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Research Article

The Impact Of Heatwaves On Healthcare Services In Developing Countries: A Systematic Review

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ARTICLE INFO | **ABSTRACT**

Heatwaves adversely affect human morbidity and mortality, especially in vulnerable groups, and ultimately strain the healthcare system. Prior studies have investigated the impact of heatwaves on healthcare services were conducted in developed countries, which are far superior in terms of financial budget and sophisticated healthcare system compared to developing countries. As a result, the impact of heatwaves on healthcare services in developing countries remains uncertain and inadequately comprehended. Therefore, this systematic review aims to address this gap specifically investigating the impact of heatwaves on healthcare services in developing countries. The study protocol was registered with PROSPERO (CRD42022365471). Primarily, extensive peer-reviewed research was conducted through the Web of Science (WoS), PubMed, and Scopus databases with adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines to collect and characterise key findings from the selected articles related to healthcare systems between January 2002 and April 2023. Subsequently, a thorough quality assessment was conducted using the Navigation Guide checklist. Based on the results, nineteen eligible studies were identified from the search process. Accordingly, it was found that heatwaves significantly increased the rate of Emergency Ambulance Dispatch (EAD), Emergency Department Visits (EDV), hospital admission, and outpatient department visits. Among the identified vulnerable groups severely affected by heatwave events were older people, children, males, outdoor workers, single, and those living in rural areas. Furthermore, various medical conditions were commonly associated with heat-related illnesses that required immediate healthcare services, such as kidney disease, mental disorder, infectious disease, cardiovascular disease, respiratory disease, heatstroke, perinatal, endocrine, nutritional, metabolic and skin problems. For evaluation of Risk of Bias (RoB), approximately 67% of the studies exhibited a ‘definitely low’ RoB, high quality of evidence (4+), and sufficient strength of evidence on the positive association between heatwave and their impacts on healthcare services. Overall, the duration and intensity of heatwaves showed a direct proportional relationship with the healthcare burden in developing countries. Therefore, policymakers and stakeholders must implement effective preparative planning and preventative efforts to ensure sustainability and efficient delivery of healthcare services, especially by allocating sufficient resources towards improving basic infrastructures and healthcare services.

Keywords: heatwaves; temperature; healthcare services; morbidity

1. Introduction

Heatwaves are one of the many catastrophic consequences of the global warming crisis that severely impact the ecosystem, human health, and the health system worldwide. As such, major heatwave events have recorded widespread death, including in Europe (2003; 72,000 deaths) and Russia (2010; 56,000 deaths) (UNDRR, 2019), Brisbane, Australia (2000, 2001, and 2004; 51,233 deaths in total) (Tong et al., 2012), and in Asia, particularly Turkey (2015, 2016, and 2017; 419 deaths in total) (Can et al., 2019) and Pakistan (2015; 1151 deaths) (Ghumman & Horney, 2016).

Heatwaves are typically defined as prolonged periods of exceptionally high or extreme temperature, characterised by the event's magnitude, duration, severity, and extension (Faye et al., 2021). However, the exact definition of heatwaves remains debatable to date (Jegasothy et al., 2017) according to geographical locations and individual acclimatisation (Y. Guo et al., 2014). World Meteorological Organisation (WMO) and the Centre for Research on the Epidemiology of Disasters (CRED) defined heatwaves as two or more consecutive days of temperatures surpassing the local region's designated temperature or percentile threshold (Centre for Research on the Epidemiology of Disasters (CRED), 2009; signals, 2021).

The impact of heatwaves to human's health is well understood including heat-related illnesses, cardiorespiratory and renal diseases, endocrine disorders, infectious diseases, and mental health disorders as well as worsen the premorbid condition (Ebi et al., 2021). In response, there has been a notable increase in demand for healthcare services across various departments, encompassing primary care, elective admissions, critical care, Emergency Department Visits (EDV), hospitalisation, and Emergency Ambulance Dispatch (EAD) (WHO, 2018). This, in turn, leads to a highly burdened healthcare system with decreased response time, a severe shortage of medicine, high bed occupancy rates, and limited resources, impacting patients' recovery process (Rizmie et al., 2022) and ultimately resulting in heavy economic expenditure (Schmeltz et al., 2016). These impacts are more pronounced among vulnerable groups, such as older people, children, females, and individuals with existing pre-morbid conditions (Kravchenko et al., 2013), which are further exacerbated by poor social situations, such as living in isolation, homeless, low socio-economic status, and lack of access to green areas (United Nations, 2018).

While numerous studies have concentrated on understanding the temperature- mortality and morbidity-relationship (Alahmad et al., 2019), there is still inadequate evaluation of the association between public health burden and morbidity due to heatwave events (S. Lin et al., 2012). Moreover, Çulpan et al. (2022) underscored the importance of utilizing morbidity indicators to evaluate the impacts of heatwaves on human health. The recent National Climate Assessment emphasized that robust public health initiatives, including the preparedness and preventive actions, are crucial to safeguard the vulnerable communities from the detrimental effects of extreme weather (USNCA Program 2014) and the World Health Organisation (WHO) (World Meteorological Organization, 2015). Despite past studies reporting lower emergency hospital admission than the mortality rate during heatwaves (Knowlton et al., 2009; van der Linden et al., 2019), additional EDVs could be crucial, particularly regarding infrastructure readiness, sufficient human resources, and cost. For instance, the 2006 California heatwave events increased EDVs to over 16,000 (Knowlton et al., 2009).

In view of this, policymakers and healthcare professionals across the globe have closely monitored the rising healthcare service applications to establish a reliable risk management plan (van der Linden et al., 2019). It is therefore essential to comprehend the effect of heatwaves alone on human health and its influence on the healthcare service to improve the assessment of climate impact beyond mortality (Watts et al., 2018), including the associated healthcare costs (Tong, Wondmagegn, Xiang, et al., 2021). This aspect is critical, especially with the steady rise in the average global surface temperature, leading to more frequent and intense heatwave events (IPCC, 2007). Nevertheless, prior literature studies on the consequences of heatwaves have predominantly been conducted in developed countries (Campbell et al., 2018). Limited evidence is available regarding the effects of heatwaves in developing countries which has poor healthcare service, limited access to infrastructure, and practical strategies to reduce the heatwave effect on their dense population (Green et al., 2019). Thus, improved readiness, suitable risk management plan, and systematic economic enhancements in healthcare infrastructure would be achieved by identifying and examining the available evidence on the impact of heatwaves on the healthcare service (Campbell et al., 2018; IPCC, 2007), ultimately reducing the morbidity and mortality due to heatwave exposures.

An intriguing research question is put forward from these issues: "How do heatwaves burden the healthcare system, particularly in developing countries?" Considering the necessity to address this question, this systematic review was conducted to access the impact of heatwaves on the healthcare service in developing countries based on recent literature studies from January 2002 to April 2023. Besides that, this review aimed to identify crucial research gaps in the existing literature, provide recommendation and assist in disseminating essential research findings to policymakers and relevant stakeholders. The ultimate goal is to facilitate the planning and implement effective measures based on the insights gained.

2. Materials and Methods

2.1. Search Strategy and Inclusion and Exclusion Criteria

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method was used as a guideline to conduct this systematic review (Moher et al., 2015). Prior to the research initiation, the protocol for this review was submitted for registration with the International Prospective Register of Systematic

Reviews (PROSPERO) with the registration number CRD42022365471. A comprehensive systematic search for peer-reviewed and published literature was performed in three electronic databases, namely Web of Science (WoS), PubMed, and Scopus, from January 2002 to April 2023 using Boolean operators 'AND' and 'OR'. The search strategy combining Medical Subject Headings (MeSH) terms and keywords used on each database, specifically: ("heatwave" OR "extreme heat" OR "heat wave") AND ("hospitalisation" OR "hospital admission") OR ("morbidity" OR "heat-related illness") OR ("ambulance" OR "outpatient visit" OR "emergency department" OR "health services") (Supplementary file S1).

