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Examining the Health Impacts of Climate Change Through Electronic Health Records: A Rapid Review

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Abstract

Introduction

Temperature extremes, including elevated heat and cold, are important environmental determinants of health whose frequency and duration are increasing due to climate change. Ecological and time-series studies have established links with adverse outcomes but often lack individual-level detail. Electronic health records (EHR) provide an alternative source, yet their use in climate-health research remains inconsistent.

Methods

We conducted a rapid review of peer-reviewed studies using EHR data to examine associations between temperature extremes and health outcomes across healthcare settings. The aim was to assess how health impacts of temperature extremes have been captured and coded within EHR-based research, and to identify methodological and coding-related gaps. Searches of seven databases identified eligible studies, and data were extracted on exposure definitions, outcome coding, methods, findings, and limitations.

Results

Of 1,616 records identified, 526 duplicates were removed, leaving 1,090 for screening; 58 studies met inclusion criteria. Extreme heat was most frequently studied, with fewer analyses of cold. Common outcomes included morbidity, cardiovascular admissions, asthma, and pregnancy-related conditions. Mental health outcomes were rarely examined, subgroup analyses were mostly age-based, and studies focused on high-income countries. Exposure metrics and coding practices varied widely, with limited reporting of diagnostic codes and individual-level mediators.

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Conclusion

Harmonized exposure definitions, broader outcome coverage, and integration of socio-demographic and individual-level factors are needed to strengthen EHR-based climate-health research and guide targeted interventions.

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Introduction

Temperature extremes, including prolonged periods of high heat or cold, are increasingly recognized as important environmental determinants of health. Their frequency and duration are projected to rise due to climate change, with significant implications for healthcare demand and health outcomes across diverse population groups [1]. Numerous studies have documented associations between extreme temperatures and a range of adverse outcomes, including increases in emergency department visits, hospitalizations, and mortality [2,3]. These effects are disproportionately observed in older adults, individuals with chronic health conditions, and residents of socioeconomically disadvantaged areas [4-6]. Despite these findings, most existing research relies on ecological or time-series designs using aggregated health data. While these approaches have advanced understanding of short-term effects, they are limited in their ability to capture individual-level variation, account for pre-existing health conditions, or consider how patterns of healthcare utilization and behavioral responses may mediate climate-health relationships. This restricts the capacity to identify the most vulnerable subpopulations and develop targeted, evidence-based interventions.

Electronic health records (EHR) offer an alternative and potentially more powerful approach. These routinely collected datasets provide longitudinal, individual-level information on diagnoses, prescriptions, consultations, and demographic characteristics. Large-scale resources such as the Clinical Practice Research Datalink (CPRD) and the Secure Anonymised Information Linkage (SAIL) Databank hold millions of records, enabling population-based analyses of climate-related health outcomes [7]. However, EHR-based studies in this field are hampered by substantial methodological heterogeneity. Differences in temperature metrics, exposure windows, and diagnostic coding systems, combined with inconsistent reporting of these methods, limit interpretability, comparability, and synthesis of

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findings. Furthermore, research to date has tended to focus on a narrow range of health outcomes and high-income settings, often neglecting mental health and other potentially climate-sensitive conditions. Accordingly, this rapid review aims to examine how health impacts of temperature extremes have been captured and coded within EHR-based research across healthcare settings, and to identify methodological and coding-related gaps in the current evidence base.

Methods

This rapid scoping review followed the methodological framework of Arksey and O'Malley [8], refined by Levac et al. [9], and adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) [10]. The process involved: (i) identifying eligibility criteria and relevant studies; (ii) selecting studies for inclusion; (iii) extracting and charting data; and (iv) collating, summarising, and reporting findings.

Eligibility Criteria

We included studies that were: (i) based on EHR or linked routinely collected health data; (ii) examined health outcomes, healthcare utilization, or interventions in the context of temperature extremes (heatwaves, cold events, extreme humidity, or other temperature-related exposures); (iii) published in peer-reviewed journals, academic books, conference proceedings, or relevant grey literature; and (iv) available in English. Studies that did not meet these criteria were excluded.

Search Strategy

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Searches were developed in consultation with an information specialist from the University of Southampton and refined with input from climate change and medical experts. Initial terms were piloted and revised before final implementation. Keywords and Medical Subject Headings (MeSH) combined terms for exposures (e.g., "temperature extreme*," "heatwave*," "hot weather," "cold spell*," "freeze*," "extreme humidity," "climate") with health data sources (e.g., "EHR," "routinely collected data," "registry data," "health administrative data"). Variants were searched using title, abstract, and indexing fields. Searches were run from database inception to 7 July 2025 in MEDLINE (Ovid), Embase (Ovid), GreenFILE, Web of Science, Scopus, CINAHL (EBSCOhost), and Cochrane.

Study Selection

Results were imported into Rayyan and duplicates removed. Titles and abstracts were screened independently by three reviewers (CP, AD, LS). Full-text screening was conducted for studies meeting inclusion criteria or where eligibility was unclear, with disagreements resolved by consensus or adjudication by a third reviewer.

Data Extraction and Charting

A standardized, piloted data extraction form was used to record: study characteristics (authors, year, country, design); population demographics; exposure type, metrics, and duration; health outcomes (morbidity, mortality, hospital admissions, primary care visits, or other utilization measures); EHR dataset and meteorological data source; coding approach (diagnostic, symptom, or utilization codes, classification system used); specific codes; key findings; and reported limitations. Data were extracted by CP, AD, LS, NH, and NKE.

Data Synthesis

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Extracted data were summarized descriptively and grouped thematically by type of climate variable studied, health outcomes assessed, exposure definitions and metrics, codes and terminology used, sources of climatic data, and patterns in study design and population characteristics. Key findings and limitations were analysed to identify trends, methodological issues, and evidence gaps, summarized narratively and presented in summary tables.

Results

Study Selection

Database searches yielded 1,616 records; 526 duplicates were removed, leaving 1,090 for title and abstract screening. A further 845 were excluded, and 245 underwent full-text review. One hundred and eighty-seven were excluded, resulting in 58 studies for analysis (Figure 1).

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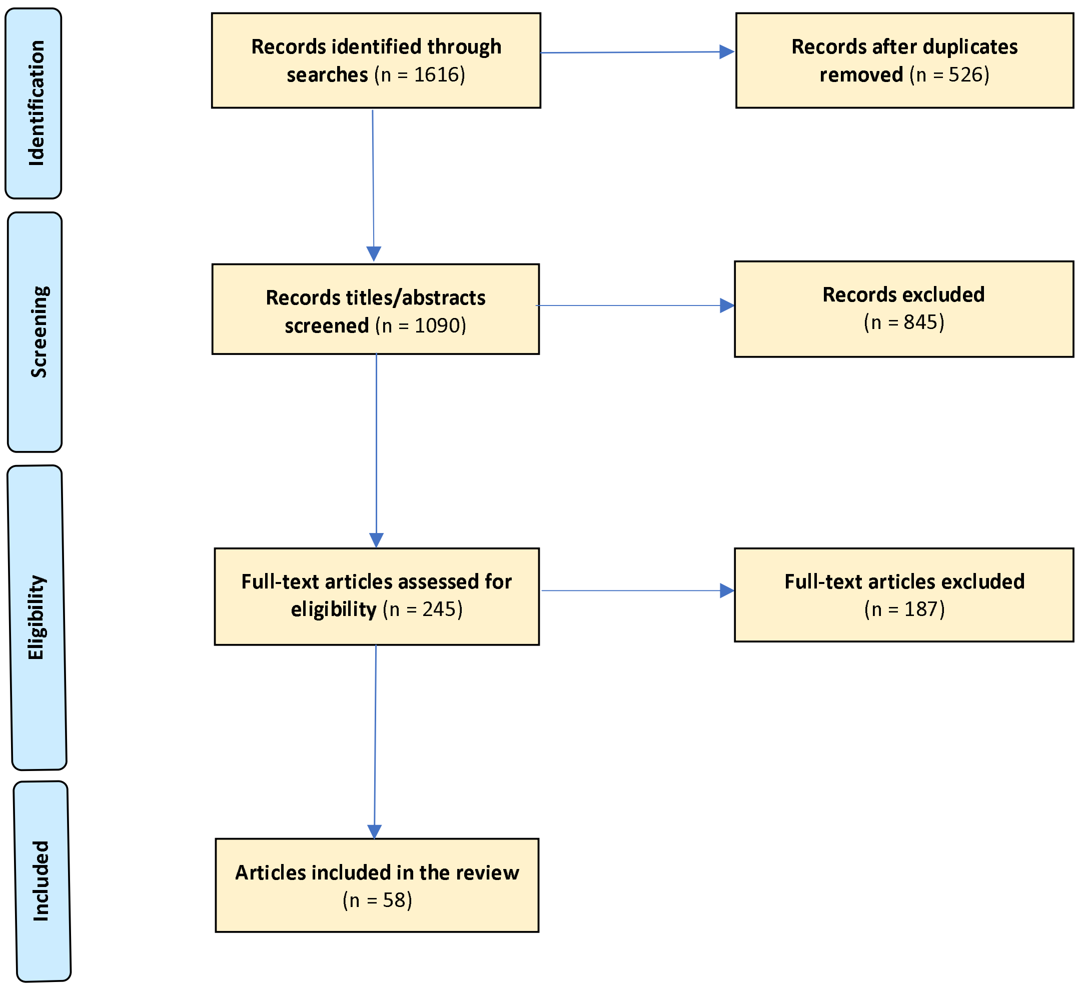
Figure 1: Adapted PRISMA Flow Chart showing explaining the study's documentary inclusion process (Examining the Health Impacts of Climate Change Through Electronic Health Records: A Rapid Review)



Study characteristics

Full details on all study characteristics can be found in supplementary data, table 1. Of the 58 studies, 42 (72%) were from high income countries [11,13,14,15,16,18,22,23,24,25,26,27,29,30,31,32,33,36,37,39,40,41,42,44,45,46,47,49,50,51

