun 2022;13:2589.
78. Hossain B, Sohel S, Ryakitimbo CM, et al. Climate change induced extreme flood disaster in Bangladesh: Implications on people's livelihoods in the Char Village and their coping mechanisms. Progress in Disaster Science 2020;6:100079.
79. Jiang C, Shaw KS, Upperman CR, et al. Climate change, extreme events and increased risk of salmonellosis in Maryland, USA: Evidence for coastal vulnerability. Environ Int 2015;83:58-62.

80. Simmering JE, Polgreen LA, Talan DA, et al. Association of Appendicitis Incidence With Warmer Weather Independent of Season. JAMA Netw Open 2022;5:e2234269.
81. Bernstein AS, Shengzhi S, Weinberger KR, et al. Warm Season and Emergency Department Visits to U.S. Children's Hospitals. Environ Health Perspect 2022;130:17001.
82. Chowdhury A, Hasan K, Labib Ul Islam S, et al. Climate change adaptation in Bangladesh: Current practices, challenges and the way forward. The Journal of Climate Change and Health 2022;6:100108.
83. Oldroyd RA, Morris MA, Birkin M. Identifying Methods for Monitoring Foodborne Illness: Review of Existing Public Health Surveillance Techniques. JMIR Public Health Surveill 2018;4:e57.
84. Smith E. The Effect of Potential Climate Change on Infectious Disease Presentation. Journal for Nurse Practitioners 2019;15:405-9.
85. Intergovernmental Panel on Climate Change. Climate change 2022: impacts, adaptation and vulnerability. 2022.
86. Nelder MP, Wijayasri S, Russell CB, et al. The continued rise of Lyme disease in Ontario, Canada: 2017. Can Commun Dis Rep 2018;44:231-6.
87. Lyon B, Dinku T, Raman A, et al. Temperature suitability for malaria climbing the Ethiopian Highlands. Environ Res Lett 2017;12:064015.
88. Thomson MC, Stanberry LR. Climate Change and Vectorborne Diseases. N Engl J Med 2022;387:1969-78.
89. Araújo HR, Carvalho DO, Ioshino RS, et al. Aedes aegypti Control Strategies in Brazil: Incorporation of New Technologies to Overcome the Persistence of Dengue Epidemics. Insects 2015;6:576-94.
90. Neta G, Pan W, Ebi K, et al. Advancing climate change health adaptation through implementation science. Lancet Planet Health 2022;6:e909-18.
91. Ritchie H, Rosado P. Natural Disasters. 2024 [cited 2024 may]. Available online: https://ourworldindata.org/natural-disasters
92. Mortensen K, Dreyfuss Z. How Many Walked through the Door? The Effect of Hurricane Katrina Evacuees on Houston Emergency Departments. Medical Care 2008;46:998-1001.
93. Wang Y, Tang Q, Wright N. Managing Urban Flood Risk and Building Resilience in a Changing Climate. In: Tang Q, Leng G. editors. Climate Risk and Sustainable Water Management. Cambridge University Press; 2022:315-41.
94. Filho WL, Tuladhar L, Li C, et al. Climate change and extremes: implications on city livability and associated health risks across the globe. International Journal of Climate Change Strategies and Management 2022;15:1-19.
95. Hwong AR, Wang M, Khan H, et al. Climate change and mental health research methods, gaps, and priorities: a scoping review. Lancet Planet Health 2022;6:e281-91.
96. Cianconi P, Betrò S, Janiri L. The Impact of Climate Change on Mental Health: A Systematic Descriptive Review. Front Psychiatry 2020;11:74.
97. Charlson F, Ali S, Benmarhnia T, et al. Climate Change and Mental Health: A Scoping Review. Int J Environ Res Public Health 2021;18:4486.
98. Massazza A, Ardino V, Fioravanzo RE. Climate change, trauma and mental health in Italy: a scoping review. Eur J Psychotraumatol 2022;13:1-16.
99. Qiu X, Danesh-Yazdi M, Wei Y, et al. Associations of short-term exposure to air pollution and increased ambient temperature with psychiatric hospital admissions in older adults in the USA: a case-crossover study. Lancet Planet Health 2022;6:e331-41.
100. Soomar SM, Soomar SM. Identifying factors to develop and validate a heat vulnerability tool for Pakistan- A Review. Clinical Epidemiology and Global Health 2022;19:101214.
101. English T, Larkin M, Vasquez Hernandez A, et al. Heat Illness Requiring Emergency Care for People Experiencing Homelessness: A Case Study Series. Int J Environ Res Public Health 2022;19:16565.
102. Johnson RJ, Sánchez-Lozada LG, Newman LS, et al. Climate Change and the Kidney. Ann Nutr Metab 2019;74 Suppl 3:38-44.
103. Brikowski TH, Lotan Y, Pearle MS. Climate-related increase in the prevalence of urolithiasis in the United States. Proc Natl Acad Sci U S A 2008;105:9841-6.
104. Lee H, Myung W, Cheong HK, et al. Ambient air pollution exposure and risk of migraine: Synergistic effect with T high temperature. Environ Int 2018;121:383-91.
105. Chen NT, Chen MJ, Wu CD, et al. Emergency room visits for childhood atopic dermatitis are associated with floods? Sci Total Environ 2021;773:145435.
106. Royal College of Emergency Medicine. Green ED. Available online: https://greened.rcem.ac.uk
107. World Bank Group. Climate-smart healthcare: low-carbon and resilience strategies for the health sector. 2017. Available online: https://documents1.worldbank.org/curated/

zh/322251495434571418/pdf/113572-WP-PUBLIC-FINAL-WBG-Climate-smart-Healthcare-002.pdf
108. Mohtady Ali H, Ranse J, Roiko A, et al. Healthcare Workers' Resilience Toolkit for Disaster Management and Climate Change Adaptation. Int J Environ Res Public Health 2022;19:12440.
109. Limaye VS. Making the climate crisis personal through a focus on human health. Clim Change 2021;166:43.
110. Salas RN, Friend TH, Bernstein A, et al. Adding A Climate Lens To Health Policy In The United States. Health Aff (Millwood) 2020;39:2063-70.
111. Benjamin GC. Shelter in the Storm: Health Care Systems and Climate Change. Milbank Q 2016;94:18-22.

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Supplementary

Appendix 1 Search strategy

Database*: *PubMed

("climate change" OR "global warming" OR "heatwave" OR "heat wave" OR "greenhouse effect" OR "wildfire" OR "natural disaster") AND ("Emergency department" OR "emergency medicine" OR "emergency department*" OR "emergency room" OR "emergency physician" OR "emergency physicians")
(("global warming"[All Fields] OR "climate change"[All Fields] OR "heatwave"[All Fields] OR "heat wave"[All Fields] OR "greenhouse effect"[All Fields] OR "wildfire"[All Fields] OR "wild fire"[All Fields] OR "natural disaster"[All Fields] OR ("climate change"[MeSH Terms] OR "wildfires"[MeSH Terms] OR "global warming"[MeSH Terms] OR "greenhouse effect"[MeSH Terms] OR "natural disasters"[MeSH Terms])) AND ("emergency department"[All Fields] OR "emergency departments"[All Fields] OR "emergency medicine"[All Fields] OR "emergency room"[All Fields] OR "emergency physician"[All Fields] OR "emergency physicians"[All Fields] OR "accident and emergency"[All Fields] OR ("emergency service, hospital"[MeSH Terms] OR "emergency medicine"[MeSH Terms] OR "emergency medical services"[MeSH Terms]))) AND (y_5[Filter])

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