The eligibility criteria were then formulated using the following Population, Exposure, Comparator, and Outcome (PECO) statements;

- Population: The inclusion criteria include the general population in developing countries who seek healthcare services, regardless of their age, gender, location, or ethnicity. We used as International Monetary Fund (IMF) definition to define the developing countries. IMF categories countries based on their economic development, which is mainly influenced by their Gross Domestic Product (GDP) per capita, diversified economy, and degree of integration into the global economy (IMF, 2023; worlddata, 2022). The list of developing countries is provided in Supplementary Materials S2. Mortality studies unrelated to healthcare services in developed countries were excluded from this review.
- Exposure: All studies related to heatwaves were included in the review regardless of the definition of the term applied in the respective study. On the contrary, studies that (i) did not provide a definition of the term heatwave, (ii) focused on ambient temperature, and (iii) focused only on cold temperature were excluded from this study.
- Comparator: The same population at a time but unexposed to the heatwave event or a comparable population unexposed to the heatwave event.
- Outcome: Healthcare services comprising EAD, EDV, outpatient department visits, hospitalisation, shortage of medicine, and response time.
- Study design: All observational heatwave studies that meet the definition of heatwaves were included. The epidemiological measures reported in Relative Risks (RR), Odds Ratio (OR), and Rate Ratios (RRs) or Excess Risk (ER) with a Confidence Interval (CI) of 95% were also included. Conversely, intervention studies (such as randomised controlled trials and single-arm studies), reviews (such as systematic and scooping), case reports, guidelines, commentary, editorial, protocols, experimental research, surveillance studies, book chapters, short communications, qualitative research, non-English articles, and missing fulltext articles were excluded from this study.

2.2. Study Selection and Data Extraction

All eligible articles were exported into Endnote software version X9 for data management and duplicate removal. This process was performed by a single reviewer (HS). Subsequently, data were exported into Covidence for data screening and extraction. Full-text articles were retrieved through various approaches, including web searching and article requests from the UiTM librarian. The title and abstract of the articles were first screened by three independent reviewers (HS, WRM, and RI). A cross-validation method was implemented to address the inconsistencies between the included and excluded articles. Another two reviewers (MRI and MIS) were assigned to resolve disagreements between HS, WRM, and RI via discussion. The evaluation included the utilization of the Kappa statistic, with a threshold set at 0.8 to signify substantial agreement

Next, HS and RI were assigned to extract data items from the selected articles, which include study characteristics (author's name, publication year, study design, study location, and study period), the definition of exposure (heatwave), population characteristics (study population geographical area, vulnerability factors, such as age, gender, and medical conditions), temperature exposure matrices, exposure assessment methods, confounders, outcome characteristics (EAD, EDV, outpatient department visits, and hospital admission), measures of outcome, and effect estimate and confidence intervals. The extracted data were then carefully examined by MRI and MIS.

2.3. Assessment of Evidence: Risk of Bias (RoB), Quality, and Strength of Evidence

The quality of the selected articles was evaluated using the Navigation Guide checklist, which provides a systematic and transparent methodology of evidence-based medicine and environmental health research synthesis, specifically for observational studies. The quality assessment was conducted in three stages: (1) individual Risk of Bias (RoB) assessment; (2) assessment of the overall quality of evidence across all included papers; and (3) rating of the overall strength of evidence across studies. The assessment was carried out by HS and RI, which was followed by a discussion session and rating agreement. Any conflicts were resolved with the help of MIS and MRI to reach the final ratings.

2.3.1. Risk of Bias (RoB) Assessment

The internal validity between exposure and outcome of the selected articles was examined using the Office of Health Assessment and Translation (OHAT) RoB assessment tool (National Toxicology Program, 2022), which was adapted by several guidelines, such as the Agency of Healthcare Research and Quality (Viswanathan et al., 2008), the Navigation Guide (Johnson et al., 2014) and Cochrane Handbook (Higgins J, 2011). However, the

OHAT tool did not explicitly include a time-series environmental health study design. Therefore, MIS and RI (qualified subject-matter experts) altered and changed certain domains according to the research question in this study. The RoB domains include selection, confounding, exposure assessment, outcome assessment, selective reporting, conflict of interest, and other possible biasness. The overall assessment was graded through four score categories, in particular, +3 (definitely low risk), +2 (probably low risk), +1 (probably high risk), and 0 (definitely high risk), with the highest possible total score of 18 (reflecting the lowest RoB) and the lowest possible total score of 0 (signifying the highest RoB) (Mellow et al., 2021). 2.3.2. Assessment of Overall Quality of Evidence across All Included Papers

The Navigation Guide employs the Grading of Recommendation Assessment, Development, and Evaluation (GRADE) approach to assess the certainty of the evidence for each exposure-outcome pair [35]. The body of evidence in this review was first graded as moderate before being downgraded or upgraded based on priority criteria in human observational evidence (Woodruff & Sutton, 2014). The five areas of downgrades are (i) individual research limitations, (ii) inconsistent results, (iii) indirectness of evidence, (iv) imprecision, and (v) publication bias, while the three areas of upgrades include (i) dose–response gradient, (ii) a large magnitude of effect, and (iii) confounding. The final grade was given as high (4+), moderate (3+), low (2+), or very low (1+) (Balshem et al., 2011).

2.3.3. Rating of the Overall Strength of Evidence across Studies

The Navigation Guide states that four elements are needed to rate the overall strength of evidence across studies, which include (i) quality of the body of evidence, (ii) direction of effect, (iii) confidence in the effect, and (iv) any other attributes that could affect the certainty (Woodruff & Sutton, 2014).

2.4. Statistical Analysis

This study did not undertake a meta-analysis approach due to the heterogeneity of the outcome measures. Instead, the evidence was summarised in a descriptive synthesis.

3. Results

3.1. The Search Process

The implemented search strategy identified 2187 titles and abstracts (570 from Scopus, 1293 from PubMed, 309 from WoS, and 15 from screening references) as of 15th May 2023. After removing duplicate contents, 1557 articles were screened based on the title and abstract. A total of 1065 articles were excluded due to ineligible study design, irrelevant outcomes, and focused on developed countries. The remaining 492 full-text articles were then assessed for eligibility, in which 473 articles were excluded due to non-English text (*n* = 7), inaccessible full-text (*n* = 8), studies focused on developed countries (*n* = 23), studies on cold temperature weather (*n* = 37), and studies on ambient temperature with no heatwave definition (*n* = 398). Finally, 19 articles met the inclusion criteria and were selected for this study. Figure 1 shows the overall search process.

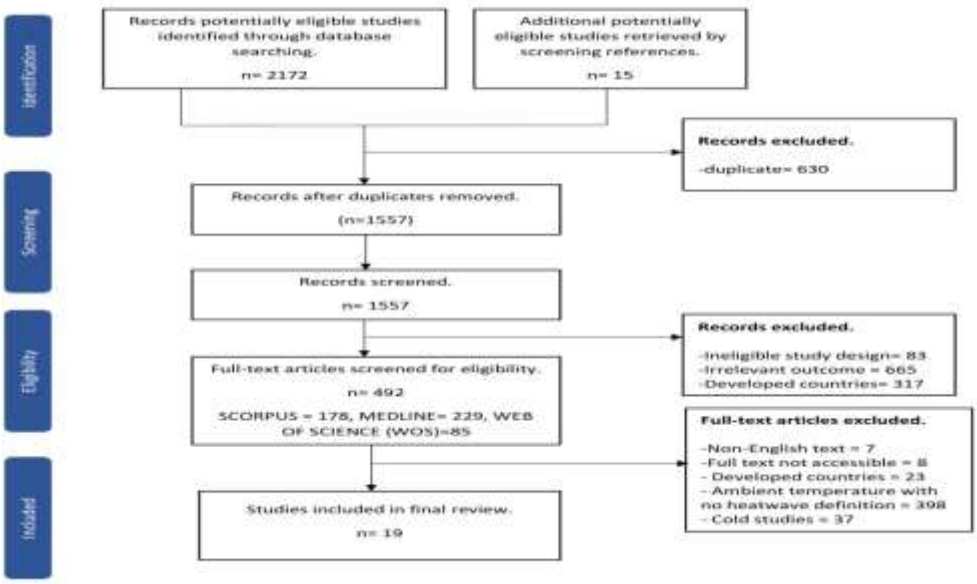

Figure 1. Flowchart of the search process using the PRISMA method in this study.