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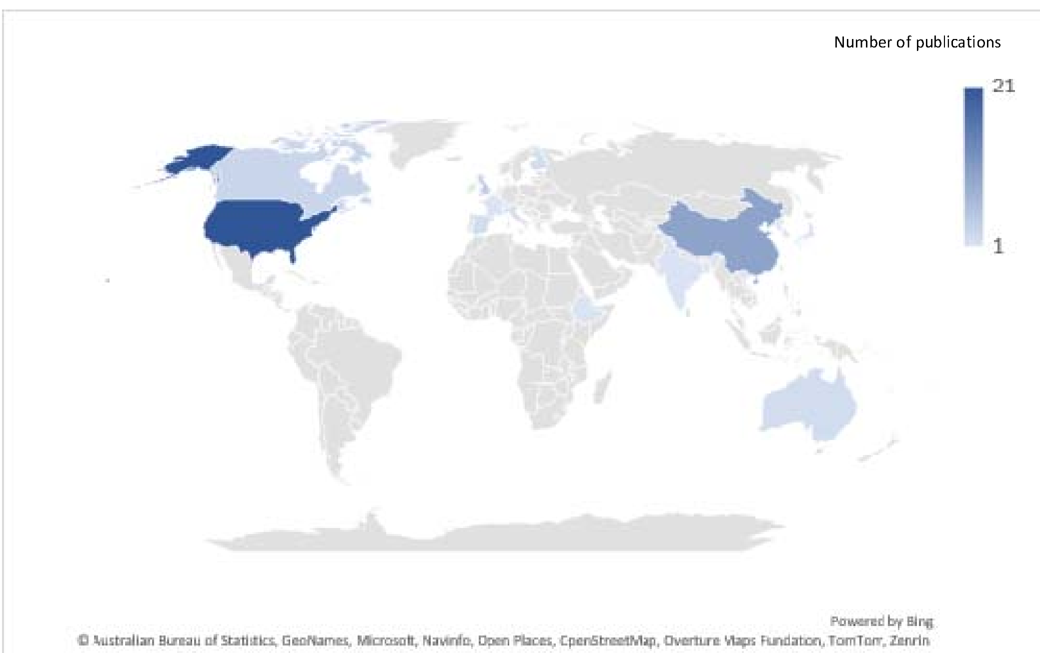
,52,53,54,55,56,57,59,61,63,64,65,66], 11 (19%) were from upper middle-income countries [17,19,20,21,28,35,43,48,58,62,68] and three (5%) were from lower middle-income countries [12,34,67]. Two studies (4%) were extracted from a mix of low and high income countries [38,60].

In total, 21 studies were located in the USA [13,14,15,16,18,22,25,26,29,30,31,33,39,42,47,50,52,53,63,64,65], 10 focused on China [17,19,20,21,28,35,43,48,58,68], four in the UK [32,51,54,59], three in Canada [11,44,57], two in Spain [27,40], Australia [45,55], Italy [36,49], Finland [24,46], and one study each from Ethiopia [67], Macao territory [66], India [62] France [61], Belgium [23], Kuwait [56], North Tanzania [12], Singapore [41], Vietnam [34] and Japan [37]. Lastly, two studies used mixed country populations [38,60]. Figure 2 visually displays the countries of origin.

Figure 2: A heat map of geographic location for all studies included in the rapid review



There has been an increasing trend in publications post 2020, with 45 papers (77%) being published between 2020-2025, as shown in figure 3. The main study type used was a

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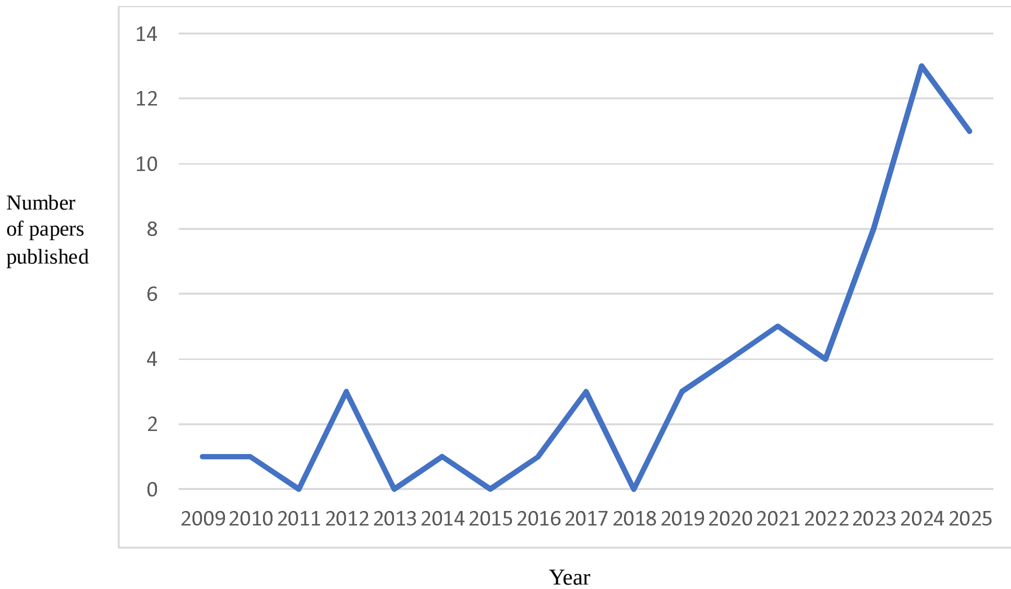
retrospective cohort design (n=33) and the look back period ranged from two to 24 years, with a mean of 9.5 years.

Four studies made predictions based on forecast models [13,14,33,37], one study included a climate change intervention [44] and one study was a systematic review [60].

Figure 3: A line frequency graph showing number of publications by year which are focused on climate change exposures and health outcomes variables



Populations included in the studies were mostly adult, although some studies included on children (n=10). No studies referred to subgroup analysis beyond age as a factor. In terms of other sub-populations, the impact of climate extremes on veterans were also analysed (n=2). Many studies referred to whole cohorts, and the demographic details of who was in this cohort were not made explicit.

The use of electronic health care records to record health outcomes

EHR were used to capture health outcomes across a broad range of themes, including mortality (n=13), neonatal/pregnancy outcomes (n=13), health service usage/cost (n=11),

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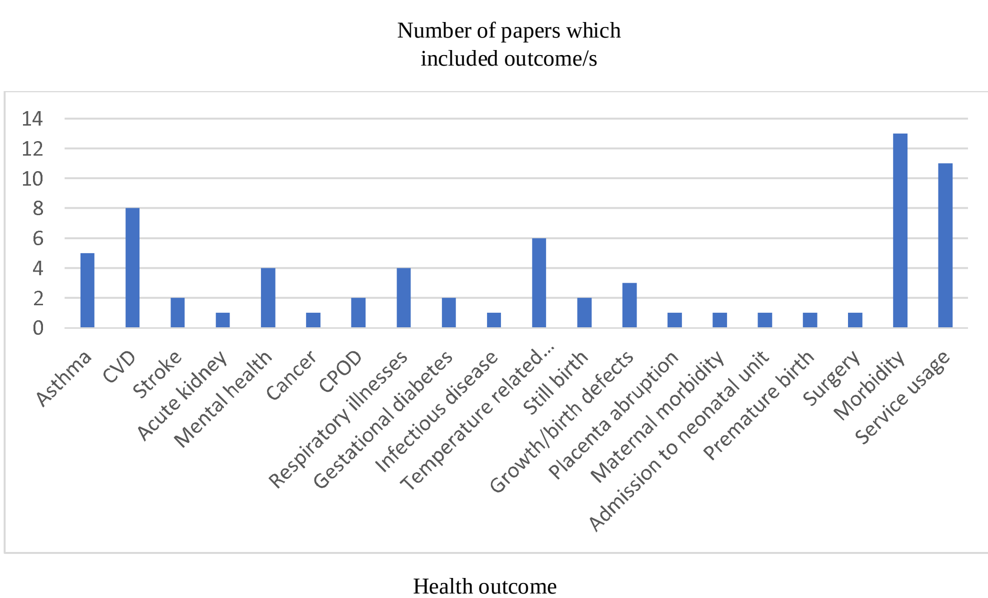
reference to a specific illness or disease area/s (n=23), temperature related illness/injuries (n=5), mental health (n=4), (two of which referred to post-partum depression) outcomes after surgery (n=1). For studies which made reference to a specific illness or disease area, the majority of studies focused on cardiovascular disease (n=8), asthma (n=5), respiratory diseases (n=4), temperature related illness or injuries such as dehydration, heat stroke or frost bite (n=6), mental health (n=4), ischemic stroke (n=2), gestational diabetes (n=2) acute kidney disease (n=1), infectious diseases (n=1). Health outcomes related to neonatal/pregnancy outcomes, included still births (n=2), placental abruption (n=1), growth and/or birth defects (n=3), placental abruption (n=1), maternal morbidity (n=1), and premature delivery (n=1). No study considered the impact of climate change exposure on people with multiple long-term conditions. Figure 4 provides a visual representation of the different health outcomes explored using EHR.

Figure 4. A bar graph to show health outcomes extracted from the EHR for all studies focused on climate change exposure variables and health outcomes



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The majority of studies used either ICD 9/10 codes to extract the data from EHR (n=31), 16 studies used different registries to obtain their data, two studies used SNOWMED codes, and nine studies did not make explicit how they extracted their data. There was a general missingness of coding detail across the studies, and in particular where ICD 9/10 or SNOWMED were used, the specific codes utilized to extract the data were only included in 15 papers**.**

Lastly, the settings from which EHR data was extracted was primarily secondary hospital level data, especially from emergency departments. Only one study examined primary care data, and this was in relation to missed appointments [65], and one study looked at visits to a tertiary mental health clinic [57].

Climate change variables

Twelve different exposure variables were extracted from the 58 papers, these included microclimate data, thunderstorms/major storms, flooding, snowfall, solar output, wind speed, humidity, rainfall/precipitation, air pollutants, extreme cold weather, extreme hot weather, and temperature including both extreme heat and cold weather events. The most common exposure variable, featured in 29 (50%) of the papers was temperature, followed by a focus on extreme heat events (n=13). Cold weather events were less frequently focused on (n=2). Table 1 shows the number of papers for each climate change variable.

