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Heat related health impacts in cities located in Low– and Middle-Income Countries: A systematic review

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LIST OF ACRONYMS AND ABBREVIATIONS

HW	Heat waves
LICs	Low-income countries
LMICs	Low- and Middle-income countries
HICs	High income countries
IPCC	Intergovernmental Panel on Climate Change
UN	United Nations
UHI	Urban Heat Island effect

TABLE OF CONTENTS

1 Introduction ... 1
2 Background ... 2
2.1 Objectives ... 6
2.2 Research question ... 6
3 Methods ... 6
3.1 Literature search ... 7
3.2 Inclusion and exclusion criteria ... 8
3.3 Extraction criteria and data collection ... 8
3.4 Risk of bias assessment ... 9
4 Results ... 9
4.1 Characteristics of included studies ... 10
4.1.1 Geographical coverage ... 10
4.1.2 Design types ... 11
4.1.3 Heat parameters ... 12
4.2 Outcome measure ... 13
4.2.1 Urban Heat Island (UHI) ... 14
4.2.2 Health outcomes ... 15
4.2.3 Sociodemographic characteristics ... 17
5 Discussion ... 24
5.1 Limitations ... 28
6 Conclusion ... 29
6.1 Recommendations ... 29
6.2 Implications ... 31
References ... 32
Appendix ... 41

LIST OF TABLES AND FIGURES

Table 1. PEO framework elaborated by the author ... 6

T**able 2**. Characteristics of reviewed studies and main findings ... 22

Figure 1. A 24-step guide on how to design, conduct, and successfully publish a systematic review and meta-analysis in medical research 7

Figure 2. Flowchart diagram of studies selected following PRISMA 2020............................10

Figure 3. Geographical location of selected articles..11

Figure 4. Number of articles reporting mortality and morbidity per age group 17

Figure 5. Number of articles reporting mortality and morbidity per sex.................................18

Figure 6. Number of articles reporting mortality and morbidity per SES 19

Figure 7. Number of articles reporting mortality and morbidity per level of education...........20

Figure 8. Number of articles reporting mortality and morbidity per employment. 21

Figure 9. Number of articles reporting mortality and morbidity per race. 21

Abstract

Background. Climate change has become the biggest global health threat of the 21st century. Heat exposure is recognized nowadays as a public health hazard affecting the most vulnerable populations, with many studies evaluating the link between heat and mortality and/or morbidity. This association has been documented primarily in High-Income Countries (HICs), but few studies have examined the heat impact on human health in Low- and Middle-Income Countries (LMICs), especially in cities.

Objectives. Review the existing evidence about how heat impacts mortality and/or morbidity rates on people living in cities located in Low- and Middle-Income Countries (LMICs) and to identify the most vulnerable groups affected by this climate hazard.

Methods. A systematic review was conducted. Three databases (PubMed, Scopus, and Embase) were used to search articles with relevant content to this thesis' objective. The thesis' author carried out screening, selection of articles, and data extraction. The selection of countries was according to the World Bank Classification.

Results. 1508 articles were initially identified, and 20 papers met the inclusion criteria. Out of the 137 Low- and Middle-Income Countries (LMICs), 7 countries and 64 cities were part of the systematic review. Selected studies were performed in Africa, Europe, America, and Asia continents with the majority (45%) of the articles being published in China.

Conclusions. This systematic review suggested that women, elderly, and a low socio-economic status were vulnerable factors to heat. The results of this review inferred that morbidity and mortality associated with cardiovascular and respiratory systems were the most affected by heat. Public health adaptations and prevention programs in LMICs could be useful to develop response plans and to enhance health care systems to adapt to extreme weather events.

Keywords: Heat, heat waves, LMICs, Vulnerability, Mortality and Morbidity

Résumé

Contexte. Le changement climatique est devenu la plus grande menace sanitaire mondiale du 21ème siècle. L'exposition à la chaleur est aujourd'hui reconnue comme un risque de santé publique affectant les populations les plus vulnérables, avec de nombreuses études évaluant le lien entre la chaleur et la mortalité et/ou la morbidité. Cette association a été documentée principalement dans les pays à revenu élevé (PRI), mais peu d'études ont examiné l'impact de la chaleur sur la santé humaine dans les pays à revenu faible et intermédiaire (PRITI), en particulier dans les villes.

Objectifs. Examiner les preuves existantes de l'impact de la chaleur sur les taux de mortalité et/ou de morbidité des personnes vivant dans des villes situées dans des pays à revenu faible ou intermédiaire (PRFM) et identifier les groupes les plus vulnérables affectés par ce risque climatique.

Méthodes. Une revue systématique a été menée. Trois bases de données (PubMed, Scopus, et Embase) ont été utilisées pour rechercher des articles dont le contenu était pertinent par rapport à l'objectif de cette thèse. L'auteur de la thèse a effectué le tri, la sélection des articles et l'extraction des données. La sélection des pays s'est faite selon la classification de la Banque mondiale.

Résultats. 1508 articles ont été initialement identifiés, et 20 articles ont répondu aux critères d'inclusion. Sur les 137 pays à revenu faible et intermédiaire (PRFM), 7 pays et 64 villes ont fait partie de l'examen systématique. Les études sélectionnées ont été réalisées sur les continents africain, européen, américain et asiatique, la majorité (45%) des articles ayant été publiés en Chine.

Conclusions. Cette revue systématique suggère que les femmes, les personnes âgées et un faible statut socio-économique sont des facteurs de vulnérabilité à la chaleur. Les résultats de cette revue ont permis de déduire que la morbidité et la mortalité associées aux systèmes cardiovasculaire et respiratoire étaient les plus affectées par la chaleur. Les adaptations de la santé publique et les programmes de prévention dans les PRFM pourraient être utiles pour développer des plans de réponse et améliorer les systèmes de soins de santé pour s'adapter aux événements climatiques extrêmes.

Mots clés: Chaleur, vagues de chaleur, PFRDV, vulnérabilité, mortalité et morbidité.

Glossary

City: A densely populated and permanent place with clearly defined administrative boundaries, whose members are predominantly involved in non-agricultural activities.

Climate change: A change in the average weather and temperature patterns, which is mainly attributed to human activity that alters the composition of the global atmosphere due to fossil fuel combustion (coal, oil, and gas)

Gross National Income (GNI) per capita: The sum of the country's gross domestic product in a year divided by its population.

Greenhouse gases (GHG): Gaseous substances which trap the heat in the atmosphere enabling the planet to be warm. The most common ones are water vapor (H_2O), carbon dioxide (CO_2), nitrous dioxide (N_2O), methane (CH_4) and ozone (O_3).

Hazard: Something which could cause harm.

Heat: Is the energy transfer between one object to another as a difference resulting in temperature.

Heat wave: Abnormal period of hot weather which is followed by high humidity.

Heat stress: A condition where the body is under stress due to overheating and it is unable to maintain a healthy temperature which could result in heat stroke, heat exhaustion, heat rashes or heat cramps.

Inequality: Differences in health, socioeconomic status, or opportunities between individuals or groups.

Mitigation: A way to reduce severity, danger, pain, or harshness.

Monsoon: Subtropical and tropical seasonal change characterized by having strongest winds and high humidity.

Natural disaster: A natural event subsequent from earth natural processes with devastating effects, generally associated with mortality, morbidity, and resource depletion.

Risk: Likelihood degree that the hazard will cause harm.

Sociodemographic characteristics: Factors that define a group of population’s social and demographic profile such as age, sex, socioeconomic status, marital status, level of education and employment.