3.2. Characteristics of the Included Studies

Based on the 19 identified articles, the highest number of articles focusing on the impact of heatwaves on the healthcare service was published in China (*n* = 8), which was followed by Vietnam (*n* = 6) and one article each from Brazil, Pakistan, Turkey, India, and Iran (*n* = 1). Most articles used the time-series analysis (*n* = 13), which was followed by case-crossover studies (n = 4), and one was used for meta-analysis (n = 1) and a cross-sectional study (n = 1). The heatwave definition varied in each study, with 13 studies using a combination of temperature limit (such as 90th, 95th, and 99th percentiles) and duration (such as at least 2, 3, or 4 days) (Cheng et al., 2016; Chu et al., 2022; Dang et al., 2019; Hu et al., 2020; Huang et al., 2023; Mohammadi et al., 2019; Nhung et al., 2023; Phung et al., 2017; Phung et al., 2016; Song et al., 2018; Sun et al., 2014; Trang et al., 2016; Xu et al., 2019), while there were three studies using the three days above a temperature threshold (Li et al., 2017; Liu et al., 2019; Zhang et al., 2019), one study using the Excess Heat Index (EHI) (van der Linden et al., 2019), and two studies using other definitions (Kakkad et al., 2014; Varghese et al., 2021).

The most frequent meteorological matrices used to define heatwave in the selected articles were daily mean temperature (n = 11), which was followed by daily maximum temperature (n = 7) and apparent temperature (n = 1). Apart from that, most of the epidemiological methods applied to measure heatwave outcomes were RR (n = 13) followed by OR (n = 2) and ER (n = 2). In addition, most of the articles emphasised single healthcare service outcomes, primarily hospital admission, followed by EAD, EDV, outpatient department visits, inhospital mortality, and healthcare expenditure. Table 1 summarises the characteristics of each selected study.

Table 1. Characteristics of the selected articles in this study (n = 19).

Author (Reference)	Location (Country)	Study Design and Period	Target Population	Heatwave Definition and Matrices	Statistical Analysis	Adjustment for Confounding Factors	Healthcare Service Outcome
Liu et al. (2019)	Jinan (China)	Case-cross over 2010	Patients with mental illness	Daily maximum temperature ≥ 35 °C for ≥ 3 days	Multifactor logistic regression	Time trends and seasonal variation	Hospital admission
Phung et al. (2017)	Multi-provinces (Vietnam)	Time-series meta-analysis 2002–2015	Residents	Apparent temperature ≥ 90th percentile for ≥ 3 consecutive days during summer (northern cities) and the whole year (southern cities)	GLM, Poisson with DLM Random effect metaanalysis, and regression	RH and day of the week	Hospital admission
Sun et al. (2014)	Pudong New Area (China)	Time-series 2011–2013	General population	Daily mean temperature ≥ 90th (29.67 °C), 95th (30.70 °C), and 99th (33.05 °C) percentiles for at least 2–3 days	Poisson with GAM	Long-term trends, seasonal patterns, calendar year, day of the year, and day of the week	1. EDV 2. EAD
Dang et al. (2019)	Ho Chi Minh (Vietnam)	Time-series 2010–2013	General population	Daily average temperature ≥ 97th percentile for ≥ 2 consecutive days	QuasiPoisson regression with DLNM	Long-term trends and seasonal patterns	Hospital admission
Cheng et al. (2016)	Huainan (China)	Time-series 2011–2013	General population	Daily mean temperature at 95th, 97.5th, and 99th percentiles for ≥ 2 consecutive days	QuasiPoisson regression with DLNM	Long-term trends, seasonal patterns, day of the week, public holidays, and RH	EAD
Phung et al. (2016)	Ho Chi Minh (Vietnam)	Time-series 2004–2013	General population	Daily mean temperature ≥ 99th percentile for ≥ 2 consecutive days	GAM and DLNM with Poisson	Long-term trends, seasonal patterns, day of the week, public holidays, and RH	Hospital admission
Trang et al. (2016)	Hanoi (Vietnam)	Time-series 2008–2012	Patients with mental health disorders	Daily maximum ambient temperature (90th percentile) above the threshold of 35 °C for 3–7 consecutive days	Binomial time-series regression	Time trends, seasonal variations, and day of the week	Hospital admission

Zhang et al. (2019)	Changnan (China)	Time-stratified casecrossover 2010–2012	Residents	Daily maximum temperature > 35 °C for at least 3 consecutive days	Conditional Poisson regression model	Rainfall, wind speed, pressure, RH, sunshine hours, and atmospheric pollutants (nitrogen dioxide, SO_2, total suspended particulates)	Outpatient visits
Chu et al. (2022)	14 provinces (Vietnam)	Casecrossover 2003–2015	Residents	Daily maximum temperature ≥ 95th percentile for 0–7 days	Conditional logistic regression	RH, day of the week, and seasonality	Hospital admission
Li et al. (2017)	Chongqing (China)	Time-series 2009–2013	Residents	Daily average temperature ≥ threshold temperature for ≥ 3 consecutive days	Zeroinflated Poisson regression model with logistic distribution	Day of the week and RH	Hospital admission
Zhao et al. (2019)	Five regions (Brazil)	Time-series 2000–2015	General population	Daily mean temperatures of 90th, 92.5th, 95th, or 97.5th percentiles of year-round temperature with ≥ 2–4 consecutive days	QuasiPoisson regression with DLM	Day of the week, holiday, seasonality, longterm trend, and RH	Hospital admission
Huang et al. (2023)	23 areas (China)	Time-stratified casecrossover 2014–2019	General population	Daily mean temperature ≥ 90th, 95th, or 97.5th percentiles for > 2–4 consecutive days	DLNM with conditional quasiPoisson regression	Day of the week, RH, and public holiday	1. Hospital admission 2. Healthcare expenditure
Song et al. (2018)	Haidian District, Beijing (China)	Time-series 2009–2012	Residents	Daily mean temperature ≥ 95th percentile for 2–4 consecutive days	GLM with quasiPoisson regression with DLNM	Long-term trends, seasonality, RH, pollutants (PM_{10}, NO_2, SO_2), and day of the week	EDV
van der Linden et al. (2019)	Karachi (Pakistan)	Time-series 2009–2016	General population	EHI	Time-series threshold regression	Seasonality and day of the week	EDV
Kakkad et al. (2014)	Ahmedabad, Gujarat (India)	Time-series 2009–2011	Neonates and infants (0–28 days)	India Meteorological Department criteria: Temperature ≤ 45 °C if the daily maximum temperature > 4 °C than the normal maximum daily temperature	GLM with Poisson regression	RH	Hospital admission
Hu et al. (2020)	Shenzhen (China)	Time-series 2013–2017	Residents	Mean temperature exceeding the 75th, 90th, 95th, and 99th percentiles for at least 2–4 days	DLNM with quasiPoisson distribution	Day of the week, RH, long-term trends, seasonality, air pollutants, and public holiday	EAD
Oray et al. (2018)	Izmir (Turkey)	Crosssectional study 2015–2015	Residents	Higher air temperatures than the seasonal average and other days during the study period (17– 25th June 2016)	Kolmogorov–Smirnov, Student's ttest, and Chi-square	Not applicable	EDV Mortality at ED
Mohammadi et al. (2019)	Sabzevar (Iran)	Time-series 2011–2017	Pre-term births (PTB)	Mean daily temperature > 90th percentile for ≥ 2 consecutive days	GAM with quasiPoisson regression and DLNM	Day of the week, raining, public holidays, air pollution, long time, and seasonal trend	Hospital admission

Nhung et al. (2023)	Southern region (Vietnam)	Time-series 2010–2018	Residents	Maximum temperature ≥ 90th percentile for at least 3 consecutive days	QLM with quasiPoisson regression	Day of the week, holiday, time trend, and RH	Hospital admission

Notes: EDV = Emergency Department Visit, EAD = Emergency Ambulance Dispatch, GLM = Generalised Linear Model, GAM = General Additive Model, DLM = Distributed-Lag Model, DLNM = Distributed-Lag Nonlinear Model, RH = Relative Humidity, EHI = Excess Heat Index, SO_2 = Sulphur dioxide, NO_2 = Nitrogen Dioxide, PM_{10} = Particulate Matter with diameter of less than 10 microns.