Table 1: Number of papers examining each climate change exposure variable

Climate change exposure variable	Number of papers	Paper reference
Microclimate	2	26, 31
Storms/thunderstorms	2	28, 29
Flooding	2	24, 29
Solar output	2	53, 66
Snowfall	1	64
Wind speed	2	49, 66
Humidity	8	29, 33, 34, 49, 52, 53, 56, 66
Precipitation	6	35, 37, 42, 49, 53, 65
Air pollutants	8	15, 19, 20, 21, 22, 61, 66, 73

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Extreme cold weather events	2	27, 50
Extreme heat weather events	13	10, 13, 15, 18, 23, 24, 31, 36, 41, 46, 56, 61, 62
Temperature (both hot and cold)	29	2, 12, 14, 16, 17, 19, 20, 25, 26, 32, 33, 34, 35, 37, 38, 39, 40, 43, 45, 48, 51, 52, 54, 57, 58, 59, 60, 63, 65

Definition and metrics used across exposure variables varied across papers. For definitions of extreme heat, studies used different percentile cut off points, ranging from a temperature over the 90th percentile, to over the 99th percentile, though the 97.5th percentile was most frequently cited as a suitable cut off point for an extreme heat threshold (n=4). Studies also varied in the number of days a certain temperature had to be experienced for it to be classified as a heat wave (between 2-4 days). Similarly, variance was seen in cut-off points for extreme cold, with temperatures ranging from below the 2.5th percentile, to below the 10th percentile. Inconsistency in duration of temperature recordings was seen, with recordings ranging from hourly (n=4), daily (n=17) weekly (n=3), monthly (n=2) to annually (n=2). Time lag data from exposure to health outcome also differed, from 24 hours, 14 days, 21 days, 30 days to 30 years. Lastly, four papers [22,29,61,68] referred to using a resolution grid to provide a spatial imagery of temperature, and areas selected varied from 1x1 km to 500 km.

Key findings by exposure variables and health outcomes

Table 2 provides a summary of key findings for each study. Overall, the findings from the narrative synthesis indicate that extreme temperatures, either cold or hot, can impact health across a range of health outcomes, and this can vary by gender and deprivation, with those who are most socially vulnerable experiencing increased risks.

In relation to neonatal outcomes, exposure to extreme temperature leads to poorer outcomes for baby, but these vary by hot and cold. Increased exposure to heat is associated with high

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risk of still birth, maternal morbidity, gestational diabetes mellitus and lower neonatal growth. Exposure to extreme cold was linked with placenta abruption and admission to the neonatal intensive care unit.

Across the papers focused on cardiovascular disease, an inconsistent pattern emerged, with some studies finding extreme heat increases CVD mortality and admissions, whilst others found that risk increased with extreme cold temperatures. Gender differences and deprivation also influenced this relationship. A more consistent pattern emerged for mental health service usage, which increased during hot temperatures.

Lastly, cold weather extremes were more likely to lead to hospital admissions for conditions such as hypothermia. An increase in mortality was consistent with extreme heat, with females and those from areas of deprivation being more at risk. Young males more at risk of heat-related admissions to hospital, which is likely linked to behavioral factors.

Limitations in climate change exposure and health outcome research

A consistent set of limitations emerged across studies. Most excluded individual-level factors, such as uncoded chronic conditions, socio-demographics, and behavioral adaptations (e.g., using air conditioning during heat events). Missing data were common due to retrospective designs, limiting follow-up and potentially omitting cases not presenting to emergency departments. Geographic coverage was often narrow, with many single-city or urban-focused studies. Accuracy of environmental exposure data varied by country, and climate models relied on assumptions that may not hold. Finally, ecological designs limited causal inference.

Table 2: Key findings from extracted papers on the impacts of climate change exposure on health outcomes of patients

Study Title and Author	Key findings
A Difference-in-Differences Approach to Assess the Effect of a Heat Action Plan on Heat-Related Mortality, and Differences in Effectiveness According to Sex, Age, and Socioeconomic Status (Montreal, Quebec) (Benmarhnia et al).	"HAP (heath action plan) contributed to a reduction in mortality overall on hot days. The effects of HAP were greater for the elderly and people living in low socio-economic neighbourhoods."
Adverse Weather Conditions can have Negative Effects on Birth Outcomes: Evidence from a birth registry cohort in Tanzania (Castro et al)	"Overall exposure to adverse weather is associated with poorer health outcomes in relation to childbirth such as low birth weight, shorter foetal length and a small head circumference."
Ambient temperature and early delivery of Singleton Pregnancies (Ha et al)	"Exposure to heat or cold early in pregnancy increased the risk of delivering early. A higher temperature just before delivery also raised this risk during warmer seasons. However, cold exposure close to delivery slightly reduced the chances of early labour in colder months."
Ambient temperature and stillbirth: Risks associated with chronic extreme temperature and acute temperature change. (Kanner et al)	"The findings indicate increased risk of still birth in women exposed to extreme heat and cold. There was also an association between increasing ambient temperatures and stillbirth."
Analysis of Heat Exposure During Pregnancy and Severe Maternal Morbidity (Jiao et al)	"High exposure (≥80th percentile of extreme heat days) was linked with a ~27-28% increased SMM odds, especially in the third trimester. Heatwaves in the final gestational week increased SMM odds by 32-139%, rising with heatwave severity. Heat-related SMM risk was most pronounced in women with lower education or whose pregnancy began in the cold season. Associations were stronger for cardiovascular- and sepsis-related SMM."

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A Population-Based Case–Control Study of Extreme Summer Temperature and Birth Defects (Van Zutphen et al)	"The study did not detect a strong association between high ambient temperatures and birth defects. Prior smaller studies had shown associations with sauna use but environmental heat did not significantly increase risk in this larger cohort."
Association between ambient temperatures and hospitalization costs for cardiovascular disease in Tianshui, Northwest China (Wang et al)	"Temperature variations-both hot and cold-were linked with changes in CVD admission costs. A non-linear relationship was found between tempera admission and the associated cost burden."
Association between Heat Vulnerability Index and Stroke Severity (Wang et al)	"Patients from high Heat Vulnerability Index neighbourhoods had significantly greater odds of severe stroke. Adjusted odds ratio for NIHSS $\geq$ 10 was 1.40 (95% CI: 1.16–1.69). The association persisted across different NIHSS cutoffs and adjustment models."
Association between hospitalizations for asthma exacerbation and weather conditions in Qingdao: an ecological study (Han et al)	"Two major peaks in asthma-related hospital admissions were observed: one in summer 2017 and another in spring 2019. The 2019 peak was linked to high air pollution during the preceding winter, which was attributed to weak winter wind systems that limited the dispersion of pollutants."
Association of Ambient Air Pollution and Temperature Exposure with Placental Abruption: A Nested Case–Control Study Based on Live Birth Registrations (Wang et al)	"The exposure to unusually low temperatures (those below the fifth percentile) during the third trimester was linked to a significantly higher likelihood of placental abruption, with an odds ratio of 3.68 (95% confidence interval: 1.67 to 8.08), compared to pregnancies exposed to moderate temperatures (within the 25th to 75th percentile range). When the data were stratified by potential modifying factors, no statistically significant differences were observed."
Association of Cardiovascular Disease Mortality and Ambient Temperature Variation in Shanghai, China: Beyond Air Quality Index PM2.5 (Li et al)	"An inverted "J"-shaped link was found between daily temperature and cardiovascular deaths; both cold and hot extremes increased mortality. The temperature associated with lowest mortality (25–26 °C) was higher for females (26 °C) than males (24 °C). The greatest relative risk (2.42 overall; females 2.24, males 2.64) occurred at −6.1 °C. Cold effects peaked three days after exposure and persisted for up to 21 days, while heat-related risk spiked immediately and dissipated within a day."
Association of Postpartum Temperature Exposure with Postpartum Depression: A Retrospective Cohort Study in Southern California (Sun et al)	"Higher average daily temperatures and larger daily temperature fluctuations during the postpartum period were linked to increased odds of depression. Each interquartile range increase in average temperature was associated with a 7 percent higher risk; fluctuations had a similar impact. Risks were more pronounced for maximum temperatures."
Associations of heat with diseases and specific symptoms in Flanders, Belgium: An 8-year retrospective study of general practitioner registration data (Ali et al)	"Main findings showed an association between heat and various ICPC-2 codes of patients including general (skin rash, cough) and specific (allergy, postural hypotension) ICPC-2 codes."
Climate Change, Summer Temperature, and Heat-Related Mortality in Finland: Multicohort Study with Projections for a Sustainable vs. Fossil-Fueled Future to 2050 (Kivimäki et al)	"A strong link was found between elevated summer heat index ($\geq$ 21 °C vs 14–15 °C) and cardiovascular mortality (rate ratio 1.70; 95% CI: 1.28–2.27). No significant association was seen with non-cardiovascular mortality."
Clinical outcomes of temperature related injuries treated in the hospital setting, 2011-2018 (Friedman et al)	"Annually, there were about 23.6 heat-related and 23.2 cold-related emergency visits per 100,000 people. Hospital admissions were four times more common for cold injuries than heat injuries (10.2 vs. 2.4 per 100,000). Hypothermia constituted 27% of cases but accounted for 94% of deaths. Several patient demographics, weather extremes, and existing health conditions significantly raised the risk of dying in the hospital."
Critical windows of susceptibility for the effects of prenatal exposure to heat and heat variability on gestational growth (Carlson et al)	"Exposure to highly variable heat (especially heat index) during weeks 10–29 of pregnancy was linked with lower birth weight (up to 287 g reduction) and higher risk of small-for-gestational-age births (odds ratio ~4.7). Consistent exposure to average temperatures did not show a significant impact."
Effects of extreme temperatures on cardiovascular emergency hospitalizations in a Mediterranean region: a self-controlled case series study (Ponjoan et al)	"The researchers discovered an overall increase in cardiovascular admissions in cold spells. Cardiovascular admissions did not increase during periods of extreme heat."