Urban: Human settlement characterized for having high population density and good infrastructure.

Urban heat Island (UHI): A phenomenon which occurs in urban areas characterized by experiencing higher temperatures than outlying areas.

Vulnerability: The degree to which an individual/ community or country can cope with the effects of a hazard.

1 Introduction

Heat is recognized as a public health hazard and climate change represents one of the main environmental and health equity challenges worldwide and described as the most critical threat nowadays, creating a “perfect storm” of global health risks (1–4). As a result of climate changes directly influenced by human beings, the global surface air temperature has had a growing trend in the last century according to the Intergovernmental Panel on Climate Change (IPCC) (2,5). This has led to an increase in the frequency, intensity, and duration of extreme heat events worldwide (6).

Periods of extreme temperature with various lengths are known as heat waves, nonetheless, there is no universal definition. For some authors, the duration is 2 days while for others it is at least 3 days (7). The combination of high temperatures and humidity can increase the disaster risk, therefore a heat wave can be considered a natural disaster as they are becoming more harmful, intense, and frequent worldwide (6,8). This phenomenon had caused during 2003 in Europe around 72.000 deaths (9).

Several health impacts generated by heat exposure are threats for Low-and Middle-Income Countries as they have fewer resources to adopt disaster response and recovery measures (10–12). These inequalities increase the exposure of the most vulnerable populations as well as the susceptibility to tackle disasters and subsequent recovery (8). Exposure to high temperatures puts on the risk population's health, increasing the mortality and morbidity rates which are commonly associated with cardiovascular, respiratory, and other diseases affecting more the urban people with low economic income. However, women, the elderly, youth, children, people with pre-existing diseases, and indigenous in developing countries are the ones most affected by climate change impacts. Factors that are still controversial according to the literature (10,11,13).

Urban vulnerabilities are highly variable as they depend on specific geographic, demographic, health, and social contexts. The urban heat island (UHI) effect also increases vulnerabilities, threatening the sustainability of rapidly growing urban settlements worldwide (14–16).

Therefore, it is necessary to raise awareness of how the heat impacts affect especially different population groups in cities located in Low and Middle-Income Countries and how these inequalities can be reduced (11).

2 Background

According to the United Nations and its Intergovernmental Panel on Climate Change (IPCC), climate change has become one of the main environmental challenges worldwide, causing multiple disasters regardless of countries' economic levels (1,2,17). These natural hazards have generated an estimated cumulative global loss of US$ 2,24 billion from 1998 to 2017, per the United Nations Office for Disaster Risk Reduction (UNISDR) (18)

The impact of high temperatures is one of the most harmful effects of climate change, representing a significant environmental and health equity challenge as climate-sensitive diseases mainly affect vulnerable populations in Low and Middle-Income Countries (2,10,11,13,18). The evidence in these countries is scarce, limiting actions in a timely manner to avoid the consequences not only on the ecosystems, agriculture, and water resources, but also in human health (10,13,16–19)

Heat is recognized as a public health hazard as it generates significant consequences on human health, especially in the climate change context (1–3,17,20). The increase of high temperatures is a risk by itself, exposing approximately 30% of the global population to health-threatening heat and raising the risk of deaths and illnesses (17,19,21). A common definition of extreme heat is highly controversial as it depends on the context and location, nevertheless what is clear is that the frequency of these events is rising worldwide (3).

Abnormal and prolonged periods of excessive heat are known as heat waves. There is no universal definition and benchmark of heat waves as these vary between countries, therefore it is common to find different definitions in the literature. Even so, heat waves have been defined by researchers according to their intensity, frequency, and duration (1,16,19,22,23). There is a general agreement in the literature and IPCC that heat wave duration has increased worldwide throughout the years. A clear example of such an increase is the situation in India where its population has experienced the fastest increment of heat waves exposure worldwide according to an IPCC report which showed rising mortality rates during past years (24).

A great number of scientific studies have evidenced that heat exposure has a direct consequence on mortality (death) and morbidity (illness) (3,17,18,21,23). Two clear examples of high mortality resulting from this phenomenon are the heat waves in Paris, France in 2003 with 14.800 casualties in six cities over 19 days, and in India in both 1998 and 2003 with 4.441 total deaths records (1,23,25)

Heatwaves' behavior and impacts on health change according to their intensity, duration, frequency, latitude, predominant season, country geographic location, and human settlement. The interaction of one or more of these elements play an important role in heat related health consequences (25–28). Epidemiological studies state that heat waves intensity could lead to heat stroke, heat exhaustion, heat syncope, and death in vulnerable populations ((10,13,29)

The most notable heat impacts in human health are infectious, cardiovascular, respiratory, and mental diseases, allergies, child development illnesses, maternal and pregnancy issues, and death (10,13,27,30). The most affected group to these health impacts are the socially vulnerable populations that have fewer resources to mitigate the effects of heat leading to higher inequities (10,14,17,19,31).

People's sensitivity to heat will majorly depend on social stressors and climatic, environmental, and individual risk factors ((10,19,31). Intrinsic factors acting from within an individual (age, genetics) and extrinsic factors, commonly known as aspects influenced by the outside (housing, economic), also influence the individual's exposure because they modify environmental factors' effects and act as an instrumental tool to control the severity of environmental heat diseases (10,18,31,32).

Concerning intrinsic factors, ethnic minority groups have higher heat related health consequences than others as they are more frequently exposed to multiple environmental hazards and social stressors including social inequalities, poor house conditions, and poverty (18,19,31). Existing literature recognize and debate that heat effects will be most severe in vulnerable populations, prominently elderly, women, children and infants, and racial minorities (3,10,13,19,27,31). Some articles suggest that women are more heat sensitive than men due to gender physiological differences, while other literature shows an unequal risk distribution in the sex variable (23,26,33,34).

Regarding extrinsic factors, the interaction of social and economic characteristics influences directly or indirectly an individual susceptibility to heat (1,3,5,17,18,22). At a city level, economic factors influence an individual heat susceptibility risk because low socioeconomic status amplifies such risk. People who live in these conditions do not have enough economic resources for better construction materials, ventilation, and other heat protection measures in comparison with those who can afford them, implying greater vulnerability and inequality driven consequences (11,26,31,32).

A country or city climate has been another important element to understand the relationship between heat exposure and its impact on humans and their surroundings (4,11,23). According to Köppen, climate is classified in four climatic zones: humid subtropical, tropical wet and dry, warm semi-arid and warm desert. The factors used for this classification are associated with temperature and the period of the year when precipitation occurs (4,11,23). Additionally, areas in the tropical zone tend to mostly experience hot summers than other zones, generating a greater heat exposure as these have the highest incidence of sunlight hours per year (21,23). Multi-city studies suggest that countries located in tropical regions are predisposed to higher heat related health impacts in comparison with other zones, while other studies suggest that heat mortality and morbidity are higher in warmer regions (4,10,33).

Understanding that heat waves are an extreme weather phenomenon categorized as a natural disaster, the individual or collective analysis of this disaster and inequalities behavior can be analyzed via three elements, the exposure level, the population size exposed, and the population sensitivity (2,6,21,35). Those three aspects are part of the IPCC disaster risk framework and named by hazard, exposure, and vulnerability (17,21,26).