3.3. Impact of Heatwaves on Health Services

3.3.1. Impact of Heatwaves on Hospital Admission

According to Table 2, 12 studies (63.0%) reported a significant association between heatwave exposure and hospital admissions. Most heatwave effects led to acute morbidity involving medical-related disorders, especially on days 0–3 after exposure. At the country-level pooled effect, Phung et al. (2017) showed an increased risk of hospital admission for all-cause during a heatwave event at lag 0 with RR = 2.5% (95% CI: 0.8–4.3). Additionally, 2 of the 12 studies found a significant increase of 1–3 times higher in hospitalisation among patients with mental disorders during heatwave periods compared to non-heatwave periods (Liu et al., 2019; Trang et al., 2016). A 1 °C increase in maximum temperature was associated with an increased risk of hospitalisation for all mental disorders with RR = 1.02% (95% CI: 1.007–1.02) (Trang et al., 2016). Kakkad et al. (2014) also estimated a 43% increase in Neonatal Intensive Care Unit (NICU) admission during heatwave events. Other medical conditions associated with the increase in hospital admissions include infectious disease (Phung et al., 2017), respiratory disease (Dang et al., 2019; Nhung et al., 2023), cardiovascular disease (Phung et al., 2016), kidney disease (Chu et al., 2022; Huang et al., 2023; Zhao et al., 2019), heatstroke (Li et al., 2017), Pre-Term Births (PTB) (Mohammadi et al., 2019), perinatal, endocrine, nutritional and metabolic disorder, and skin problems (Zhao et al., 2019). Urolithiasis is the most common and highest subtype of kidney disease that requires hospitalisation during heatwave events with RR = 1.19 (95% CI: 1.100–1.136) and Attributable Fraction (AF) = 16.581% (95% CI: 9.109–23.439) (Huang et al., 2023).

Table 2. Impacts of heatwaves on hospital admission.

Reference (Location)	**Heatwave Definition and Matrices**	**Effect Estimates ***	**Vulnerable Groups**	**Summary**
Liu et al. (2019) (China)	Daily maximum temperature ≥ 35 °C for ≥ 3 days	Hospital admission for patients with mental illness: • OR = 2.231 (95% CI: 1.436–3.466) at 3-day lag on 1st heatwave • OR = 2.836 (95% CI: 1.776–4.525) at 2-day lag on 2nd heatwave • OR = 3.178 (95% CI: 1.995–5.064) at 3-day lag on 3rd heatwave • OR = 2.988 (95% CI: 2.158–4.140) at 2-day lag on 4th heatwave	Elderly (≥65 years old): OR = 3.034 (95% CI: 1.802–5.139) Urban population: OR = 1.523 (95% CI: 1.120–2.074) Outdoor workers: OR = 1.714 (95% CI: 1.198–2.398) Singles: OR = 1.709 (95% CI: 1.233–2.349)	Heatwaves significantly increased hospitalisation of patients with mental illness within 1–3 days of lagged effect
Phung et al. (2017) (Vietnam)	Apparent temperature ≥ 90th percentile for ≥3 consecutive days	Country-level pooled effect at lag 0: • RR = 2.5 (95% CI: 0.8– 4.3) increase in all-cause admission • RR = 3.8 (95% CI: 1.5– 6.2) increase in infectious admission	1. Country-level pooled effect in northern regions: • All-cause RR = 5.4 (95% CI: −0.1–11.5) • Infectious disease RR = 11.2 (95% CI: 3.1–19.9) • Cardiovascular disease RR = 7.5 (95% CI: 1.1–14.4) 2. Country-level pooled effect for gender: • Male, all-cause RR = 4.3 (95% CI: 2.1–6.5) at lag 1	• Pooled estimates at country level showed that heatwaves significantly increased hospitalisation at lag 0, especially for allcause and infectious disease • Pronounced effect of hospitalisation in the northern region of Vietnam compared to the southern region • Insignificant modification effects of age and socioeconomic factors indicate the presence of adaptive capacity

Dang et al. (2019) (Vietnam)	Daily average temperature ≥ 97th percentile for ≥ 2 consecutive days	Respiratory disease admission: • RR = 1.3 (95% CI: 1.19–1.42)	Elderly RR = 1.28 (95% CI: 1.14–3.45)	Significant effect of heatwaves on hospitalisation among older people and patients with respiratory diseases
Phung et al. (2016) (Vietnam)	Daily mean temperature ≥ 99th percentile for ≥ 2 consecutive days	• Increased cardiovascular admission by 12.9%: RR = 1.129 (95% CI: 0.972–1.311) during heatwave events (lag 0)	• Male RR = 1.2 (95% CI: 0.98–1.47) • 0–64 years old RR = 1.22 (95% CI: 1.00–1.49)	Temperatures > 29.6 °C were associated with an increased risk of cardiovascular admission (J-shaped relationship)
Trang et al. (2016) (Vietnam)	Daily maximum ambient temperature (90th percentile) ≥ the threshold of 35 °C for 3–7 consecutive days	A 1 °C increase in maximum temperature was associated with an increased risk of hospitalisation for all mental disorders with RR = 1.02 (95% CI: 1.007–1.02): • Day 1 RR = 1.04 (95% CI: 0.95–1.13) • Day 3 RR = 1.15 (95% CI: 1.005–1.31) • Day 7 RR = 1.36 (95% CI: 1.00–1.90)	At lag 3 of heatwaves: • Male RR = 1.26 (95% CI: 1.04–1.52) • Rural population RR = 1.15 (95% CI: 1.0–1.33) At lag 7 of heatwave: • Elderly (> 60 years old) RR = 3.2 (95% CI: 1.63–6.29) • Rural population RR = 1.69 (95% CI: 1.08–2.64)	Significant increase in RR of hospitalisation for patients with mental disorders under prolonged heatwave events
Chu et al. (2022) (Vietnam)	Daily maximum temperature ≥ 95th percentile for 0–7 days	Increased odds of hospitalisation per 1°C increases in temperature for kidney disease at lag 0–6: • Glomerular disease OR = 1.07 (95% CI: 0.99–1.16) • Renal tubulointerstitial disease OR = 1.06 (95% CI: 0.96–1.17) • Chronic kidney disease OR = 1.12 (95% CI: 1.00–1.24) • Urolithiasis OR = 1.09 (95% CI: 1.02–1.16)	Not specified	Elevated temperatures increased the risk of hospitalisation for kidney disease, especially chronic kidney disease and urolithiasis, at lag 0–6 days
Li et al. (2017) (China)	Daily average temperature ≥ threshold temperature for ≥ 3 consecutive days	ER of heatstroke of 30.5% (95% CI: 23.6–37.8) at lag 0	1. Elderly (> 65 years old): ER = 32.3% (95% CI: 19.0–47.2) with a peak at lag 2 2. Gender: • Male ER = 34.5% (95% CI: 25.6–44.1) at lag 0 • Female ER = 24.7% (95% CI: 15.6–34.6) at lag 1	Increased intensity and prolonged heatwave duration significantly increase the daily risk of heatstroke. The proportion of severe heatstroke was also higher with more intense stronger heatwaves
Zhao et al. (2019) (Brazil)	Daily mean temperature ≥ 90th, 92.5th, 95th, or 97.5th percentiles of year-round temperature for ≥ 2–4 consecutive days	National-level pooled effect showed an increased risk of hospitalisation: • RR = 2.6 (95% CI: 1.9– 3.2) at 97.5^{th} percentile, especially for: (I) perinatal, (ii) endocrine, nutritional, and metabolic, (iii) skin problems, and (iv) genitourinary	Age at 97.5th percentile: • Children (0–9 years old) with 11% increased risk • Elderly (> 80 years old) with 18% increased risk	High temperatures and prolonged heatwave durations significantly increased hospitalisation, which peaked on day 1