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Epidemic thunderstorm asthma in Hohhot, Northern China: A retrospective analysis of clinical characteristics in 155 patients (Fan et al)	"The study analysis revealed a correlation between peal pollen concentrations following thunderstorms with allergic rhinitis/asthma."
Estimating changes in emergency department visits associated with floods caused by Tropical Storm Imelda using satellite observations and syndromic surveillance (Ramesh et al)	"During flooding, asthma-related emergency visits increased by approximately 10% (95% CI: 1%–19%), and insect bite-related visits rose 22% (95% CI: 5%–41%) in flooded areas compared to controls. One month following the flooding there was an increase in diarrhoea related visits to ED."
Evaluation of the secondary use of electronic health records to detect seasonal, holiday-related, and rare events related to traumatic injury and poisoning (Bergquist et al)	"Confirmed known seasonal patterns in emergency department visits for trauma, (e.g. cold weather, and frostbite, snowboarding injury). Holidays were enriched for alcohol poisoning and assaults. Hanukkah Eve Windstorm was associated with increased coding for carbon monoxide poisoning"
Examining the Relationship between Extreme Temperature, Microclimate Indicators, and Gestational Diabetes Mellitus in Pregnant Women Living in Southern California (Teyton et al)	"Extreme low temperatures during gestational weeks 20–24 increased GDM risk. Extreme high temperatures during weeks 11-16 increased GDM risk Relative risk due to interaction (RERI) was positive for high temperature and low greenness; RERI was negative for low temperature and high impervious surface."
Exploratory analysis of seasonal mortality in England and Wales, 1998 to 2007. (Brown et al)	"Significant relationship between temperature and excess mortality. Temperature explains 7-8% of variance in daily deaths and 1-20% in excess mortality (higher in summer than winter); There were five statistically significant excess-mortality days corresponding with heatwaves."
Exposure to acute ambient temperature extremes and neonatal intensive care unit admissions: A case-crossover study (LaPointe et al)	"Cold exposure in the week prior to delivery was associated with a significant increase in NICU admissions: 1 °C decrease below the 10th percentile results in 30% higher odds of NICU admission. 1 °C decrease below the 5th percentile led to 47% higher odds. Heat exposure had an even stronger effect: 1 °C increase above the 90th percentile more than doubled the odds of NICU admission. 1 °C increase above the 95th percentile over 4-fold higher odds. The strongest associations were during summer, suggesting heat exposure may be particularly detrimental to neonates peripartum."
Extremely Hot Ambient Temperature and Injury-related Mortality. (Nguyen et al)	"Extreme heat was significantly associated with increased injury-related mortality in the general population: 12 days after extreme heat exposure. The effect was more pronounced among men and older adults. Heat had a stronger delayed impact than low temperature on injury related deaths."
Extreme precipitation and climate-related infectious diseases in Taiwan (1994-2008) (Chen et al)	"Extreme precipitation (>350 mm/day) increased risk of water-borne diseases (bacillary dysentery and enterovirus). Vector-borne diseases (e.g., dengue) rose with moderate rain but declined at >350 mm/day (due to habitat disruption). Geographic variability in risks; lag effects varied by disease."
From heatwaves to 'healthwaves': A spatial study on the impact of urban heat on cardiovascular and respiratory emergency calls in the city of Milan (Zendeli et al)	"Cardiovascular calls increased by 22% on extreme heat days compared to normal."
Future projections of temperature-related excess out-of-hospital cardiac arrest under climate change scenarios in Japan (Onozuka et al)	"Cold temperatures were associated with a greater burden of OHCAs compared to heat. Specifically, moderate cold accounted for the largest proportion of excess OHCAs."
Global Health Emergencies of Extreme Drought Events: Historical Impacts and Future Preparedness (Mani et al)	"Over 1.6 billion people impacted globally by extreme drought during 2000–2023; India (~688 m) and China (~327 m) most affected. Reported ~24,000 deaths, majority in Somalia (>20,000). Southern Asia and Sub-Saharan Africa identified as highest-burden regions."
Heat and Cold Wave-Related Mortality Risk among United States Veterans with Chronic Obstructive Pulmonary Disease: A Case-Crossover Study (Rau et al)	"Heat waves and cold waves were associated with significantly increased short-term mortality risk among veterans diagnosed with COPD. Heat waves were associated with 4% increased odds of mortality on the same day. Cold waves had effects peaking around lag day 4, also showing a 4% increase in odds of mortality. Female veterans demonstrated higher vulnerability to heat-related mortality. Native American/Alaska Native and Hispanic veterans had disproportionately higher mortality risk during cold spells."
Heat-related first cardiovascular event incidence in the city of Madrid (Spain): Vulnerability assessment by demographic, socioeconomic, and	"Heat exposure increased risk of first CV event. Higher risk among men and people of non-Spanish origin. Effect gradient by area-level deprivation: higher risk in more deprived tertiles. No consistent effect modification by comorbidities, age, or diagnosis type."

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health indicators. (Salvador et al)	
Heat-related illness in Singapore: Descriptive analysis of a tertiary care center from 2008 to 2020 (Okada et al)	"426 cases of heat-related illness were recorded over 13 years, comprising a small fraction (~0.023%) of ~1.83 million ED visits. Case numbers fluctuated, with a peak in 2015 (n=49) and a sharp decline in 2020 (n=4), likely due to reduced outdoor activity during the COVID-19 pandemic. The majority of patients were young males (median age 32; 71% male); 47% were non-citizens, highlighting the vulnerability of migrant workers and foreign nationals. Seasonality & Events: A disproportionate number of cases (23%) occurred in December, aligning with Singapore's annual Standard Chartered Marathon; 21% of all cases were marathon related."
Heavy precipitation and asthma exacerbation risk among children: A case-crossover study using electronic health records linked with geospatial data (Schinasi et al)	"Odds ratio 1.11 (95% CI 1.02–1.21) for asthma exacerbation on heavy precipitation vs dry days; effect was not modified by age, sex, PM or greenspace."
Hourly Heat Exposure and Acute Ischemic Stroke (Zhu et al)	"Cumulative OR (lag 0–10 h) for AIS onset at 33.3 °C vs 12.1 °C was 1.88 (95% CI 1.65–2.13). Higher ORs observed in men and patients with dyslipidaemia or atrial fibrillation, though differences were not statistically significant. The exposure-response curve was steeper in the north than in the south (OR, 1.80 [95% CI, 1.53-2.11] vs 1.57 [95% CI, 1.31-1.87])."
Impact of Ontario's Harmonized Heat Warning and Information System on emergency department visits for heat-related illness in Ontario, Canada: a population-based time series analysis (Clemens et al)	"Mean ED visit rate: ~47.5 per 100,000 per 2-week interval, peaking in June–July. No statistically significant change at population level post HWIS (change = 0.04, 95% CI –0.03 to 0.1; p = 0.278)."
Long-Term Effect of Temperature Increase on Liver Cancer in Australia: A Bayesian Spatial Analysis. (Gan et al)	"A 30-year lagged increase in mean temperature was positively associated with higher liver cancer incidence: posterior mean ≈ 29.5 (95% CI 1.27–58.95). Highest relative risk in Northern Territory, Northern Queensland. Relationship remained after controlling for hepatitis B/C prevalence and socioeconomic disadvantage."
Mortality risk related to heatwaves in Finland - Factors affecting vulnerability (Kollanus V. et al)	"Among age ≥75: 12.8% (95% CI 9.8–15.9%) higher mortality on heatwave days; age 65–74: 6.7% (2.9–10.8%) higher. Women had greater increase (≈12.5%) than men (~7.2%). Cause-specific increases: respiratory +25.3%, renal +38.4%, mental/behavioral disorders +29.7%, nervous system diseases +17.3%, cardiovascular +7.6%. In long-term inpatients (>30 days): mortality raised 13.1%; in other inpatients: raised 5.8%; outpatients: raised 26.9%. At home: mortality increased 8.1% (1.9–14.6%); social care facilities also saw elevated risks."
Neighborhood Disadvantage and the Association of Hurricanes Sandy and Harvey With Veterans' Mental Health (Yip, C.S. et al)	"Veterans in high-disadvantage neighborhoods (ADI ≥ 85) and low CAN risk had increased acute MH visit risk post-hurricane (HR 1.32, 95% CI 1.25–1.39). No significant association was observed in high CAN-risk veterans (HR 1.03, 95% CI 0.99–1.08). Hurricane exposure alone was not associated with increased risk without accounting for neighborhood disadvantage (ADI ≥ 85) and low CAN risk had increased acute MH visit risk post-hurricane (HR 1.32, 95% CI 1.25–1.39)."
Preconceptional and prenatal exposure to diurnal temperature variation increases the risk of childhood pneumonia (Zheng et al)	"Childhood pneumonia was significantly associated with exposure to an increase in DTV during one year before conception and entire pregnancy, with ORs (95 % CI) = 2.53 (1.56–4.10) and 1.85 (1.24–2.76). A significant risk of pneumonia of DTV exposure identified during the first and second trimester of pregnancy. Sensitivity analysis showed that boys were more susceptible to the effect of prenatal exposure to outdoor DTV during pregnancy particularly in the first two trimesters compared to girls."
Presentation Rates for Acute Pharyngitis in the Emergency Room Are Influenced by Extreme Weather Events (Haas, M. et al)	"Same-day RR (lag0) was elevated more than 3-fold after prolonged extremely low mean temperatures (P = .028). Furthermore, same-day RR after single-day and prolonged extremely high relative humidity was elevated by 51% (P =.024) and 46% (P = .036), respectively. Significant delayed effects on cRR were observed for extreme mean temperatures, relative humidity, and mean wind speeds within eight days and for extreme atmospheric pressure within 14 days."
Relationship Between Very Cold Outside Weather and Surgical Outcome: Integrating Shallow and Deep Artificial Neural Nets...The 17th World Congress of Medical and Health Informatics, 25-30 August 2019, Lyon,	"There is as association between increased LOS patients undergo surgeries, including cardiac and orthopaedic as first case in a day and very cold outside weather."