The health and environmental consequences of climate change have disproportionately affected Low- and Middle-Income Countries (LMICs), as they have less adaptation capacity, are more regularly exposed to high temperatures, have economies dependent on weather variability, and have a less available risk-management approaches in comparison with developed countries (6,10,11,27). Most of the studies developed in High-Income Countries (HICs) such as the United States, Italy, Australia, and Canada have demonstrated a diminished level of sensitivity to heat. This insight infers a heat adaptation increase as these countries present ongoing mitigation plans and better economic resources and technological developments, enabling a superior heat control and management plans in comparison with LMICs (3,10,11,13,14,22), hence HICs studies cannot be extrapolated to all regions worldwide as social structures, geography, conditions, and technology are drastically different than LMICs (3,10,13,36).

Per the World Bank, countries are classified into four income groups. The first one is Low-Income Countries (LICs), 27 countries with a gross national income (GNI) per capita of US$1.045; the second is Lower-Middle Income Countries, 55 countries with a GNI per capita between $1.046 and $4.095; the third is Upper-middle Income Countries (UMICs), 55 countries with a GNI per capita between $4.096 and $12.695; and the fourth is High-Income Countries (HICs), 80 countries with a GNI per capita of $12.696 or more (37,38). The scope of this systematic review clusters the first, second, and third categories, named Low- and Middle-Income Countries (LMICs), a grouping convention utilized by all articles reviewed in this study.

Heat exposure in urban areas is higher as recently demonstrated by the IPCC which states that intensity, frequency, and duration of extreme hot events have increased particularly in cities as a result of Urban Heat Island (UHI) (14–16), an effect caused by the replacement of soil and vegetation with asphalt and concrete (6,14,39). As there is a lack of tree cover, more asphalt and concrete in roads and buildings, and poor ventilation, more heat is trapped and less evaporation is generated, producing a complex climate (6,14,39). Living in an urban area presents differences in terms of exposure in comparison with a rural area because the latter tend to cool off faster at nights (4,27,28,34). By 2030, it is expected that urban living increases to 60% of world's population and that the number of megacities increases to 43 against 31 in 2016 (3,40).

As a result of UHI, people in urban areas usually have a higher risk of death or developing an illness related with a climate-change hazard present in cities (4,27,41). The need of more vegetation and changes in buildings is urgent to prevent extreme heat harm. Countries such as the United States, China, and Canada have developed heat health warning systems which support their governments to raise awareness in the community. These warning systems are characterized by being more inclusive and improving equity (4,14,32,39).

Nowadays, the evidence in LMICs is scarce as they are not represented in the literature, limiting the understanding and identification of heat exposure in those countries (10). According to Alizadeh et al. (11), heat waves increased over 40% between 2010 and 2019 in LICs, extending the association between heat and inequality. For this reason, this thesis is focused in LMICs which are highly vulnerable to environmental shocks, and are generally associated with poor health care, lower education levels, severe inequalities, and lack of interest in research about how heat impacts mortality and/or morbidity rates within urban areas (6,11,25,32,42).

The evidence herein displayed will be useful to design public health policies and strategies seeking to reduce inequalities, to raise the necessity of creating heat health warning systems in a changing climate, and to demonstrate the need of further research tackling heat impacts in LMICs. (13,18,21,32,43). Thus, this thesis's main objective is to collect and present the most relevant results concerning heat exposure found in the available literature.

2.1 Objectives

The primary objective of this thesis and systematic review is to investigate how heat impacts mortality and morbidity rates in cities located in Low- and Middle-Income countries (LMICs). The secondary objective is to identify who are the most vulnerable populations affected by heat.

2.2 Research question

This thesis research question is: How does heat impact mortality and morbidity rates in cities located in Low- and Middle-income countries?

The research question was created using the PEO framework which helps to understand the etiology and/or a risk of the main topic. Munn et al. (44) say this framework facilitates the understanding of the 3 main elements: population (P), exposure (E), and outcome (O), as displayed in the following table.

P	Population	Cities located in Low- and Middle-Income Countries (LMICs)
E	Exposure	Meteorological events associated with heat
O	Outcome(s)	1. Mortality and/or morbidity indicators associated with heat. 2. Key factors associated with vulnerabilities

Table 1. PEO framework elaborated by the author

The countries selected for this systematic review were in accordance with the list of countries belonging to the Low- and Middle-Income Countries (LMICs) classification from the 2022 World Bank data help desk website (37).

3 Methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews (PRISMA-2020) guidelines (45) seeking the inclusion of relevant items and assurance of internal consistency (**Appendix 1: PRISMA checklist**). This systematic review was carried out following the 24 steps described in the article “A 24-step guide on how to design, conduct, and successfully publish a systematic review and meta-analysis in medical research”. **(Figure 1)** (46).

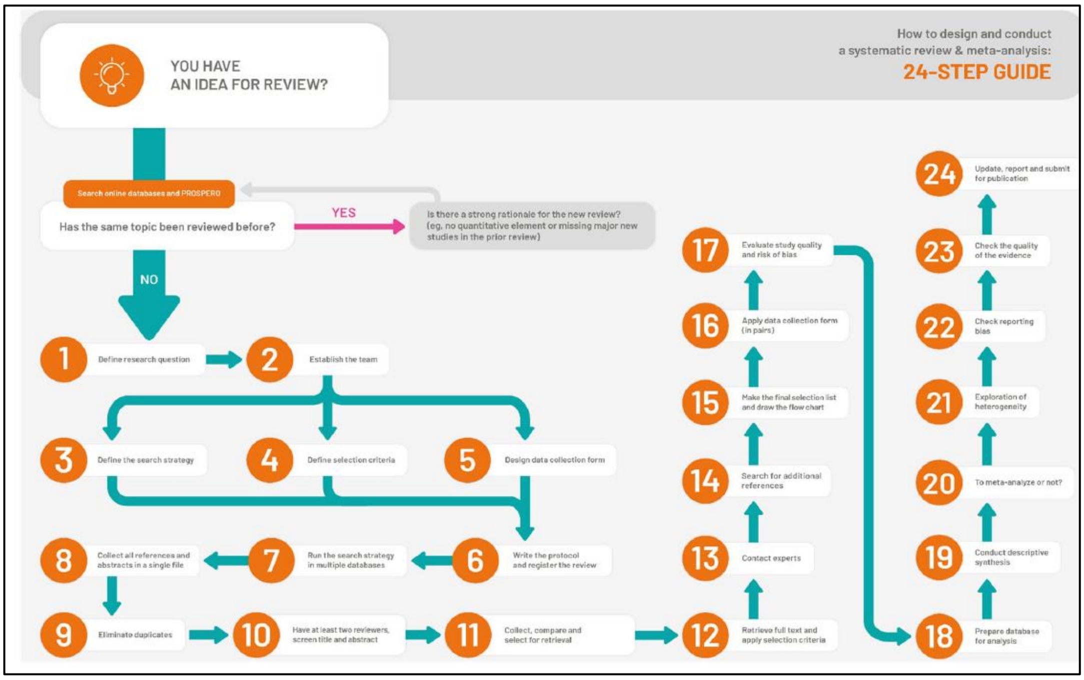

Figure 1. A 24-step guide on how to design, conduct, and successfully publish a systematic review and meta-analysis in medical research

3.1 Literature search

Three bibliographic databases - Scopus, PubMed and Embase - were utilized to identify articles published per Cochrane training guidelines[1]. The keywords used for the literature search were related with heat waves or heat, inequalities impact, and mortality, morbidity and hospital admissions rates in cities located in LMICs. **(Appendix 2: Bibliographic search record).**

The keywords for each country were extracted from Cochrane database list based on the 2019 World Bank list of economies[2]. From this list, the name and possible descriptions for each country were extracted and combined in MeSH terms (Medical Subject Headings) and text words for the creation of each database search.