Huang et al. (2023) (China)	Daily mean temperature ≥ 90th, 95th, or 97.5th percentiles for >2–4 consecutive days	Urinary-related hospital admission at 90th percentile for ≥ 3 consecutive days: • RR = 1.090 (95% CI: 1.050–1.132) and pooled AF = 8.27% (95% CI: 4.77–11.63) Urolithiasis • RR = 1.19 (95% CI: 1.100–1.136) and AF = 16.581% (95% CI: 9.109–23.439)	1. Male RR = 1.103 (95% CI: 1.058–1.149) 2. Age group ● 15–64 years old RR = 1.092 (95% CI: 1.040–1.145) ● Elderly (>65 years old) RR = 1.080% (95% CI: 1.020–1.143) 3. Geographic location ● Temperate continental climate zones RR = 1.310 (95% CI: 1.022–1.680) ● Temperate monsoon climate zone RR = 1.150 (95% CI: 1.084–1.220) ● Subtropical monsoon climate zone RR = 1.067 (95% CI: 1.020–1.116)	Heatwaves significantly increased urinary-related hospital admissions, especially urolithiasis
Kakkad et al. (2014) (India)	India Meteorological Department criteria: Temperatures ≤ 45 °C if daily maximum temperature > 4 °C above the normal maximum daily temperature	● Moving the maternity ward to the ground floor reduced heat-related admissions to the NICU by 6.4% (95% CI: 1.03 – 1.89) ● Approximately 43% of heatrelated NICU admissions were reported when temperature ≥ 42 °C (95% CI: 1.09–1.88)	Not specified	Heatwaves increased NICU admission. Reassigning the maternity ward to the ground floor showed a protective effect and can be implemented as one of the hospital adaptation measures to reduce NICU admission due to heatrelated illnesses
Mohammad i et al. (2019) (Iran)	Mean daily temperature > 90th percentile for ≥ 2 consecutive days	● Increased risk of PTB during heatwave events RR = 1.21% (95% CI: 1.08–1.37)	Not specified	Heatwaves increased the risk of PTB, especially at lag 0
Nhung et al. (2023) (Vietnam)	Maximum temperature ≥ 90th percentile for at least 3 consecutive days	● Heatwaves increase hospital admission for respiratory diseases at lag 2 ER = 8.31% (95% CI: 0.64–16.55)	Not specified	Heatwaves significantly increased the risk of hospital admission of patients with respiratory disease

Note: * Effect estimates are based on 95% CI and *p*-value < 0.05); OR = Odds Ratio, ER = Excess Risk, RR = Risk Ratio, AF = Attributable Fractions, RRs = Rate Ratio, PTB = preterm birth.

In terms of the vulnerability factors, certain groups in the community, including those 0–9 years old (Zhao et al., 2019), 0–64 years old (Phung et al., 2016), older people (> 60 years old) (Dang et al., 2019; Huang et al., 2023; Li et al., 2017; Liu et al., 2019; Trang et al., 2016; Zhao et al., 2019), outdoor workers (Li et al., 2017), singles (Liu et al., 2019), those living in urban (Liu et al., 2019), rural (Trang et al., 2016), specific geographic locations (Huang et al., 2023; Phung et al., 2017), and male (Li et al., 2017; Phung et al., 2017; Phung et al., 2016; Trang et al., 2016) and female gender(Li et al., 2017) were significantly associated with heatwave events.

3.3.2. Impacts of Heatwaves on Other Healthcare Services

3.3.2.1 Emergency Ambulance Dispatch (EAD)

Three studies examined the impact of heatwaves on EAD, as listed in Table 3. For instance, Sun et al. (2014) revealed a significant and rapid increase of 3–4 times higher in EAD with a J-shaped effect following exposure to heatwaves at least for 2–3 days compared to during non-heatwave events. Meanwhile, Cheng et al. (2016) and Hu et al. (2020) reported a significant increase in EAD with a U-shaped relationship between heatwaves and EAD. External causes, mainly related to suicidal behaviours, were significantly linked to and the most sensitive to heatwaves with EAD, which was followed by assaults and accidents.

Table 3. Impacts of heatwaves on other healthcare services.

Reference (Location)	Heatwave Definition and Matrices	Effect Estimates *	Vulnerable Groups	Summary
1. Emergency Ambulance Dispatch (EAD)				
Sun et al. (2014) (China)	Daily mean temperature ≥ 90th (29.67 °C), 95th (30.70 °C), and 99th (33.05 °C) percentiles for at least 2–3 days	EAD at 90th percentile: RR = 1.048 (95% CI: 1.014–1.084) increased in EAD for at least 2 days RR = 1.039 (95% CI: 1.008–1.071) increased in EAD for at least 3 days	Not specified	Significant immediate effects observed (J-shaped) in EAD following exposure to heatwave until lag 3
Cheng et al. (2016) (China)	Daily mean temperature at 95th, 97.5th, and 99th percentiles for ≥2 consecutive days	Increased risk of EAD at lag 0 at 95th percentile with RR = 1.03% (95% CI: 1.01–1.05) to 99th percentile with RR = 1.07% (95% CI: 1.05–1.10)	Not specified	Temperatures ≥ 95th percentile were associated with an increased risk of EAD (U-shaped trend) that peaked at lag 0 and lasted up to 21 days
Hu et al. (2020) (China)	Mean temperature ≥ 75th, 90th, 95th, and 99th percentiles for at least 2–4 days	Increased EAD observed in: - Suicidal behaviour with RR = 4.53% (95% CI: 1.23–16.68) at ≥75th percentile for ≥3 consecutive days - Assault with RR = 2.36% (95% CI: 1.25–4.48) at ≥ 95th percentile for ≥4 consecutive days - Accidents with RR = 1.72% (95% CI: 1.30–2.28) at ≥ 90th percentile for ≥ 2 days	Not specified	- U-shaped association between ambient temperature and EADs - Small and negligible effect of heatwaves compared to the main effect of heatwaves on EADs
2. Emergency Department Visit (EDV)				
Sun et al. (2014) (China)	Daily mean temperature ≥ 90th (29.67 °C), 95th (30.70 °C), and 99th (33.05 °C) percentiles for at least 2–3 days	EDV at 90th percentile: RR = 1.026 (95% CI: 1.018–1.035) increased in EDV for at least 2 days RR = 1.009 (95% CI: 1.002–1.017) increased in EDV for at least 3 days Every 1 °C increase in the daily mean temperature was associated with a 0.90% increase in EDV (95% CI: 0.67–1.12%)	Not specified	Significant immediate effects in EDV following exposure to heatwave until lag 3
Oray et al. (2018) (Turkey)	Higher air temperatures than the seasonal average and other days during the study period (17–25 June 2016)	Significant increase in the number of EDV during heatwave periods compared to the same period in the previous year (320 ± 30/day vs. 269 ± 27/day) ($p < 0.01$)	Insignificant finding for age ($p > 0.05$)	Increased EDV admissions during heatwaves
Song et al. (2018) (China)	Daily mean temperature ≥ 95th percentile for 2–4 consecutive days	- Minimum morbidity temperature = 21.5 °C - Increased risk of EDVs due to respiratory illnesses when heatwaves lasted for ≥ 4 consecutive days, and intensity increased from 95th to 99th percentile (RR = 1.932% (95% CI: 1.461–2.554))	1. Gender Females (RR = 1.166% (95% CI: 1.007–1.349)) at 96th percentile when heatwaves lasted ≥ 4 consecutive days	Significant trend of the risk of EDV for respiratory illnesses during more intense and prolonged heatwaves
(van der Linden et al., 2019) (Pakistan)	EHI ≥ 4	Not mentioned	Increased EDV from 65–74 years old when EHI ≥ 4 ($p \leq 0.005$)	Increased EDV for elderly during heatwaves
3. Outpatient Department Visit				
Zhang et al. (2019) (China)	Daily maximum temperature ≥ 35 °C for at least 3 consecutive days	-Total respiratory disease at lag 0: RR = 1.115 (95% CI: 1.084–1.232) -Infectious respiratory disease: RR = 1.182 (95% CI: 1.106–1.263) at lag 0, mainly in the upper respiratory tract: RR = 1.227 (95% CI: 1.128–1.335)	Gender Female at lag 0: RR = 1.161 (95% CI: 1.046–1.298) Male at lag 4: RR = 1.161 (95% CI: 1.096–1.261) 2. Age a) Children 4–17 years at lag 0: RR = 1.741 (95% CI: 1.524–1.990) b) Elderly ≥ 65 years at lag 5: RR = 1.412 (95% CI: 1.111–1.794)	Heatwaves significantly increased the risk of respiratory tract infections, particularly in the upper respiratory tract, and decreased the risk of non-infectious diseases
4. Mortality				
Oray et al. (2018) (Turkey)	Higher air temperatures than the seasonal average and other days during the study period (17–25 June 2016)	Significant increase in the number of mortalities in hospitals during heatwave periods compared to the same period in the previous year (RR = 2.03, $p < 0.01$)	Insignificant findings for gender and age ($p > 0.05$)	Increased in-hospital mortality rates during heatwave periods