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France (Tafti et al)	
Seasonality of acute kidney injury phenotypes in England: an unsupervised machine learning classification study of electronic health records (Bolt et al)	“Admissions involving AKI in England between 2015 and 2019 show a seasonal pattern with the highest peaks in December/January and further increases in June/July, coinciding with heatwaves, >80 years had increased risk at winter.”
Seasonality of medically attended norovirus gastroenteritis and its association with climatic factors within an US integrated healthcare system, 2016–2019 (Mattison, C.P. et al)	“Norovirus AGE exhibited winter seasonality from 2016–2019, associated with lower temperatures and humidity. Understanding this seasonality may help predict peak transmission periods and their impact on healthcare resources.”
Secular trends in heat related illness and excess sun exposure rates across climatic zones in the United States from 2017 to 2022 (Pineda-Moncusí, M. et al)	“HRI exhibits a clear seasonal pattern, peaking during the summer months (June-August), consistent with the hottest periods in the US. In contrast, excess sun exposure lacks a consistent seasonal trend, with peaks observed in both summer (March, April, June, August, September) and winter (October, November) months. These findings suggest that HRI primarily has environmental drivers, while excess sun exposure could potentially be influenced by behavioural factors over a longer period.”
Sociodemographic and geographic inequalities in exposure to projected hot and extreme summer days in England: A nationwide socio-spatial analysis (Olsen, J.R. et al)	“There were clear geographical variations in experiencing hot and extreme summer days, with the South of England seeing the highest increases. The pattern of projected temperature increases does not align with typical health inequalities, as less deprived areas will experience more hot and extreme summer days, while areas with larger ethnic minority populations will face a greater number.”
Spatiotemporal characteristics of asthma emergency department presentations in diverse geographical and climatic regions, Queensland, Australia. (Simuno et al)	“The highest morbidity of asthma ED presentations occurred during the southern hemisphere winter months. Asthma-related ED presentations exhibit spatiotemporal variation across QLD, which appears to be related to climate. Furthermore, aeroallergens and respiratory viruses may be responsible for asthma ED peaks outside the winter period. Socioeconomic status may influence asthma ED presentation rates between regions.”
Temperature and myocardial infarction among migrants in Kuwait (Wang, C. et al)	“The optimal temperature with the lowest MI cases was 39.2°C. Elevated MI risks were associated with both hot and cold temperatures above or below this threshold, particularly at shorter lag days. Hot temperatures showed a pronounced association at lag 0, while cold temperatures demonstrated a weak effect at lag 7. The cumulative risk of MI for cold temperatures was higher than the risk for hot temperatures. Annually, 300 (20.1%) MI cases can be attributed to all cool days (below 39.2°C). Very hot days (above 39.2°C) contributed to about 9 (0.6%) MI cases each year among migrants in Kuwait.”
Temperature and place associations with Inuit mental health in the context of climate change. (Middleton et al)	“This study found significant associations between warm temperatures (i.e. above -5□ C) and increased incidence rate of daily mental health-related clinic visits across the Nunatsiavut region. This study also found that the types of temperature variables, as well as the direction and magnitude of associations, varied by community. Place appeared to modify the effects of temperature on mental health-related clinic visits. This result quantitatively supports the important role that place has in climate change impacts on mental health. This study adds to the limited body of epidemiological evidence on the association between meteorological factors and mental health outcomes and provides the first quantitative estimates of the effects of air temperature on mental health in an Indigenous region.”
Temperature effects on peoples' health and their adaptation: empirical evidence from China (Wu, Y. et al)	“Our findings indicate that expected temperature variations significantly adversely affect self-reported unhealthy status and the length of hospital stays among Chinese residents, highlighting both physiological and psychological adaptation to temperature changes. We found that extremely high temperatures (>30 °C) had minimal impact on health outcomes after accounting for adaptation. However, the health risks associated with moderately high temperatures (25 °C—30 °C) remained substantial. This suggests that while residents are responsive to extreme temperatures and implement appropriate protective measures, they may underestimate the risks posed by moderately high temperatures, which could lead to significant health issues. Furthermore, our analysis of potential adaptation mechanisms indicates that increased healthcare expenditures and reduced frequency of physical activity are two possible ways in which residents respond to climate change.”
Temporal variations in maternal treatment requirements and early neonatal	“The likelihood of requiring insulin treatment was highest in November ($p < 0.05$). The average total daily insulin dose was higher at peak

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outcomes in patients with gestational diabetes. (Fox et al)	(January) compared to average by 19 units/day ($p < 0.05$). There was no temporal variation in neonatal intensive care admission, or neonatal capillary blood glucose. However, rates of neonatal hypoglycaemia (defined as <2.6 mmol/L) were highest in December (40% above average; $p < 0.05$)."
The impact of extreme temperatures on emergency department visits: A systematic review of heatwaves, cold waves, and daily temperature variations. (PoshtMashhadi, A. et al)	"Heatwaves are consistently associated with increased ED admissions for various health conditions, including orthopaedic trauma and exacerbations of chronic illnesses. At the same time, cold waves are linked primarily to respiratory and cardiovascular issues, often with delayed effects. Several studies indicate that older adults, those with pre-existing conditions, and socioeconomically disadvantaged populations may face disproportionately severe consequences during these events."
The Impact of Heat Islands on Mortality in Paris during the August 2003 Heat Wave. (Laaidi et al)	"Mortality risk was significantly associated with exposure for two indicators: minimum temperatures averaged for 1–13 August [for a 0.41°C increase, OR = 2.17; 95% confidence interval (CI): 1.14, 4.16] and minimum temperature averaged on the day of death and the 6 preceding days (for a 0.51°C increase: OR = 2.24; 95% CI: 1.03, 4.87)."
The impact of heat waves on mortality in Northwest India (Nori-Sarma A. et al)	"Across communities, total mortality increased 18.1% during heat wave days compared with non-heat-wave days, with the highest risk in Japan. Even in areas with high baseline temperatures, heat waves still pose significant health risks. Implications for understanding temperature-health associations under climate change and can inform heat wave assessments in temperate regions."
The role of insurance status in the association between short-term temperature exposure and myocardial infarction hospitalizations in New York State (Flores et al)	"During extremely cold temperatures (<5.8 °C) insured patients experienced reduced rates of MI; this was not observed among the uninsured counterparts. At warmer temperatures starting at the 65th percentile (15.7 °C), uninsured patients had higher rates than insured patients (e.g., for a 6-hour pre-event average temperature increase from the median to the 75th percentile, the rate of MI increased was 2.0% [0.0%–4.0%] higher in uninsured group)."
Time-Course of Cause-Specific Hospital Admissions During Snowstorms: An Analysis of Electronic Medical Records From Major Hospitals in Boston, Massachusetts. (Bobb et al)	"Cardiovascular disease admissions decreased by 32% on high snowfall days (relative risk = 0.68, 95% confidence interval: 0.54, 0.85) but increased by 23% 2 days after (RR = 1.23, 95% CI: 1.01, 1.49); cold-related admissions increased by 3.7% on high snowfall days (RR = 3.7, 95% CI: 1.6, 8.6) and remained high for 5 days after; and admissions for falls increased by 18% on average in the 6 days after a moderate snowfall day (RR = 1.18, 95% CI: 1.09, 1.27)."
Time Series Analysis: Associations Between Temperature and Primary Care Utilization in Philadelphia, Pennsylvania (Fitzpatrick, J.H. et al)	"Rates of missed appointments increased by 0.72% for every 1°F decrease in daily maxi- mum temperatures below 39°F and increased by 0.64% for every 1°F increase above 89°F. Individuals ≥ 65 years and those with chronic conditions had stronger associations with an increased rate of missed appointments."
Viral etiology among children hospitalized for acute respiratory tract infections and its association with meteorological factors and air pollutants: a time-series study (2014-2017) in Macao (Lei et al)	"The relative risk of viral infection increased with daily mean temperature but plateaued when temperature exceeded 23°C and increased when the relative humidity was < 70% and peaked at 50%. The effect of solar radiation was insignificant. Air pollutants (including PM10, PM2.5, NO2 and O3) showed strong and immediate effect on the incidence of viral infection."
Vulnerability to episodes of extreme weather: Butajira, Ethiopia, 1998-1999. (Emmelin A. et al)	"Mortality rate was 24.5 per 1,000 person-years, compared with 10.2 in the remainder of the period 1997−2001. Mortality peaks reflect epidemics of malaria and diarrhoeal disease, associated with increasing rain fall. During these peaks, mortality was significantly higher among the poorer."
Additional outpatient expenditures due to heatwaves: evidence from the Chinese older population (Li et al)	"Each heatwave in the past 30 days increased individual outpatient costs by 2.29 CNY (95% CI: 0.31–4.27). Impact was more pronounced among those with chronic diseases, no air conditioning, or living in rural areas. Midday naps mitigated the effect. Under SSP5-8.5 climate scenario, projected additional summer 2050 outpatient costs could reach 29.14 billion CNY (95% CI: 3.94–54.33)."

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Discussion

In this study, we aimed to identify gaps in how the health impacts of climate extremes are captured and coded in EHR-based research. We found that while publications have grown over the past five years, most originate from the USA and China, with none from low-income countries, despite higher vulnerability. Research is largely based on retrospective hospital EHR, heavily reliant on ICD-9/10 codes without consistent specification, and focused on extreme heat, with little on extreme cold and inconsistent exposure definitions. Health outcomes are predominantly cardiovascular, respiratory, neonatal, and pregnancy-related, with limited attention to mental health, multimorbidity, and primary or community care. Few studies include individual-level risk factors or social vulnerability analyses. Future research should expand geographic scope, harmonize definitions, improve transparency, and include more diverse settings, disease areas, and high-risk populations.

Comparison with existing literature

This review confirms the limited attention given to mental health outcomes in relation to climate extreme exposures, consistent with previous findings [69]. Given that those most vulnerable to climate extremes are also at higher risk of mental health issues, this represents an important evidence gap [70,71]. Our results also align with literature showing that children, particularly newborns and infants, face elevated risks from climate change [72,73]. However, we identified only 10 studies on this group, primarily addressing neonatal or respiratory outcomes; further research should examine climate extremes across the full developmental trajectory [74].

A notable finding was the lack of methodological consistency in EHR-based climate-health research, also observed in other domains such as mental health [75,76]. Most studies applied retrospective time-series cohort designs, which are common in environmental health but

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limited in their ability to account for unmeasured confounders, including individual-level mediators of exposure effects [76]. Heterogeneity in climate exposure measures was rarely addressed, and few studies incorporated social vulnerability indicators such as education, housing, income, location, or access to care [77]. Similarly, although people with chronic conditions are more susceptible to climate extremes [78], none of the included studies examined the implications of multimorbidity, likely underestimating health impacts in these high-risk populations.

Strengths and limitations

This rapid review provides a structured synthesis of how temperature-related health impacts have been examined using electronic health records, offering a timely overview of current practices in exposure definition, outcome coding, and data utilization. Strengths include a comprehensive, multi-database search strategy developed with an information specialist, ensuring broad coverage of peer-reviewed literature, and adherence to established scoping review frameworks and PRISMA-ScR reporting standards, enhancing transparency and reproducibility.

Limitations include restriction to English-language publications, potentially excluding relevant research from non-English speaking regions; omission of grey literature; and the inherent constraints of a rapid review, such as the absence of full quality appraisal and exclusion of evidence published after the search cut-off date. In addition, the focus on temperature-related extremes means other climate hazards (e.g., flooding, wildfires, droughts) were not captured, limiting the broader applicability of findings across the full spectrum of climate–health interactions.