For the identification of new studies via other methods following PRISMA 2020 flow diagram (45) and the article from Muka, et al.(46), 5 articles were requested to the main authors through email and ResearchGate[3], a networking site for scientists and researchers to share papers.

[1]Chapter 4: Searching for and selecting studies [Internet]. Training.cochrane.org. 2022. Available from: https://training.cochrane.org/handbook/current/chapter-04#section-4-3-1-1

[2] LMIC Filters [Internet]. Epoc.cochrane.org. 2022. Available from: https://epoc.cochrane.org/lmic-filters

[3] ResearchGate | Find and share research [Internet]. ResearchGate. 2022. Available from: https://www.researchgate.net/

Despite the lack of response from the authors, step 13 from the 24 step-guide was accomplished by contacting them.

3.2 Inclusion and exclusion criteria

Studies included in this systematic review follow these criteria: (1) address humans, (2) considered heat the main exposure of interest, (3) analyze the association between heat and vulnerabilities, (4) include mortality and morbidity (5) encompass cities in LMICs per World Bank's definition **(Appendix 3),** and (6) study observational, cross over studies, longitudinal studies, cases controls, and retrospective studies. This thesis author evaluated the abstracts and titles according to the selection criteria, as well as the full texts. Articles which examined hospital admissions were included within the morbidity outcome following environmental research usual practice (4,10).

The studies conducted in non-humans, rural areas in LMICs as well as countries, cities, and rural areas in HICs were excluded. Clinical trials, cohort and qualitative studies, systematic reviews, meta-analyses, conference abstracts, letters to the editor, and books were excluded as well. To retrieve further relevant publications, the references list of the included articles in the review was checked via backward reference searching.

3.3 Extraction criteria and data collection

The main identification, screening, eligibility, and final selection were accomplished using Endnote V.20 software. A Microsoft Excel file was created for the extraction of the most important information of selected articles such as bibliographic information, study design, country and city name, continent, climate classification, sample size, exposure as well as the main outcomes per analyzed sociodemographic characteristics and health impacts. When a study evaluated more than one city, all locations were recorded. In case the authors did not specify the city name, the article was not included. The measures of association (e.g., relative risk (RR), percentage increase (PI) among others) were extracted from articles' information, tables, or supplementary material. In the case of an author referring to a heat wave definition, its parameter was also included. The outcomes expressed in the results section were extracted as the authors report them in their articles. The vulnerabilities in this thesis were analyzed according to sociodemographic characteristics as these factors increase or attenuate the impact of heat hazard in the population. In case the authors specify the period of exposure by specific subgroups, the relevant information such as location, key findings and type of exposure was also noted in the Excel file.

3.4 Risk of bias assessment

To accomplish step number 17 – evaluate study quality and risk of bias - out of the 24 steps to carry out a systematic review (46), an attempt for time-series studies was made to evaluate the risks using the Newcastle-Ottawa Scale (47) for cohort studies as it is the most similar design and because it was not found a proper checklist for this type of studies. Additionally, a kind of protocol/checklist for time-series studies was tried also in parallel experts in the field were contacted for advice.

Experts such as Alice McGushin, N. Charles Hamilton, Frances MacGuire, and Mathilde Pascal, as well as Cochrane experts and Antonio Gasparini, a recognized author in environmental sciences, were contacted. According to Gasparini, having a checklist for time-series studies would be useful but it will not be easier to create as there are many design extensions and analytical methods which would require a lot of additional work.

Nonetheless, it was not possible to achieve this point because there is no checklist for time-series studies seeking to evaluate the risk of bias assessment.

4 Results

Overall, 1508 references were initially identified, 1505 from electronic databases and 3 via backward reference searching. Among the databases, the studies came from PubMed (n=343), Scopus (n=657) and Embase (n=505). Out of the 1505 total records, 414 were duplicates using a reference manager (Endnote V.20 software) and manual check. After the initial screening by title and abstract, 913 articles were excluded because they did not meet the inclusion criteria leaving 178 for retrieval. 17 articles were assessed for eligibility after reviewing the full text. In total, 20 articles were selected for the systematic review by combining the 17 selected articles and the additional 3 via backward reference searching. **Figure 2** shows the detailed process of screening according to the PRISMA 2020 flow diagram template for systematic reviews (45).

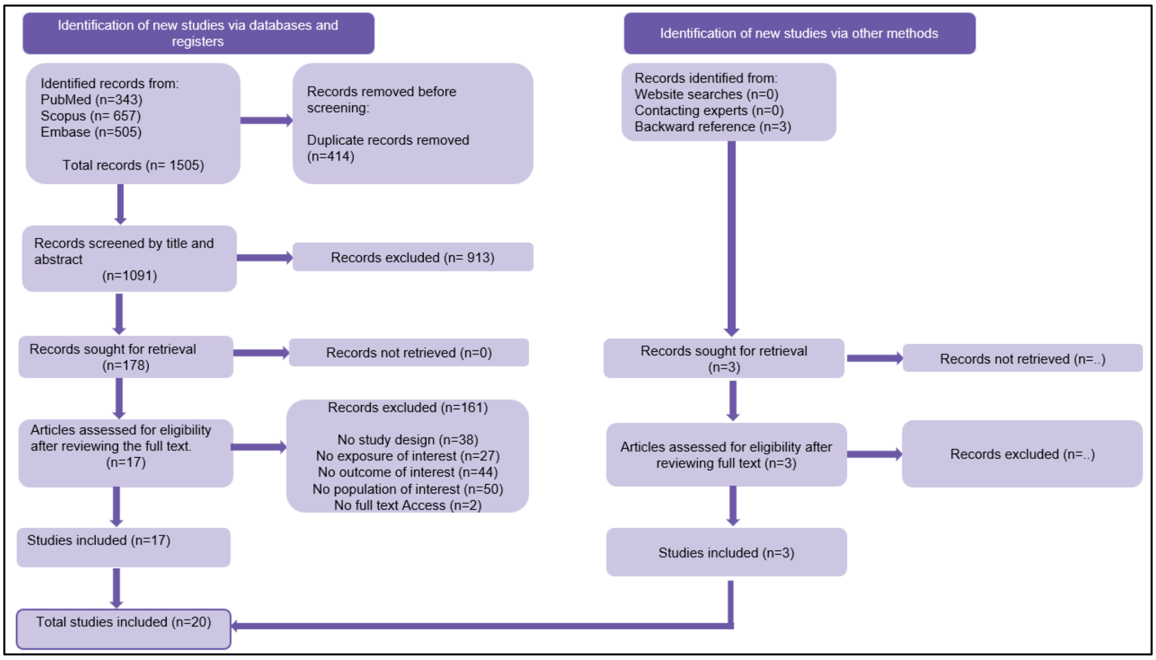

Figure 2. Flowchart diagram of studies selected following PRISMA 2020

4.1 Characteristics of included studies

4.1.1 **Geographical coverage**

The chosen articles were published between 2005 and 2021, in which 2019 was the year with more articles published in this topic (25,30,48–51). Out of the 20 final studies included, 64 cities were identified in 7 countries for the final review. Four articles are from India (25,35,43,48), three from Vietnam (30,52,53), one from Kenya (54), one from Tunisia (55), one from Brazil (56), one from Turkey (49), and nine from China (33,34,41,50,51,57–60). Regarding continents, two articles are from Africa (54,55), one from Europe (49), and Americas (56), and 16 from Asia (25,30,33–35,41,43,48,51–53,57–61). **Figure 3** shows the geographical coverage distribution. Scale-wise, reviewed papers were conducted mostly on one city-scale (30,33,34,43,48,49,52–54,56,57,60) but 8 out of the 20 articles include multi-cities studies (25,35,41,51,55,58,59,61).