5. Healthcare Expenditure				
Huang et al. (2023) (China)	Daily mean temperature ≥ 90th 95th, or 97.5th percentiles for > 2–4 consecutive days	National annual excess cost for urinary disease hospitalisation: CNY 2.42 billion (95% CI: 1.35–3.45) Direct medical treatment: CNY 2.23 billion (95% CI: 1.29–3.14) Indirect cost: CNY 0.19 billion (95% CI: 0.06–0.31) Inpatient urolithiasis accounted for about half of the total urinary disease's expenditure: CNY 8.69 million (95% CI: 4.71–12.34)	Higher cost of treatment for males by CNY 10.64 million (95% CI: 6.07–15.07). Direct and indirect costs for people aged 15–64 were twice higher than older people (> 65 years old)	High healthcare expenditure on urinary diseases, particularly urolithiasis, indicating the need to promote a healthy lifestyle to prevent urolithiasis

Note: * Effect estimates are based on a 95% CI and $p < 0.05$; OR = Odds Ratio, ER = Excess Risk, RR = Risk Ratio, AF = Attributable Fraction, EDV = Emergency Department Visit, EAD = Emergency Ambulance Dispatch, CNY = Chinese Yuan.

3.3.2.2 Emergency Department Visit (EDV)

Four studies stated that heatwaves increased the risk of EDV compared to non-heatwave periods, as depicted in Table 3. In one study, Sun et al. (2014) showed that exposure to heatwave caused an immediate increase in EDV until lag 2–3 days. In addition, every 1 °C increase in the daily mean temperature was associated with a 0.90% (95% CI: 0.67–1.12) increased risk in EDV. The risk of EDV related to respiratory illnesses was significantly higher with more intense heatwaves that lasted for at least four days (RR = 1.932 (95% CI: 1.461–2.554)) (Song et al., 2018).

3.3.2.3 Outpatient Department Visit

Only one article (8.3%) described the relationship between outpatient department visits and heatwaves (Zhang et al., 2019). The study found that heatwave significantly increased the risk of outpatient department visits for total respiratory disease with the most substantial effect at lag 0 (RR = 1.115 (95% CI: 1.084–1.232)). Moreover, infectious diseases, mainly upper respiratory tract infections (RR = 1.227 (95% CI: 1.128–1.335)), were the highest cause and symptoms for outpatient department visits. Outpatient department visits for males and females differed at lag days after heatwave events. Older and younger age groups (4–17 years old) were the most vulnerable groups seeking treatment for respiratory diseases and upper respiratory tract infections in the outpatient department.

3.3.2.4 In-hospital Mortality

Only one article (8.3%) conducted in Turkey examined the impact of heatwave on in-hospital mortality (Oray et al., 2018) (Table 3). All-cause mortality was reported to increase by 181% during heatwave periods compared to the reference period in 2015 (RR = 2.03, $p < 0.01$).

3.3.2.5 Healthcare Expenditure

A study by Huang et al. (2023) demonstrated high healthcare expenditure during heatwave periods in terms of urinary disease hospitalisation, with a national annual cost of Chinese Yuan (CNY) 2.42 billion (95% CI: 1.35–3.45) (Table 3). Further analysis highlighted direct medical treatment and indirect costs of more than twice higher among patients aged 15–64 compared to the elderly group with an excess loss of CNY 1.70 billion (95% CI: 0.76–2.59) and CNY 0.68 billion (95% CI: 0.18–1.16), respectively. Males recorded higher urinary disease healthcare expenditures by CNY 10.64 million (95% CI: 6.07–15.07) compared to females. In addition, urolithiasis hospitalisation accounted for almost half of the total cost of urinary diseases' health expenditure with an excess loss of CNY 8.69 million (95% CI: 4.71–12.34).

3.4. Assessment of Evidence

3.4.1. Risk of Bias (RoB) Assessment

Figure 2 shows the synthesis of RoB across studies in this review, while the assessment, justification, and individual studies' details are summarised in Supplementary Materials (S3–S5). In general, most of the selected articles presented a 'definitely low risk' of biasness (67%). Exposure assessment was one of the domains that recorded a 'probably high risk' of bias. This may be due to the methodology applied in the studies, which utilised data from a single meteorological station or lacked adjacent meteorological stations (within 40 km) for exposure assessment. Meanwhile, three articles were given a score of 'definitely high risk' of bias due to non-adjusted confounding Oray et al. (2018), using non-standard diagnostic criteria for the outcome assessment (Kakkad et al., 2014; Oray et al., 2018; van der Linden et al., 2019), and the effect estimates were excluded from the Results section(van der Linden et al., 2019).

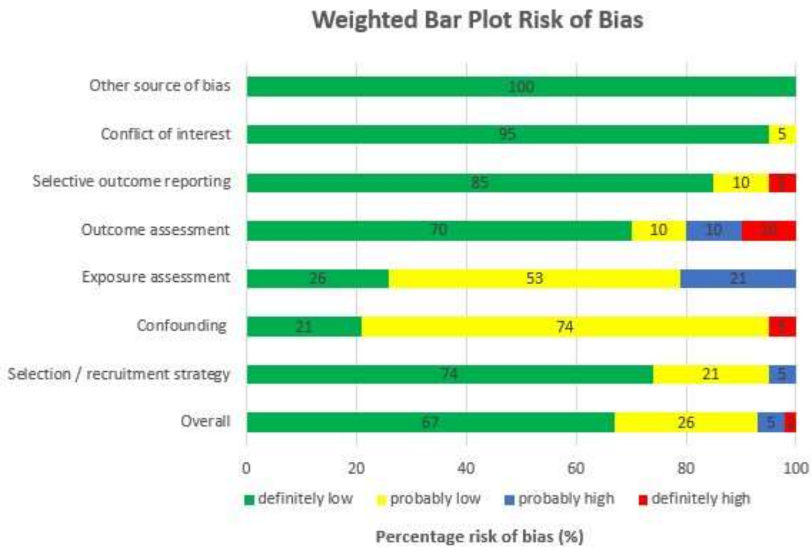

Figure 2. Synthesis of the RoB assessment across studies in this review.

3.4.2. Quality of Evidence Assessment and Strength of Evidence across Studies

No justification to downgrade the overall quality of evidence was observed, as shown in Table 4. Interestingly, when the quality of evidence for the dose–response gradient was upgraded, the overall quality of evidence recorded a high score (4+). It was deduced that the results from all the included studies were consistent, implying that exposure to heatwave significantly increased the usage of healthcare services. The assessment of the strength of evidence can be summarised as "sufficient", indicating a positive association between heatwaves and their impact on healthcare services with high-quality evidence.

Table 4. Summary of quality of evidence assessment and strength of evidence based on the relationship between heatwaves and health services.