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Conclusion

Our review findings suggest that EHR-based climate-health research is expanding but remains geographically narrow, methodologically inconsistent, and limited in its inclusion of high-risk populations. Future studies should extend to low-income and climate-vulnerable regions; incorporate primary care, community, and mental health settings; and address neglected areas such as mental health, paediatric life-course outcomes, and multimorbidity. Harmonized exposure definitions and fully specified code lists are essential for comparability, while prospective designs linking EHR with environmental and socio-demographic data, and integrating individual-level mediators and social vulnerability metrics, will generate evidence that can inform targeted, equitable clinical and public-health interventions. Addressing these gaps is critical to guide effective policy and strengthen health system resilience in the face of intensifying climate extremes.

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Availability of data and materials: Data used during the current study are available from the corresponding author on reasonable request.

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Appendix:

Supplementary material

Supplementary Table 1: Search terms and number of papers extracted by database

Database	Terms Used	Results (English)
EMBASE	(climate change/ OR climate/) OR (temperature extreme*.ti,ab. OR heatwave*.ti,ab. OR hot weather.ti,ab. OR cold weather.ti,ab. OR freeze*.ti,ab. OR cold spell*.ti,ab. OR extreme humidity.ti,ab. OR climate.ti,ab. OR extreme weather.ti,ab.) AND (electronic health record/ OR electronic health record*.ti,ab. OR electronic medical record*.ti,ab. OR routin* collected data.ti,ab. OR routin* collected health* data.ti,ab. OR routin*-collected data.ti,ab. OR health adj2 admin* data.ti,ab. OR registr* data.ti,ab.)	55

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GREEN FILE	(climate change OR climate OR temperature extreme* OR heatwave* OR hot weather OR cold weather OR freeze* OR cold spell* OR extreme humidity OR extreme weather) AND (electronic health record* OR electronic medical record* OR routin* collected data OR routin* collected health* data OR routin*-collected data OR health N2 admin* data OR registr* data)	26
Web of Science	TS=("climate change" OR climate OR "temperature extreme*" OR heatwave* OR "hot weather" OR "cold weather" OR freeze* OR "cold spell*" OR "extreme humidity" OR “extreme weather”) AND TS=("electronic health record*" OR "electronic medical record*" OR "routin* collected data" OR "routin* collected health* data" OR "routin*-collected data" OR "health admin* data" OR "registr* data")	478
Scopus	TITLE-ABS-KEY(("climate change" OR climate OR "temperature extreme*" OR heatwave* OR "hot weather" OR "cold weather" OR freeze* OR "cold spell*" OR "extreme humidity" OR "extreme weather") AND ("electronic health record*" OR "electronic medical record*" OR "routin* collected data" OR "routin* collected health* data" OR "routin*-collected data" OR "health admin* data" OR "registr* data"))	436
CINAHL (via EBSCOhost)	(climate change OR climate OR temperature extreme* OR heatwave* OR hot weather OR cold weather OR freeze* OR cold spell* OR extreme humidity) AND (electronic health record* OR electronic medical record* OR routin* collected data OR routin* collected health* data OR routin*-collected data OR health N2 admin* data OR registr* data)	576

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MEDLINE (Ovid)	(Climate Change/ OR Climate/) OR (temperature extreme*.ti,ab. OR heatwave*.ti,ab. OR hot weather.ti,ab. OR cold weather.ti,ab. OR freeze*.ti,ab. OR cold spell*.ti,ab. OR extreme humidity.ti,ab. OR climate.ti,ab.OR extreme weather.ti,ab.) AND (Electronic Health Records/ OR Medical Records Systems, Computerized/ OR electronic health record*.ti,ab. OR electronic medical record*.ti,ab. OR routin* collected data.ti,ab. OR routin* collected health* data.ti,ab. OR routin*-collected data.ti,ab. OR health adj2 admin* data.ti,ab. OR registr* data.ti,ab.)	30
Cochrane	"climate change" OR climate OR "temperature extreme*" OR heatwave* OR "hot weather" OR "cold weather" OR freeze* OR "cold spell*" OR "extreme humidity" AND "electronic health record*" OR "electronic medical record*" OR "routin* collected data" OR "routin* collected health* data" OR "routin*-collected data" OR "health admin* data" OR "registr* data"	14

Supplementary Table 2: Study characteristics*

Study Title and Author	Paper number	Year	Country of origin	Climate extreme exposure	Definition and metric of exposure variable	Data source	EHR health outcomes	Coding	Study design	Look back period	Population
"A Difference-in-Differences Approach to Assess the Effect of a Heat Action Plan on Heat-Related Mortality, and Differences in Effectiveness According to Sex, Age, and Socioeconomic Status (Montreal, Quebec). (Benmarhnia et al)	1	2016	Canada	Summer heat exposure during embryo-foetal critical window	Not stated	Environment Canada meteorological observation stations	Frequency of non-accidental deaths related to heat	Codes not stated	Observational quasi design	7	Residents of Montreal who died during 2000-2007
Adverse Weather Conditions can have Negative Effects on Birth Outcomes: Evidence from a birth registry cohort in Tanzania (Castro et al)	2	2014	north Tanzania	Daily ambient temperature	Effective drought index, Multivariate ENSO Index	Weather stations	Neonatal birth weight, Apgar scores, premature deaths,	not stated	Observational registry based cohort study	11	30,068 singleton term pregnancies, lower risk cohorts
Ambient temperature and early delivery of Singleton Pregnancies (Ha et al)	3	2017	USA	Neighbourhood heat Vulnerability score	Hourly temperature obtained from weather research and forecasting model v3.22	Weather research and forecasting model v3.22	Likelihood of early delivery	ICD-9 diagnostic codes, delivery and hospital discharge records	Retrospective observational cohort	6	220,000 singleton births across 12 hospitals
Ambient temperature and stillbirth: Risks associated with chronic extreme temperature and acute temperature change. (Kanner et al)	4	2020	USA	Year to year change in weather	Weather research forecasting model wrf v3.2.1 at a 12 x 12km2 resolution, hourly temperature exposure	Weather research and forecasting model v3.22	Risk of stillbirth	ICD-9 diagnostic codes, delivery and hospital discharge records	Case controlled study	0	498 still births over 20 weeks gestation
Analysis of Heat Exposure During Pregnancy and	5	2023	USA	Ambient air pollution and temperature exposure	Grided meteorological data mapped to maternal residence,	20 condition algorithm; gridMET data, street view	Severe maternal morbidity	ICD algorithms refined by CDC, used to classify SSM	Retrospective case controlled	10	403,602 singleton pregnancies,

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Severe Maternal Morbidity (Jiao et al)					proportion of day exposure above 75th, 90th and 95th percentiles of max daily temperature= chronic exposure, acute exposure = heatwaves in last gestational week	images with 500mile radius to estimate green space exposure			design		3446 SMM
A Population-Based Case–Control Study of Extreme Summer Temperature and Birth Defects (Van Zutphen et al)	6	2012	USA	Ambient air temperature variation	Regional weather data,	National climatic data centre (2009) national centre for atmospheric research (2009)	Birth defects assessed from congenital defects registry	ICD-9-CM codes for selected defects across 6 organ systems	Retrospective case controlled design	18	Liveborn infants from New York between 1992-2006
Association between ambient temperatures and hospitalization costs for cardiovascular disease in Tianshui, Northwest China (Wang et al)	7	2025	Tianshui (China)	Postpartum temperature exposure	Daily mean below 2.5 centile = extremely low, above 97.5th centile = extremely high	Gansu Meteorological Bureau website, hospital and billing records	Hospitalization cost data for CVD	ICD-10 codes for different forms of heart disease	Retrospective time-series analysis	4	Residents in Thianshui city hospitalised with CVD conditions during 2016-2019
Association between Heat Vulnerability Index and Stroke Severity (Wang et al)	8	2024	USA	Daily min, max and average temperature for delayed or immediate health impacts over a 14 day period during summer months	Patients post codes scores range from 1 (low vulnerability) to 5 (high vulnerability), then 1-3 (low) to 4-5 (high)	Heat variability index acquired from NYC Department of Health	Number of ischemic stroke incidents	ICD-9 and ICD-10 codes (433.x21) (434x1) (196xx)	Retrospective analysis	10	3429 adult patients admitted with ischemic stroke
Association between hospitalizations for asthma exacerbation and weather conditions in Qingdao: an ecological study (Han et al)	9	2022	China	Daily temperature exposures	Monthly meteorological data, air quality measures (AQI, PM2, PM10) atmospheric variables e.g. upper variable winds winter 2018, linked to weaker east Asian winter monsoon and vertical transport	China National Environmental monitoring centre, weather variables from National centre for environmental prediction	Patients admitted to hospital asthma exacerbations from 2017-2019	Not stated	Ecological retrospective analysis	2	All adult patients admitted for asthma flare ups between 2017-2019
Association of Ambient Air Pollution and Temperature	10	2025	China	Temperature related injuries, cold or hot temperatures	Daily exposure levels based on advanced modelling for 6 common air	National centre for environmental prediction	Placental abruption	ICD codes for placental abruption	Nested case controlled study	4	798 women with placental abruption

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Exposure with Placental Abruption: A Nested Case–Control Study Based on Live Birth Registrations (Wang et al)					pollutants, local air ambient temp assessed across pre pregnancy, pregnancy and each trimester						versus 3192 matched controls recorded live births from 2018-2022
Association of Cardiovascular Disease Mortality and Ambient Temperature Variation in Shanghai, China: Beyond Air Quality Index PM2.5 (Li et al)	11	2025	China	Weekly average temperature	Lag period of 21 days, daily average outdoor temp, adjustments for fine particulate pollutants	China meteorological administration meteorological information centre	CVD mortality	ICD 10 cause of death codes	Retrospective population based study	5	308,116 adults who died from CVD 2015-2020
Association of Postpartum Temperature Exposure with Postpartum Depression: A Retrospective Cohort Study in Southern California (Sun et al)	12	2024	USA	Effects of extreme temperature	Historical daily ambient temperature obtained from 4-km resolution gridMET dataset	Satellite derived weather data matched to address at delivery	Postpartum depression	ICD 10 codes related to depression and corresponding medication	Retrospective cohort study	0	429,839 mothers, 46,114 had PPD
Associations of heat with diseases and specific symptoms in Flanders, Belgium: An 8-year retrospective study of general practitioner registration data (Ali et al)	13	2024	Belgium	Thunderstorm exposure	Daily min, max and average ambient temperatures for an immediate and up to 14 day window, also air pollutants (particulate matter, humidity, ozone)	Uccle weather station	Reasons for visits to the GP assessed for 14 categories	ICPC-2 to extract data on GP attendance	Ecological retrospective analysis	8	Didn't state