No articles from the 27 countries classified as Low-Income Countries were found in the final analysis. From the Lower-Middle Income Countries category which includes 55 countries, four countries were included (Tunisia, India, Kenya, and Vietnam). Finally, from the Upper-Middle Income Countries category encompassing 55 countries, three countries were included in the systematic review (China, Turkey, and Brazil).

Following the climate classification of Köppen, the most predominant climates in the articles presented in this systematic review were Mediterranean climate, humid subtropical, tropical wet, tropical savanna, tropical wet and dry and semi-arid climates. Two out of seven countries were characterized for having tropical climates, mostly characterized by hot summers in comparison with countries located in middle latitudes or temperate regions (51,54). Furthermore, casualties and hospital admissions were a consequence of the exposure to extreme heat and heat waves in countries which experience hot summers Mediterranean climate (55) and humid subtropical climate (48), a phenomenon visible in these cities. In the case of Vietnam, temperatures above the threshold of 29°C were related to cardiovascular mortality risk increase but not hospital admissions in children, while for the study performed in the most tropical city in Vietnam - Ho Chi Minh City (HCMC) cardiovascular admissions reported an increase to high temperature and heatwave events (52,53).

The death percentage increase in subtropical climates such as Varanasi and hot summer Mediterranean climate in Tunis was 5.6% and 2.6% respectively, due to heat exposure. Finally, the daily mortality rate increased to 12% in Varanasi as a result of a heat waves exposure (48,55).

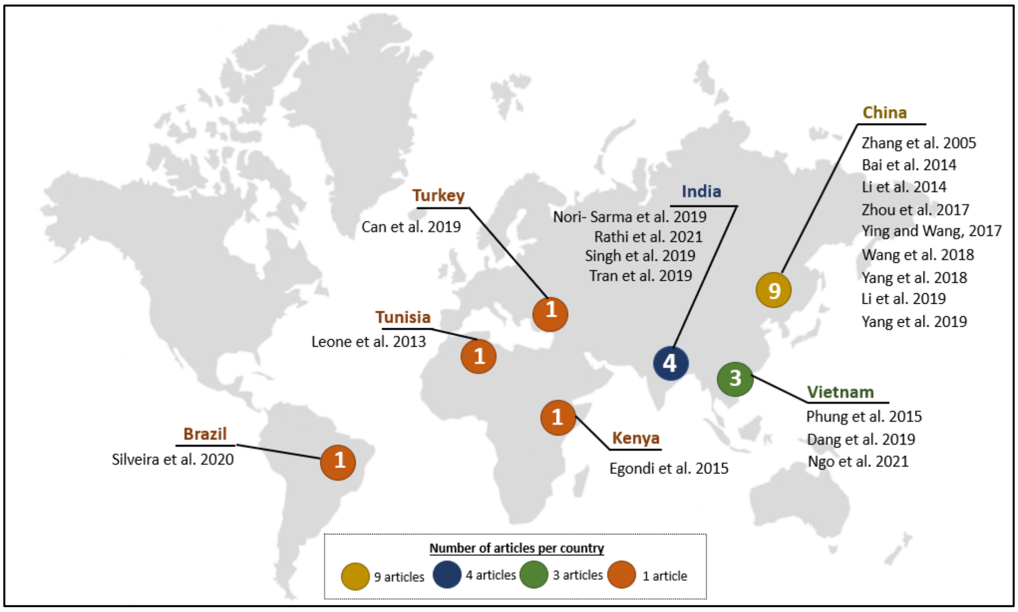

Figure 3. Geographical location of selected articles

4.1.2 Design types

Different designs were utilized, with time-series being the most common one, identified in 16 articles (25,30,33,41,48–55,57–60). In addition, two articles used case-crossover (34,56) while two had cross-sectional studies (35,43). Out of the seven studies analyzing the association between heat waves and mortality/morbidity, six presented time-series studies (25,30,33,49,50,54), and the remaining one was a case- crossover (34). In these seven studies, the most common way to evaluate heat wave impacts was calculating past heat waves, projecting new heat waves, and comparing deaths occurred in days with and without heat waves.

The articles using time-series designs were also characterized by including air pollution and meteorological parameters confounders such as barometric pressure, wind speed, seasonal variations, and comparison between weekdays and weekends (25,41,48,52,55,59) meteorological variables and the release of pollutants controlled by the study's methodology did not demonstrate a significant confounding (25,48,52,55). Regarding possible effect modifiers, a study conducted in five Indian cities (25) stated that due to the paucity of individual information, important modifiers like gender, age, socio-economic status, and behavior factors for the heat-mortality relationship could not be assessed. The control of most of these confounders was not necessary for case-crossovers or cross-sectional studies because the authors generally controlled potential confounders from the beginning or adjusted them by weekdays or months across the years.

4.1.3 Heat parameters

With regards to the exposure of interest, diverse terms were found referring to heat. Seven articles referred it as heat waves (25,30,33,34,49,50,54), six articles as high temperature (41,52,53,55,56,60), another five as extreme heat (35,43,48,51,57), one as heat (59) and one as temperature variability (58).

Considering the heterogeneity of exposure concepts, it was relevant to identify how each concept was displayed and analyzed when associated with the main outcomes part of this systematic review. Six articles assessed the association between heat waves and mortality (n=6) (25,33,34,49,54,61) and one between heat waves and mortality and morbidity (n=1) (30). For extreme heat, two studies evaluated its association with mortality (n=2) (48,51), one with vulnerability (n=1) (35), one with vulnerability-morbidity (n=1) (43), and one with heat and morbidity (n=1) (57). With respect to high temperatures, three articles evaluated its association with mortality (n=3) (41,55,56), and another three with morbidity (n=3) (52,53,60). Finally, one article evaluated the association between heat exposure and mortality (n=1) (59), and one analyzed the association between temperature variability and mortality (n=1) (58). **Table 2** summarizes the main information of these studies.

Diverse approaches were used in the reviewed articles to define heat exposure aiming to quantify the temperature and establish the relationship between heat and mortality and/or morbidity. In general, temperature thresholds were calculated based on changes in daily temperatures (34,35,41,43,48–50,53–55), changes on specific percentiles of temperature distribution (25,30,33,56–60), and on 1-degree Celsius increases above temperature threshold studied city (51,52).

In relation to heat waves, diverse definitions were found. Nine out of 20 articles had a heat wave definition (25,30,33,34,39,48–50,53) **(Table 2).** Their definitions were based on each country's national entities or created by the authors using specific percentiles from the temperature data. Two articles performed in India used the Indian Meteorological Department (IDM) parameters but adjusted these according to their research purposes (25,48). Furthermore, two studies conducted in China used the parameters established by the Chinese Meteorological Administration (33,34) five remaining articles wherein authors created their own heat waves definitions were from Kenya with 1 study (54), Vietnam with 3 studies (30,48,55), Turkey with one study (49), and China with one study (50).