Category	Summary of Criteria	Downgrades	Justification
Quality of evidence assessment			
Initial rating of human evidence = 'Moderate' (3+)			
Individual study limitation of evidence	Substantial risk of bias across the body	0	Most articles were graded as 'definitely low risk' and 'probably low risk' of bias. Approximately 5% were graded as 'probably high risk', and 2% were graded as 'high risk'. Hence, no substantial risk of bias was observed in most of the included articles
Indirectness of evidence	Certain evidence did not follow the pre-determined PECO statement	0	Most articles used standard criteria for outcome assessment, with direct measures of exposure variables, as outlined in the PECO statement
Inconsistent results	Presence of heterogeneity that ultimately affects the sample size	0	17 out of 19 studies reported an overall effect estimate that demonstrated an association between heatwaves and their impact on health services
Imprecision	Presence of considerable variation in 95% CI	0	Most of the 95% CI of the included studies did not reveal a wide variability
Publication bias	Presence of a missing body of evidence that may affect the true effect of exposure	0	No justification or evidence to downgrade the quality level for publication biasness without an informative funnel plot
Category	**Summary of criteria**	**Upgrades**	**Justification**
Dose–response gradient	Consistent relationship between dose (exposure) and response (outcome)	+1	All studies showed an exposure–response gradient, where an increased heatwave duration and intensity increased the usage of health services
Large magnitude effect	Studies exhibit a large effect with an RR > 2 and a substantial effect with an RR > 5	0	Less than half of the included studies (n = 6) demonstrated a large-size effect
Confounding	Upgraded if all plausible confounders that may shift the RR towards null were recognised, and a substantial RR was still recorded	0	Certain studies may have residual confounding due to failure to account for all relevant, well-studied variables. However, there is no proof that it nullifies the benefit by residual confounders
Strength of evidence assessment			
Quality of evidence	High (from the above finding)		
Direction of effect	Increase in the usage of healthcare services with increasing temperature intensity and duration (heatwave)		
Confidence in the effect	It was projected that future research would not significantly alter the conclusion of the present study		
Other attributes	None		

4. Discussion

4.1. Impact of Heatwaves on Health Services

This review summarised the findings of 19 selected articles regarding the impact of heatwaves on healthcare services, specifically on hospital admission, EAD, EDV, outpatient department, and healthcare expenditure. To the best of the author's knowledge, this is the first reported attempt to analyse the available evidence on the isolated impact of heatwaves on healthcare services in developing countries. Based on the results, the increasing temperature intensity and duration of heatwave events were expected to raise the burden of healthcare services immediately and lasted up to 21 days, especially in terms of hospital admissions, EDV, EAD, and outpatient department visits.

The impact of heatwaves on EAD is a significant concern, as heatwaves can exert a strain on public health and emergency medical services. Health impacts such as heat stroke, dehydration, cardiorespiratory illness, and mental disorder drive people to seek emergency medical assistance, hence increasing EAD. Populations with low socio-economic status, poor housing and transport, and poor health status are susceptible to heat-related health issues leading to an increased need for medical attention and ambulance services (Varghese et al., 2021). Ambulance services may experience increase response times, longer waiting times, and potential resource limitations during heatwaves (Becker & Hugelius, 2021). It becomes crucial for top management to access and anticipate the potential impact of heatwaves on ambulance services; to effectively allocate resources such as pre-positioning ambulances in high-demand areas and ensure adequate emergency response capacity (Plat et al., 2011).

This review also revealed that mental disorders and kidney diseases were the most commonly reported illness requiring healthcare service during heatwave events, which agreed with previous studies' findings in developed countries (Borg et al., 2017; Hansen et al., 2008; Kim et al., 2018). It was assumed that a higher incidence of kidney disease, particularly urolithiasis and chronic kidney disease, during heat stress resulted from extreme perspiration and fluid loss induced by the diversion of renal blood flow from the splanchnic and renal vasculature to the periphery. The impact of heat stress due to these physiological changes is frequently manifested as dehydration, hyperthermia, and renal failure (Kim et al., 2018). In addition, this review discovered that the risk of kidney-related hospitalisation lasted up to 6 days following heatwave exposure, similar to previous studies conducted in developed countries (Chi et al., 2017). However, several studies conducted in Australia (Borg et al., 2019), the United States (Vicedo-Cabrera et al., 2020), Italy (Condemi et al., 2015), and South Korea (Choi et al., 2016) reported that the risk of urolithiasis was associated with the high temperature of the heatwave, and the effect period ranged around 2–4 days, 10 days, 16 days, and 20 days, respectively. Thus, more research is required to identify the causes of this heterogeneity.

Furthermore, extreme temperatures are often linked to mental illness due to the disturbance in the social, economic, and environmental factors that determine mental health at the community level (Nurse et al., 2010). Previous studies have also found that extremely high temperatures could aggravate pre-existing psychiatric problems as a result of the disruption of normal thermoregulation by specific psychotropic drugs and the inability of psychiatric patients to adapt themselves to extreme weather changes (Berry et al., 2010; Page & Howard, 2010). Acknowledging that mental illness is predicted to be the second leading cause of non-fatal disease by 2030, it is thus crucial for healthcare workers to understand the relationship between mental illness behaviours and heatwaves (Berry et al., 2010).

Prior research has emphasised the necessity of using various temperature matrices, such as Excess Heat Factor (EHF), maximum temperature, and daily average temperature, to classify heatwave events. Different formulas are established using multiple definitions to understand the dose–response relationship and construct practical heatwave response plans, ultimately anticipating the burden on healthcare services (Scalley et al., 2015). Based on the findings of this study, heatwaves increased the risk of both EDVs and hospital admissions. In China, heatwave events were associated with a 2%, 6%, and 8% increase in total, respiratory, and cardiovascular hospitalisations, respectively (Ma et al., 2011). In contrast, a recent study in Vietnam revealed an 8% increased risk of respiratory hospitalisation but not cardiovascular admission. This discrepancy is probably due to the different geographical areas, adaptation ability, population, society, lifestyle characteristics, and a variety of morbidity indicators used in the studies, such as hospital admissions, EDV and AED (Liu et al., 2022; Nhung et al., 2023).

4.2. Vulnerability Factors

In this review, the elderly population was the most vulnerable group to heatwaves, which was followed by children. However, a slight inconsistency was observed regarding the susceptibility of the subgroups, such as gender and specific age groups. Minor groups were also believed to exist in the vulnerable population and remain contentious depending on the socio-demographic, health outcomes, geographical locations, type of diseases, and different methodologies during recruitment and analysis (Kim et al., 2018; Li et al., 2017). However, most studies reported that older people (≥ 65 years old) and males were more likely to seek healthcare services during heatwaves. It is well understood that the ageing process is associated with a low adaptive tolerance to heat due to impaired thermoregulation and homeostasis on top of pre-morbid medical conditions and medicinal use (Moghadamnia et al., 2017). On the other hand, children are more susceptible to heatwave effects due to their immature thermoregulatory systems, greater body area-to-mass ratio, higher metabolic rates, longer outdoor activities, and minimal awareness to care for themselves (Xu et al., 2014). In addition, most studies highlighted in this review showed a higher risk of experiencing morbidity among males than females, which was probably due to more males being involved in outdoor activities rather than indoors. Onda and Yokota (2012) also reported that males were three times more at risk of experiencing heatstroke than females. Moreover, a systematic review by Gifford et al. (2019)supported the findings that males were at a higher risk of mortality, hospital visits, and admissions, which is related to psychological and behavioural factors rather than physiological factors.

Working age groups were also highly susceptible to heatwaves as they were exposed to extremely hot days while working outdoors (Kakkad et al., 2014) aside from their low-income salaries contributing to unfavourable living conditions (Al-Sayyad & Hamadeh, 2014). Other known factors, such as being single, confined to bed, inability to self-care, homeless, and living in rural areas, are associated with higher morbidity and mortality risk following heatwave exposures (IPCC, 2001; Mayrhuber et al., 2018). Hence, gaining further understanding of these vulnerable groups and their conditions should be the main priority for stakeholders and policymakers before developing any action plans, strategies, policies, and regulations to address extreme temperatures and heatwaves (Dima Sayess, 2021). In addition, state governments and relevant authorities in developing countries should commit to implementing climate-resilient health systems by conducting vulnerability and adaptation assessments as well as devising National Adaptation Plans (NAP) (Blom et al., 2022; Nations, 2023).