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Climate Change, Summer Temperature, and Heat-Related Mortality in Finland: Multicohort Study with Projections for a Sustainable vs. Fossil-Fueled Future to 2050 (Kivimäki et al)	14	2023	Finland	Flooding following Tropical Storm Imelda	Summer heat index calculated a week before mortality day, matched to 1 x 1 km residential grid, projections based on sustainable scenario and high emissions fossil field scenario to predict deaths for 2030-2050	Finnish meteorological institute	Heat-related mortality	ICD 10 cause of death data	Multicohort observations study	18	363,754 adult residents in Finland who died between 2000 and 2018
Clinical outcomes of temperature related injuries treated in the hospital setting, 2011-2018 (Friedman et al)	15	2020	USA	Seasonal, holiday and rare environmental events	Temperate changes and precipitation at time of temperature related illness	Weather station at Chicago O Hare Airport	Incidences of admissions to hospital, or in hospital death due to heat or cold injuries	ICD 10 codes for heat or cold related injuries	Retrospective analysis	7	Not clear
Critical windows of susceptibility for the effects of prenatal exposure to heat and heat variability on gestational growth (Carlson et al)	16	2023	USA	Extreme temperatures (hot and cold) and microclimate indicators	Weekly average temperature and heat index, exposure linked to residential location linked to geocoded data including maternal address and location	Spatial climate datasets aggregated by PRISM climate group	Prenatal exposure on gestational growth	Coding linked for material address	Retrospective cohort study	0	4442 mother infant pairs for children health watch cohort in Boston
Effects of extreme temperatures on cardiovascular emergency hospitalizations in a Mediterranean region: a self-controlled case series study (Ponjoan et al)	17	2017	Spain	Daily and monthly central England temperatures	Cold spells - at least 3 consecutive days of weather below 5th percentile for Winter months, heat waves = at least 3 consecutive days with temp above 95th percentile for summer months. Impact days 3 and 7 day cumulative period after cold spells	Catalan meteorological weather station Capturing hourly temperature data	Cardiovascular emergency hospitalization Admission risk during extreme temp exposure versus risk during no exposure periods	ICD 9 and 10 for CVD, Stroke, heart failure	Retrospective case controlled study	0	Adults aged over-18 in Catalonia experiencing first admission for CVD disorder
Epidemic thunderstorm asthma in Hohhot, Northern China: A retrospective analysis of clinical characteristics in 155 patients (Fan	18	2024	China	Extreme temperatures, ambient daily temperatures	Not mentioned	Not mentioned	Asthma attacks which occurred following a three day thunderstorm	Clinical presentations of asthma attacks	Retrospective review	0	Children and adults presenting with asthma symptoms during the 3 day thunderstorm

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et al)											, n = 155
Estimating changes in emergency department visits associated with floods caused by Tropical Storm Imelda using satellite observations and syndromic surveillance (Ramesh et al)	19	2022	USA	Extreme hot temperature and absolute humidity	Flood exposure determined by remote sensing from satellite imagery classifying flooded versus non flooded postal zone (ZCTAs). Time included the flood period and post-flood follow up months	MODIS and Sentinal 10A, flood resolution maps by AER Floodscan	Emergency department visits for asthma, insect bites, diarrhoea, dehydration in children and other related conditions	Data collected linked with geographically mapped satellite flood observations.	Retrospective analysis	0	Residents in postal areas with flooding versus those in non-flooded areas
Evaluation of the secondary use of electronic health records to detect seasonal, holiday-related, and rare events related to traumatic injury and poisoning (Bergquist et al)	20	2020	USA	Extreme precipitation	Seasonality winter = Dec-Feb, Spring March - May, summer June - Aug, autumn Sept - Nov,	Not stated	All trauma related emergency department visits over 24 years	ICD 10 and 9 codes for all trauma visits to ED	Retrospective temporal analysis	24	4.5 million patients
Examining the Relationship between Extreme Temperature, Microclimate Indicators, and Gestational Diabetes Mellitus in Pregnant Women Living in Southern California (Teyton et al)	21	2023	USA	Heatwaves	Weekly exposure to heat (97-99th percentile) and low temp (1-3 percentile) geocoded to residential address, microclimate modifiers, vegetation index, tree canopy, impervious surface %, land surface temp, human settlement, evapotranspiration	High resolution gridded surface meteorological dataset	Gestational diabetes mellitus in pregnant women	Screening between 24-38 week pregnancy	Retrospective cohort study	10	Pregnant women delivering between 2008 - 2018
Exploratory analysis of seasonal mortality in England and Wales, 1998 to 2007. (Brown et al)	22	2010	UK	Daily Temperature 2005-2015 and projections of temperature 1990-2099	Not stated	Meteorological office, Haley centre	Seasonal mortality	Office for statistical death registration database	Retrospective ecological time series regression	10	Six million deaths between 1998 - 2007
Exposure to acute ambient temperature extremes and	23	2024	USA	Extreme drought events 2000-2023	Weekly average temperatures, with 1 degree increments above 90th/95th %	Hourly temperature and relative humidity values estimated using Weather research and	Neonatal intensive care unit admissions	Neonatal intensive care unit admissions	Case crossover study	6	27,188 infants admitted to NICU

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neonatal intensive care unit admissions: A case-crossover study (LaPointe et al)					and below 10th/5th %	forecasting, model developed by the national centre for atmospheric research (NCAR)					
Extremely Hot Ambient Temperature and Injury-related Mortality. (Nguyen et al)	24	2023	Vietnam	Heat waves and extreme cold	Daily lagged events up to 30 days following extreme heat, daily ambient temperature and absolute humidity	National centre for hydrometeorological daily temp	Injury related deaths related to heat	Vietnamese A6 mortality registry, ICD code S00 to Y59	Retrospective time series study	2	Adults over 16 n = 3949 injury related deaths (2005-2007)
Extreme precipitation and climate-related infectious diseases in Taiwan (1994-2008) (Chen et al)	25	2012	China	Extreme heat	Precipitation thresholds <130 mm/day, 130-350 mm/day, > 350 mm/day	Geographic information system, integrated nationwide Taiwanese weather and health surveillance data	Incidences of 8 nationally notifiable infectious diseases	Taiwan centre for disease control	Ecological time series analysis	14	358 townships in Taiwan
From heatwaves to 'healthwaves': A spatial study on the impact of urban heat on cardiovascular and respiratory emergency calls in the city of Milan (Zendeli et al)	26	2025	Italy	Extreme heat	Modelled universal thermal climate index	Surface temperature	CVD emergency calls	Daily counts of CVD and respiratory emergency calls	Spatial study	0	Emergency call records in Milan
Future projections of temperature-related excess out-of-hospital cardiac arrest under climate change scenarios in Japan (Onozuka et al)	27	2019	Japan	Heavy precipitation	Not mentioned	Japan Meteorological Agency	Out of hospital CVD deaths	OHCA registry (2005 - 2025)	Series analysis and projection modelling	10	739,717 cases of OHCA
Global Health Emergencies of Extreme Drought Events: Historical Impacts and Future Preparedness (Mani et al)	28	2024	China, Hong Kong, Macao and Taiwan, Africa, India	Hourly temperature exposure 24 hours before acute ischemic stroke	Extreme drought events identified via EM-DAT thresholds >10 fatalities or >100 affected persons	International disaster database	Health emergency data, mortality, morbidity, outbreaks, indirect effects of famine and malnutrition	ISO-3 codes from EM-DAT dataset	Retrospective cohort study	23	1.6 billion people impacted
Heat and Cold Wave-Related Mortality Risk among United	29	2024	USA	Maximum daily temperature	Heat waves = days >90th percentile of warm centre mean, cold waves = days	Gridmet	All-cause mortality risk of chronic obstructive	ICD 9 and 10 at least two clinical encounters with COPD	Time stratified case crossover study	5	377, 545 deceased veterans diagnosed

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States Veterans with Chronic Obstructive Pulmonary Disease: A Case-Crossover Study (Rau et al)					<10th per centile of cold season mean		pulmonary disease				with COPD between 2016-2021
Heat-related first cardiovascular event incidence in the city of Madrid (Spain): Vulnerability assessment by demographic, socioeconomic, and health indicators. (Salvador et al)	30	2023	Spain	Increase in annual ambient temperature	Heat extremes = 97.5th percentile of max temperature	Meteorological state agency	First acute cardiovascular event	ICD 10, 120-124 codes	Time stratified case crossover study	5	19,149 adults aged 40-74 in Madrid with first CV event
Heat-related illness in Singapore: Descriptive analysis of a tertiary care center from 2008 to 2020 (Okada et al)	31	2024	Singapore	Heatwaves	Not stated	Singapore government open data	Heat-related illnesses, heatstroke, heat exhaustion, cramps, syncope	Emergency department records linked with meteorological content	Observational study	13	426 patients with heat related illnesses
Heavy precipitation and asthma exacerbation risk among children: A case-crossover study using electronic health records linked with geospatial data (Schinasi et al)	32	2020	USA	Hurricane Sandy and Harvey	Heavy precipitation = >95th percentile of summer daily distribution	National centre for environment information climate data online	Asthma exacerbation risk	97 snowmed codes	Stratified case cross over design	4	Children presenting to CHOP in summer months between 2011-2016
Hourly Heat Exposure and Acute Ischemic Stroke (Zhu et al)	33	2024	China	Maternal exposure diurnal temperature variation	Hourly temperature and single hour temperature exposure lag up to 24 hours before the AIS onset	China meteorological data sharing service system	Acute ischemic stroke	ICD 10	Stratified case cross over design	2	Adults over 18, who were hospitalised with AIS over warm season
Impact of Ontario's	34	2022	Canada	Extreme weather events	Not stated	Meteorological service for Canada,	ED visits for heat related	ICD 10 heat related illness	population based	6	Urban Ontario