The main differences between heat waves' definitions proposed by the authors and the national entities concerned duration and temperature percentile. Two authors agreed that a heat wave period lasts 2 consecutive days (25,46), three pointed out at least 2 days (30,53,61), and the remaining four defined heat waves as having a duration of 3 days or more of duration (33,34,48,49). Regarding the percentile, the same one was not found in the articles. The temperature percentiles utilized by the nine above-mentioned authors to define heat waves were 90th, 92.5th, 95th, 97th, 98th, and 99th (25,30,33,34,39,48–50,53). Lastly, out the nine articles establishing their own heat wave definition, six looked at the association between heat waves and mortality (25,33,34,49,50,54), one explored the relationship between heat wave and mortality/morbidity (30), one between extreme heat and mortality (48), and one between high temperature and morbidity (53).

The nine authors mentioned above (25,30,33,34,39,48–50,53) coincided that the degree of heat waves' impacts alters according to frequency (number of heat waves per year), intensity (temperature required to ensure a higher exposure during a heat wave), and duration (heat wave longest period). These elements were seen as the most relevant ones to heat waves.

Authors such as Nori-Sarma et al.(25) and Phung et al. (53) agreed that the risk of mortality increased when the heat wave parameters changed. For Nori et al.(25), the mortality risk was estimated to be 18.1% higher on the 97-percentile against non-heat wave days. Finally, Phung et al. (53) stated that at the 99-percentile the overall risk for cardiovascular admissions increased 12.9% during the same day of exposure.

4.2 Outcome measure

The outcome of relationships between heat and mortality and/or morbidity were presented by the authors using different measures of association, most notably Relative Risks (RR) (30,49,52,53,56,57,59,61), Odds Ratio (OR) (34), composite outcome adjusted Odds Ratio

(OR) (43), Percent Increase (PI) (33), Percentage Change (PC) (48,51,58), cumulative Relative Risk (cRR) (60), and Years of Life Lost (YLL) (54).

To evaluate the relationship between heat and mortality and/or morbidity, six articles considered the mean temperature as the best predictor of this relationship (25,30,43,48,53,54). Eight articles added relative humidity to minimum, mean and maximum temperatures (33,34,41,50,51,56,57,59), and one compared daily minimum and maximum temperature (58), one daily mean, maximum and minimum (49), one the average and maximum temperatures (52), and lastly one used the maximum apparent (Tappmax) (55). The source of this data was local stations and from national meteorological departments.

All the articles' authors of this systematic review used weather data either from stations close to the airports where the research was performed or obtained from a national meteorological department. The analyzed periods in the time-series studies spanned between 1 year to 17 years. (25,30,33,41,48–55,57–60)

In this systematic review, the evaluated lag periods varied between the studies. It is important to highlight that the relationship between heat exposure and mortality and/or morbidity outcomes can differ on different aspects such as weather conditions, climate classification, socioeconomic status, and demographic characteristics. The studied articles showed variations in the evaluated period, irrespective of its length and health outcomes. Essentially, these periods were measured between the same day (lag 0) up to 27 days (30,48–54,57–60).

4.2.1 Urban Heat Island (UHI)

Out of the 20 articles, one from Li et al. (51) explored the Urban Heat Island (UHI) effect associated with extreme heat, which authors stated that cities with higher green spaces had lower heat effects. In urban areas, green coverage acted as protective factors against heat exposure (PI= -0.42; 95% CI = -0.82, -0.2) and extreme heat (PI= -80; 95% CI = -1.35, -0.25) for having a cooling effect (51). 3 other articles briefly mentioned this effect (35,57,58) wherein one said that the heat risk in vulnerable populations and in urban settings is magnified by UHI (35). Furthermore, cities with dense populations exposed to higher mean temperatures and lower diurnal temperatures had a higher risk of mortality caused by temperature variations (58).

The studies conducted by Rathi et al. (35) and Tran et al. (43) recognized that vulnerability is evaluated with the elements of exposure, sensitivity, and adaptive capacity, as well as measured in certain domains such as housing, risk perception, quality of life, habits, and livelihood. Both studies also revealed that vulnerability changed according to city location (35,43).

4.2.2 Health outcomes

Most of the studies in this systematic review examined the heat exposure effects on non-communicable diseases as a total or specific cause of mortality and morbidity outcomes. Hospital admissions are included in morbidity because they are the most prevalent representation of morbidity outcome.

Out of the 20 final articles, mortality was the most exemplary outcome with 13 articles referring it (65%) (25,33,34,41,48,49,51,54–56,58,59,61), followed by hospital admissions with 4 articles (20%) (52,53,57,60), and 1 article mixing the two outcomes (5%) (30). The most common diseases reported by the articles were: cardiovascular (n=4) (33,49,53,56) and respiratory (n=3) systems (30,51,52). Studies were found referring to all causes (n=2) (41,58) mental disorders (n=1) (57), as well as infectious, cerebrovascular system, circulatory, renal, and digestive systems diseases (n=4) (34,50,59,60). However, seven articles did not mention a specific disease (n=7) (25,35,41,43,48,54,55), and among these ones, Egondi et al., (54) observed a year of life lost (YLL) of 56,66 per day concerning all death causes and a total of 206.712 YLL over the study period (2003-2012).

Exposure to heat had a lag effect on mortality and morbidity. Some studies have shown heat-related mortality with different lag periods and the impact of temperature on some diseases changing in different lag days (30,48–54,58–60). The most common method to discover these effects was the pooled effect under meta-analysis, useful for city-level analysis for being considered a good predictor and model.

Mortality

In the case of mortality, lags between 0 and 7 days were the periods to develop heat diseases leading to death (48,49,58–61), except for Egondi et al. (54) who mentioned that longer lags up to 14 days would be a better time frame to capture the delayed effects of heat wave and death.

Concerning heat waves, Nori et al. (25) and Zhang et al. (34) concluded that health outcomes are higher during heat wave periods. Zhang et al. discovered that the average daily number of total non-accidental deaths and deaths due to circulatory diseases in Jinan, China was significant ($p<0.001$) in comparison with non-heat wave days. Additionally, for Nori et al., (25) cumulative lags arising from exposure to heat waves in regions with precarious resources increase mortality rates in India.

In a study developed in 4 cities located in different climatic zones in China, Li et al. (41) found the most common diseases were related to cardiovascular diseases as well as endocrine and metabolic systems. For specific causes such as respiratory diseases, Li et al. (51) said that extreme heat exposure would appear within 0-5 days with a slight difference between the cities, however, mortality displacement of moderate heat effects occurred in 12 out of the 16 Chinese cities between lag 5 to 15 days. Pneumonia was the main cause of respiratory mortality with an effect estimate of 4.90% (95% CI= 3.14–6.70%) during dry seasons.

For circulatory diseases, it was found that significant delayed effects can also happen for up to 5 days because of heat wave exposure, according to a study performed in Jinan, China (34).

For cerebrovascular diseases, stroke mortality happened between 0 and 7 days due to temperature variability (58). For Zhou et al. (59), specific strokes such as ischemic and hemorrhagic caused death in a maximum of 6 days. One of the reasons Zou et al. considered 6 days is because previous studies suggested that heat exposure effects within a week could estimate a truer reflection of mortality impact.

Yang et al. (58) stated that mortality driven by ischemic heart diseases (RR 1.21, 95% CI= 1.10–1.32) happens between 0 and 10 days as a consequence of heat waves exposure. Other mortality consequences driven by this exposure were respiratory diseases such as Chronic Obstructive Pulmonary Disease (COPD) and stroke.