4.3. Economic Impact of Heatwave on Health Services

Estimating the healthcare expenditures associated with climate change is vital to evaluate health-policy decisions (Kim Knowlton, 2011). Extreme high temperatures could contribute to a direct or indirect significant increase in healthcare costs, such as using disposable materials, medicine, transportation, labour productivity loss, and excess life loss (Schmitt et al., 2016). For instance, a study in the United States estimated an increase in the baseline hospitalisation costs for respiratory diseases of about USD 0.64 million per annum during the summer, and it is projected to rise to USD 5.5–7.5 million by 2046–2065 (Tong, Wondmagegn, Williams, et al., 2021). Furthermore, it was reported that the excess costs of hospitalisation, EDVs, and outpatient visits during the severe heatwave in California in 2006 were approximately USD 28.4 million, USD 14.1 million, and USD 136.4 million, respectively (Kim Knowlton, 2011). During Australia's 2006–2012 heatwave period, approximately AUD 79.5 million of hospital expenditure was spent to mitigate the heatwave crisis. The cost is expected to rise to AUD 125.8–129.1 million by 2026–2032 (Shao Lin et al., 2012). The same author further examined the cost of healthcare services related to heat illnesses, specifically for EDV in 2012–2019, and found an extra 3697 visits accounting for AUD 2.9 million and projected to increase around 4.5–5.6% by 2030–2050 (Tong, Wondmagegn, Xiang, et al., 2021).

Conversely, developing countries have lower GDP allocations for health, less access to advanced healthcare services, and inadequate basic infrastructure, ultimately leading to health inequality and inequity. Those with lower socio-economic status might also care less about their health (Liu et al., 2013). Consequently, these factors contribute to higher morbidity and mortality, particularly under extreme temperatures and heatwaves. Hence, government officials and policymakers should allocate sufficient resources towards improving basic infrastructures and healthcare services. In addition to understanding the cost of healthcare expenditure, managing climate change through effective governance, such as implementing a circular economy and conducting continuous Health Impact Assessment (HIA), Environmental Impact Assessment (EIA), Social Impact Assessment (SIA), and Cost–Benefit Analysis, could reduce the negative outcome of climate change and contribute to better human well-being and healthcare systems (Girard & Nocca, 2020).

4.4. Strengths and Limitations of the Findings

As far as the author's knowledge is concerned, this present review is the first to explore the impact of heatwaves on healthcare services in developing countries. Policymakers and stakeholders can utilise the evidence gathered in this review to improve the government's readiness and risk management plans for future heatwaves and enforce systematic improvements in healthcare infrastructure and costs, eventually reducing the morbidity and mortality associated with heatwave exposures.

Few limitations were encountered in this review. Firstly, only a handful of articles solely focused on the isolated impact of heatwaves on healthcare services in developing countries (Campbell et al., 2018). Certain regions in these developing countries were poorly presented or completely overlooked due to the lack of basic meteorological observations and funding. Thus, the absence of long-term data further complicates the assessment of the heat warning threshold (Campbell et al., 2018; Ouyang et al., 2022).

In addition, this review had to be precisely interpreted, since some countries may have a wide range of geographical areas and vulnerable groups, as well as adaptation capabilities, which might differ from other developing countries. Considering these, the review underlined the essence of bridging the heat-impact assessment gap for developing countries to understand better the effects of heatwaves on healthcare systems in the future. In addition, the physiological, socio-economic, and environmental mechanisms at different lags of extreme temperatures also remained unclear, warranting further studies (Li et al., 2017).

Moreover, several articles in this review disregard the influence of other air pollutants, which were identified as a confounder (Yuming Guo et al., 2014; Zanobetti & Peters, 2015). Hence, future research is recommended

to include air pollutants, such as particulate matter and ozone, when analysing the heat–health relationship. Future works should also establish a heatwave early warning system as an effective prevention strategy.
Further examination of the knowledge, attitude, and practice of adaptation and protection strategies, particularly among vulnerable groups during heatwave events, would assist in developing effectual heat protection plans for the community.

4.5. Recommendations for Policymakers and Healthcare Providers

Previous studies have demonstrated that developing countries exhibit a higher heat sensitivity with lower adaptation than developed countries (Rataj et al., 2016). Therefore, understanding the vulnerability factors and conducting adaptation assessments are vital to formulating policies that reduce the future health burden related to high temperatures and address the increasing burden on sensitive and vulnerable subgroups of the local population in developing countries. Such practical interventions, for example, mapping the high-risk group, exposure reduction measures, and active outreach programs, can also be implemented to resolve the issue (Mayrhuber et al., 2018).
A comprehensive approach, including planning, programming, implementing, monitoring, and evaluating the establishment of climate-related policies, needs to be formalised to ensure a resilient healthcare system that can successfully mitigate heatwave events in the future. The development of public health policies should be tiered according to the severity level of heatwaves (Scalley et al., 2015). Furthermore, preparedness, prevention, and promotion with public health intervention and primary healthcare shall be prioritised over individual care (Ghebreyesus et al., 2022). For instance, a review by Toloo et al. (2013) revealed that costeffective life-saving early warning systems decreased mortality and reduced the risk of EAD. Morbidity indicators should also be adopted during heatwave impact assessments and in developing early warning systems to carry out effective public health action plans (Li et al., 2015). For example, India became the first South Asian country to develop and implement the Heat–Health Action Plan based on available evidence and ongoing evaluations (Knowlton et al., 2014).
Establishing the temperature threshold and duration of heatwaves is essential for public health and healthcare management, as this information can be used as an early warning indicator for emergency departments, public health agencies, and residents to make the necessary preparations to prevent, predict, and manage heat- and non-heat-related illnesses (Li et al., 2017). This is evidenced by an increased risk of heatstroke on the same day by 30.5% when the temperature threshold in Chongqing, China (34 °C) is exceeded by 1 °C, which is almost similar to that in Japan (Akihiko et al., 2014). Other successful examples of mitigation actions that policymakers can promote include developing cooling centres, building cool roofs, providing free access to public pools, creating effective communication strategies with the public, designing effective urban planning, and ensuring adequate food and water security (Broadbent et al., 2020; Çulpan et al., 2022; Hondula et al., 2015).
Furthermore, constructing sufficient healthcare facilities and infrastructure, such as beds, power supply, and water and sanitation systems (Li et al., 2015), and preparing adequate human resources is compulsory to ensure sustainability and efficient healthcare. Primary healthcare must also be more innovative, accessible, and equipped with essential infrastructure as a cost-effective alternative to reduce hospital visits (Vashishtha et al., 2018). Therefore, clinicians in primary care are expected to set up robust and resilient primary care frameworks for patients with heat-related health concerns, including health promotion and health practices, such as proper fluid intake and adequate access to electric fans (Michelozzi et al., 2021).

5. Conclusions

This review provides new insights into understanding the impact of heatwaves on healthcare services in developing countries. The research findings of 19 selected articles in this review are expected to be utilised as a reliable reference for future research and implement proactive measures to mitigate the impact of heatwaves on healthcare services. The rising frequency and intensity of heatwave events due to rapid climate change pose numerous challenges, such as increased morbidity and mortality, overburdened healthcare services, limited infrastructure, and bloating healthcare expenditure, especially for vulnerable populations. For developing countries to address these challenges, they must prioritise vital investments in heatwave preparedness, including effective early warning systems, extensive public health campaigns, practical heatwave response plans, and improved healthcare infrastructure, capacity, and human resources. Furthermore, international cooperation and support are essential to assist developing countries in building resilience and adapting to the impact of heatwaves on their healthcare systems. Overall, developing countries can better protect their populations' health and well-being in the face of future heatwaves events by taking proactive measures, raising awareness among the local population, and mobilising available resources.

Supplementary Materials: Table S1: Preliminary pilot search strategy in Web of Science (WOS), Pubmed, and Scopus. Table S2: The list of 152 developing countries according to IMF. Table S3: Instructions for the Risk of Bias (RoB) assessment in individual studies. Table S4: Criteria for the quality assessment for each study according to the OHAT risk of bias rating tool. Table S5: Summary of the Risk of Bias (RoB) assessment results in individual studies. References [28, 30, 37–54] are cited in Supplementary Materials.

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