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Harmonized Heat Warning and Information System on emergency department visits for heat-related illness in Ontario, Canada: a population-based time series analysis (Clemens et al)						Environment and Climate Change Canada	illness before and after heat warning information intervention		interrupted time series		residents during summer season
Long-Term Effect of Temperature Increase on Liver Cancer in Australia: A Bayesian Spatial Analysis. (Gan et al)	35	2024	Australia	Temperature increase (hotter)	30 year lag period, increases in ambient means in annual temperature	Bureau of meteorology	Liver cancer	ICD 10 C22	Ecological spatial analysis	18	All liver cancer cases in Australia
Mortality risk related to heatwaves in Finland - Factors affecting vulnerability (Kollanus V. et al)	36	2021	Finland	Impact of seasonality	Heatwave = daily mean temperature >90th percentile of May - Aug baseline for four consecutive days	Finnish meteorological institute	Mortality risk	ICD 10	Retrospective time series study	14	Entire Finnish population
Neighborhood Disadvantage and the Association of Hurricanes Sandy and Harvey With Veterans' Mental Health (Yip, C.S. et al)	37	2025	USA	Impact of seasonality	Hurricane exposure, area deprivation index,	Housing damage, aps, disaster declaration maps	Acute mental health care visits	ICD 10, care assessment needs score	Retrospective cohort study	0	960,394 veterans in sandy cohort, 795,746 in Harvey cohort
Preconceptional and prenatal exposure to diurnal temperature variation increases the risk of childhood pneumonia (Zheng et al)	38	2021	China	Sun exposure	Diurnal = diff between daily max and min temp. Air pollution = 24 hr concentration of 3 pollutants	China meteorological administration	Risk of childhood pneumonia	Not listed	Retrospective cohort study	16	699 children with pneumonia and 811 control children under 14 years
Presentation Rates	39	2024	Italy	Extreme hot summer	Extreme weather	Not listed	ED admission	ED visits for acute	Retrospective	4	1511 visits in

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for Acute Pharyngitis in the Emergency Room Are Influenced by Extreme Weather Events (Haas, M. et al)				days	events = 1st, 5th, 95th and 99th percentile of all daily measurements over 4 year period, also humidity, wind speed, atmospheric pressure and precipitation		for pharyngitis	pharyngitis	time series study		Vienna general hospital
Relationship Between Very Cold Outside Weather and Surgical Outcome: Integrating Shallow and Deep Artificial Neural Nets...The 17th World Congress of Medical and Health Informatics, 25-30 August 2019, Lyon, France (Tafti et al)	40	2019	USA	Seasonal trends	Not clear	National Oceanic Atmospheric Administration data cross-checked with the Weather Underground	Surgical outcomes from 1st surgery in the morning	Length of stay, readmission rates, functional health status, patient satisfaction	retrospective study	12	First in a day surgical cases, 132,096
Seasonality of acute kidney injury phenotypes in England: an unsupervised machine learning classification study of electronic health records (Bolt et al)	41	2023	England	Daily temperatures and humidity	Dec- Jan, June July seasons	Not stated	Acute kidney injury phenotypes	AKI ICD 10 CPRD GOLD	Clustering population based study	4	133,488 patients with AKI
Seasonality of medically attended norovirus gastroenteritis and its association with climatic factors within an US integrated healthcare system, 2016–2019 (Mattison, C.P. et al)	42	2025	USA	Daily temperature	Focus on the winter seasons, daily weather info, Temperature and humidity data	Portland international airport weather station, integrated surface Dataset and global historical climatology network	Norovirus gastroenteritis	ICD 9/10 codes	Population based study	3	198,191 confirmed cases on norovirus
Secular trends in heat related illness	43	2025	USA	Temperature, humidity, wind seed, sun duration and precipitation	Sun exposure by climatic region and across seasons	Not stated	Heat related illnesses	Snowmed and ICD 10	Population based study	0	33603572 people

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and excess sun exposure rates across climatic zones in the United States from 2017 to 2022 (Pineda-Moncusí, M. et al)											
Sociodemographic and geographic inequalities in exposure to projected hot and extreme summer days in England: A nationwide socio-spatial analysis (Olsen, J.R. et al)	44	2025	England	Temperature variation	Annual number of days where daily max temp is above 30C, number of extreme summer days, annual number of days where temp was over-35 degrees.	Met office	Hospital admission for COPD or CHD and preventable mortality for under 75s	UK government for health improvement and disparities database	Population based study	0	Not clear
Spatiotemporal characteristics of asthma emergency department presentations in diverse geographical and climatic regions, Queensland, Australia. (Simuno et al)	45	2021	Australia	Extreme temperatures	Seasonal trend decomposition procedure based on the LOESS method	Not stated	Admission to ED for asthma or asthma like presentations	ICD 10	Retrospective study design	6	Aged over 3 years, across 16 local districts in Australia, with an ED asthma diagnosis n 65,012
Temperature and myocardial infarction among migrants in Kuwait (Wang, C. et al)	46	2025	Kuwait	Heat wave	Daily average temp and humidity data	Meteorological department of civil aviation, monitor from Kuwait international airport	Hospital admissions for myocardial infarction	ICD 10 codes	Retrospective cohort study	17	MI admissions from 17 public hospitals, migrants, 26839 cases
Temperature and place associations with Inuit mental health in the context of climate change. (Middleton et al)	47	2021	Canada	Heat waves/exposure to warming and climatic hazards	Daily mean, max and minimum temperatures	Environment and climate change Canada weather	Mental health	ICD 10 codes	Retrospective study	4	5373 visits for mental health at LGH community clinics
Temperature effects on peoples' health and their adaptation:	48	2025	China	Ambient temperature	Data from 820 weather stations pooled together	China meteorological sharing system	Length of hospital stay, self-reported unhealthy status,	Not listed	Population based study	0	35,000 adults from the China family panel

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empirical evidence from China (Wu, Y. et al)							total cost of illness/injury				
Temporal variations in maternal treatment requirements and early neonatal outcomes in patients with gestational diabetes. (Fox et al)	49	2021	UK	Seasonal variations in temperature	Data linked to temperatures and month of the year	Not stated	Gestational diabetes mellitus in pregnant women treatment requirements and neonatal outcomes	Not listed	Retrospective study	4	791 women receiving treatment for gestational diabetes and 790 neonates
The impact of extreme temperatures on emergency department visits: A systematic review of heatwaves, cold waves, and daily temperature variations. (PoshtMashhadi, A. et al)	50	2025	Varied	Extreme heat and cold	Varied	Varied	Number of emergency department visits	Varied	Systematic review	0	42 studies
The Impact of Heat Islands on Mortality in Paris during the August 2003 Heat Wave. (Laaidi et al)	51	2012	France	Meteorological and air pollutant factors	61 images take from 1st-13th august to produce thermal indicators of mean surface temp and diurnal temp. amplitudes	National Oceanic and Atmospheric Administrations advanced very high resolution radiometer	Mortality data from all causes expect accidental, or acute surgery complications	Not stated, mortality data	Time series study	0	241 people > 65 years of age who died in the city of Paris during the august 2003 heat wave
The impact of heat waves on mortality in Northwest India (Nori-Sarma A. et al)	52	2019	India	Heatwaves	Heat waves = >2 days with local temp > 97th percentile for that community,	Indian Meteorological data, National Oceania and atmospheric Administration global summary of the day	Mortality	Local municipal registries	Observational retrospective cohort study	12	Adults aged 35 and older in 4 communities in northwest India
The role of insurance status in the association between short-	53	2023	USA	Temperature exposure	Hourly ambient temperature estimates and SPA bitemporal covariates	North American land data assimilation system	Hospitalisation from myocardial infarction	ICD 10 codes	Bidirectional case-cross-over study design	0	1095,051 MI admissions, 966,475 insured,

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term temperature exposure and myocardial infarction hospitalizations in New York State (Flores et al)											128,578 uninsured
Time-Course of Cause-Specific Hospital Admissions During Snowstorms: An Analysis of Electronic Medical Records From Major Hospitals in Boston, Massachusetts. (Bobb et al)	54	2017	USA	Snowfall	Daily weather data, min, max, average, daily amount of snow accumulation	Weather Source, Boston Logan Airport	Hospital admissions after low, moderate and high snowfall for 3 CVD categories, cold-related injuries and falls/accidents	Discharge diagnosis codes using ICD 9	Time course study	5	All admissions of adults over 18 years from 2010-2015 across 4 hospitals in Boston
Time Series Analysis: Associations Between Temperature and Primary Care Utilization in Philadelphia, Pennsylvania (Fitzpatrick, J.H. et al)	55	2024	USA	Daily ambient temperature	Extreme heat = 46 - 103 F, median 82 F; extreme cold = 13 - 92F and median was 52F., annual daily maximum temp, snowfall and precipitation	Philadelphia international airport	Rates of missed primary care appointments	ICD 9	Retrospective timeseries analysis	17	91580 patients, 1048,575 scheduled appointment s
Viral etiology among children hospitalized for acute respiratory tract infections and its association with meteorological factors and air pollutants: a time-series study (2014-2017) in Macao (Lei et al)	56	2022	Macao	Neighbourhood heat vulnerability score	Average value per unit, average value of the 5th, 25th, 75th and 95th percentiles, daily mean temps, daily mean humidity, daily mean solar radiation duration, daily mean wind speed, air pollutant data	Macao Meteorological and Geophysical Bureau	Viral etiology for acute respiratory tract infections hospitalization	ICD codes	Retrospective analysis	3	4880 children aged 1 - 14 years old
Vulnerability to episodes of extreme weather: Butajira,	57	2009	Ethiopia	Year to year change in weather	Monthly rainfall data from the weather station	National Meteorological Authority, Crop statistics provided by	Mortality data	Not used	Retrospective analysis	16	All deaths registered at the household

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Ethiopia, 1998-1999. (Emmelin A. et al)						District Agriculture Bureau of the Meskan and Mareko District Authority					level
Additional outpatient expenditures due to heatwaves: evidence from the Chinese older population (Li et al)	58	2024	China	Heatwave exposure on outpatient healthcare expenditure	Periods of high temperature above 95th percentile of records, high-resolution grid data set	Local meteorological stations	Outpatient expenditure	Not stated	National survey data, retrospective cohort study	0	22,023 adults over 45 from China 2011-2018"

***The text in this table is quoted directly from the papers included in this study**

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