Morbidity

There are fewer disagreements about the correlation between lag periods and higher rates of hospital admissions. Same-day or lag 0 are considered the same term according to the literature. Bai et al. (60) observed that renal diseases' hospital admissions were higher in lag 0 but could also increase between lag 0 to 2 days. The same effect was present in respiratory diseases.

Schizophrenia daily hospital admissions were higher during lag 0 to 2 days, and up to 6 days admissions continued to increase (RR 1.06, 95% CI = 1.03-1.11) (57). These effects are influenced by temperatures higher than 28°C in Hefei, China.

Lags between 0 and 7 days had a higher impact on respiratory diseases in both children and adults (30,52). Extended periods and delayed effects of high temperatures between 0-14 days and 0-27days were higher for non-external hospitalizations and infectious diseases admissions (RR 2.067, 95% CI = 1.026–4.027)

In the articles of Phung et al. (53) and Li et al. (51), tackling mortality and hospital admissions respectively, an increase of 1°C from one percentile to another generated by high temperatures leads to higher effects concerning respiratory mortality and cardiovascular admissions which vary across different lag days.

4.2.3 Sociodemographic characteristics

Age, sex, socioeconomic status, education level, and employment have been studied in 18 out of the 20 selected articles due to their importance to heat vulnerability because they could change based on heat exposure which can be expressed as extreme heat, high temperatures, temperature variability, and heat waves (30,33,34,41,43,48–60). **Table 1** displays the main findings.

4.2.3.1 Age

Out of the 20 articles in the systematic review, 18 studied the impact of heat in different age ranges (30,33,34,41,43,48–60), wherein one focused on children between 3 and 5 years old (52). The presented results were analyzed in 4 categories (children: 0-15 years, Youth: 15-19 years, Adults: 25-64 years, Elderly: 65+ years) to synthetize its heterogeneity, however, the mortality and morbidity main results in the articles were explained with the original age ranges exposed by the authors. **(Figure 4)**

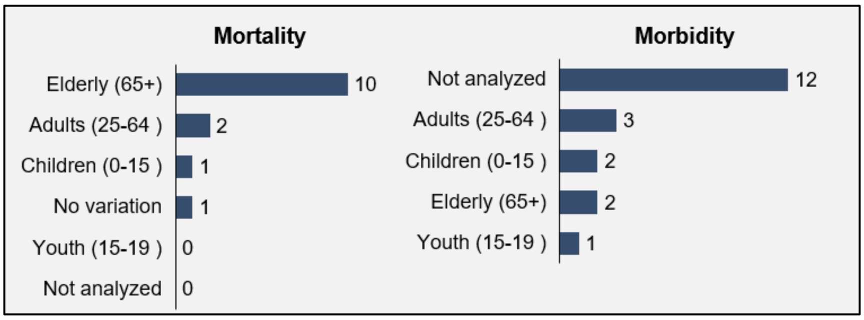

Figure 4. Number of articles reporting mortality and morbidity per age group

Mortality

Concerning mortality, variability was found across the age groups. Eight papers noticed that elderly over 65 years were at higher risk. It should be noted that the original categories stated by the authors were >75 years old (33,34,49,50,59) and >65 years old (48,51).

According to Silveira et al. (56), people over 60 years old were the most vulnerable, however per Dang et al. (30) Yang et al. (58) the age group over 65 years old was at a higher risk in people presenting respiratory diseases as comorbidities but with non-significant results which may reduce this statement's reliability.

According to Can et al. (49), elderly over 75 years old are more vulnerable to heat waves, as the mortality rate in this group has increased from 15% in 2015 to 38% in 2017. On the other hand, two studies pointed out that the age ranges at higher risk were over 55 years old (41) and between 0 and 14 years old (55). For Egondi et al. (54), there were no variations between age groups. Li et al. (41) stated that the 55 to 64 age group was at higher risk of mortality in three Chinese cities out of the 4 evaluated in their article located in various climatic zones.

Morbidity

The age groups in which the papers evaluate the association between heat and morbidity were over 60 years old (43), 0-64 (30), 0-48 (53), 21-40, 41-60 (57), and 45-64 (60). One article only evaluated children between 3 and 5 years old (50).

Hospital admissions were higher in children between 3- and 5-years old presenting Acute Lower Respiratory Infection (ALRI) (52). Per Bai et al. (60), exposure during 0-2 lag days was significantly higher in hospital admissions concerning infectious diseases.

4.2.3.2 Sex

14 articles (70%) analyzed the relationship between heat exposure and morbidity/mortality in males and females. (30,33,34,41,48,49,51,53,56–61). **(Figure 5)**

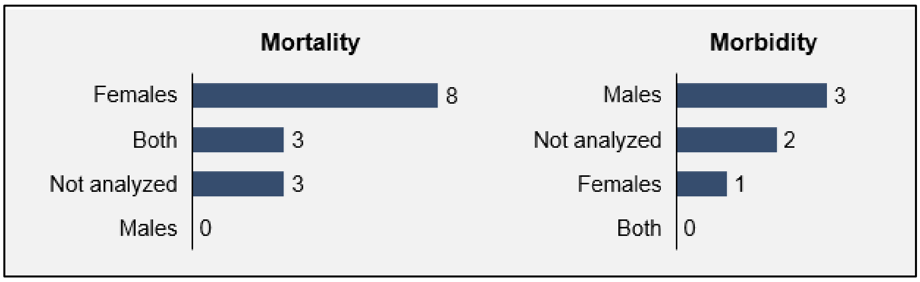

Figure 5. Number of articles reporting mortality and morbidity per sex.

Mortality

Nine studies (30,33,48–51,56,58,59) (57%) identified females with a higher risk of mortality in comparison with men. Conversely, three articles found out that males had a higher risk (54,57,60), two highlighted a non-significant difference between females' and males' deaths (34,58), while one did not observe any variation in the daily average of deaths by sex (54). Nevertheless, Egondi et.al. (54) detected that the number of deaths was higher in males than females, with 56,8% and 43,2% death ratios respectively. Lastly, Li et. al. identified male and female deaths from all causes showed significant relationships with high temperatures (41).

Morbidity

Five papers evaluated the sex variable (30%) (26,47,48,51,54). Three articles showed males had a higher risk of hospital admissions in comparison with females (53,57,60), while one stated that females were at higher risk (RR 1.08, 95% CI = 1.03–1.14) (30), and other one did not encounter differences between males and females with regards to hospital admissions (52). Furthermore, Wang et al. (57) observed that male and married patients had a higher risk of schizophrenia related hospital admission, and highlighted acute effects that tend to happen between lag 0 to lag 6 (RR 1.06; 95% CI = 1.01-1.11).

4.2.3.3 Socioeconomic status (SES)

Poor housing conditions and lack of healthcare facilities are associated with heat-related health outcomes, especially in summer or extreme heat periods (35,48). Those aspects, according to Singh et al. (48) and Rathi et al. (35), could reflect an inaccessibility to health insurance and inadequate housing materials, resulting in a lack of adaptive capacity in households. **(Figure 6)**

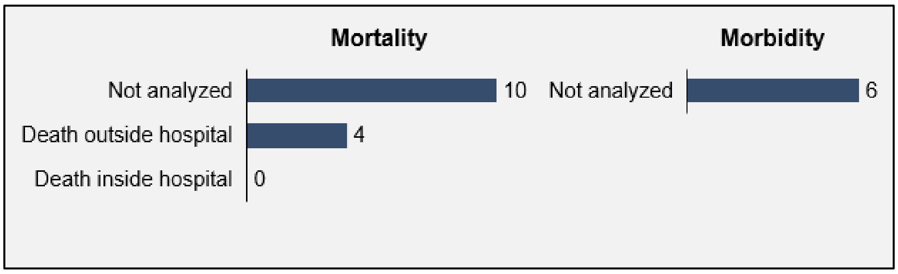

Figure 6. Number of articles reporting mortality and morbidity per SES

Mortality

Four articles converged on the understanding that mortality rates caused by cardiovascular diseases and ischemic strokes outside hospitals were higher in comparison with deaths inside a hospital (34,49,56,59). These articles' authors perceive the issue of people without adequate accessibility to hospitals as a serious socio-economic problem one when interlinking it with the higher mortality rates outside hospitals.

4.2.3.4 Level of education

Six out of the 20 selected articles (30%) (34,50,51,56,58,59) detected people with lower education levels with higher risk of heat exposure related mortality. Four of those articles (50,56,58,59) noticed significant associations with vulnerability while other two observed no significance in low educational levels (34,51). Only one article identified higher or secondary education as protective against mortality with an estimated percent change of -0.12% (-0.47-0.23%) in cardiovascular, respiratory, and non-accidental deaths (58). **(Figure 7)**

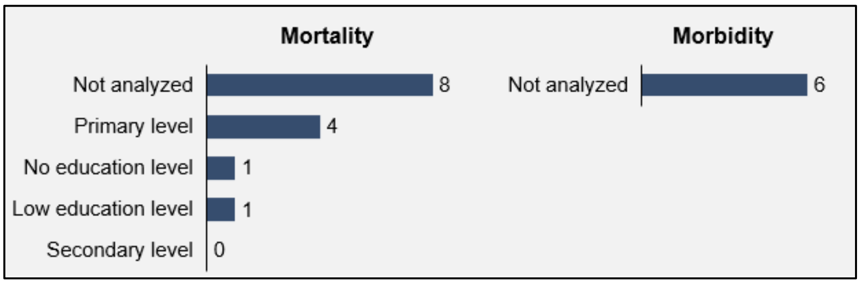

Figure 7. Number of articles reporting mortality and morbidity per level of education

For some authors (50,56,59) people with lower educational status were more vulnerable as they may have poorer living and working conditions and limited access to medical care services. Additionally, they associate the lower educational status variable with deaths outside the hospital as demonstrated in previous epidemiological studies as an indication of high vulnerability among those people. Moreover, such association between poor living conditions and accessibility to medical care was highlighted in **section 3.2.3.3 Socioeconomic status (SES)** via articles from Singh et al. (48) and Rathi et al. (35). Silveira et al. (56) broadly observed an indirect correlation between high temperature effects and level of education, in which the lower the latter is the higher the former becomes.

4.2.3.5 Employment

Working outdoors during heat waves or periods with temperature increases is a notable risk factor. The activity among outdoor workers was associated with a percentage increase of 149% (IC = 95%, 87.1 - 230.5) regarding cardiovascular mortality, turning them a susceptible population to heat risks (33). According to Tran et al. (43), this activity could also develop illnesses and entail higher vulnerabilities during extreme heat periods. **(Figure 8)**

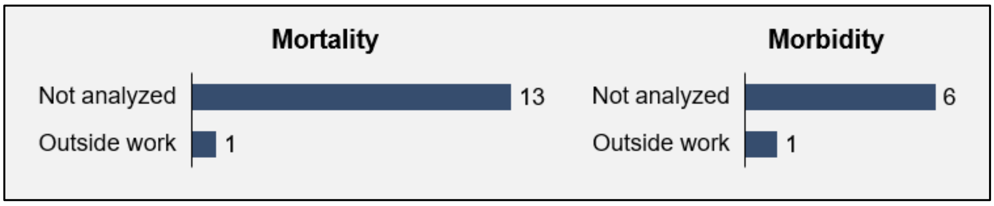

Figure 8. Number of articles reporting mortality and morbidity per employment.

4.2.3.6 Race

Race as an individual-level factor was only evaluated in the article of Silveira et al. (56) detected similar high-temperature exposure behavior among white and non-white people. Nonetheless, this study showed white people with a slightly higher difference which authors did not explicitly mention if it was statistically significant for any conclusions. **(Figure 9)**

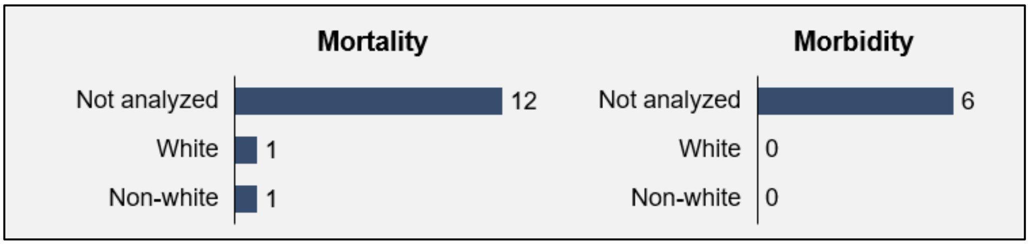

Figure 9. Number of articles reporting mortality and morbidity per race.

Table 2. Characteristics of reviewed studies and main findings

Reference	City/country	World Bank Classification	Study design/time	Exposure concept	Population/ Sample size	Age	Sex	Study outcome	Exposure definition used in the article	Main results / Sociodemographic characteristics					
										Age	Sex	Education level	Socioeconomic status	Race	Employment
Egondi et al. (2015) (54)	Kenya/Nairobi	Lower-Middle Income Country	Time series /2003-2012	Heat wave	66.000 people	0-5 years; 5-15 years; 15-25 years; 25-50 years and 50+ years	Male and female	Mortality	-percentiles of 90th, 95th, and 98 th. - two consecutive days.	No variation in the daily average number of deaths	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Nori- Sarma et al. (2019) (25)	India/ Jaipur, Churu, Idar, Himmatnagar and Mumbai.	Lower-Middle Income Country	Time series/ Jaipur (2005-2012) Churu (2003-2012), Idar and Himmatnagar (2008-2012) and Mumbai (2000-2012)	Heat wave	1952 death records	No provided	No provided	Mortality	-Indian Meteorological Department -2 consecutive days - percentiles of 90, 92.5, 95 and 97.5	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Dang et al. (2019) (30)	Vietnam/ Ho Chi Minh City	Lower-Middle Income Country	Time series/2010-2013	Heat wave	101.959 descendants	0-14 years old ; 15-64 years old and ≥65 years old.	Male and female	Mortality and morbidity	- ≥2 consecutive days -≥97th percentile of daily average temperature.	**Mortality**: Elderly people (65+) (RR =1.43, 95% CI=1.34–1.53) Morbidity: **Elderly people** (65+) (RR = 1.3, 95% CI = 1.19–1.42)	**Mortality** - Female group (RR=1.11, 95% CI = 1.04–1.18). **Morbidity -** Female group (RR= 1.08, 95% CI= 1.03-1.14)	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Singh et al. (2019) (48)	India/ Varanasi	Lower-Middle Income Country	Time series/2009-2016	Extreme heat	64.712 death records	≤4 years old, 5–44 years old, 45–64 years old, ≥65 years old.	Male and female	Mortality	- event during summer -95th percentile of annual mean (≥34.5 °C) - 3 consecutive days	≥65 years in summer (PC 6.83%)	Female higher during summer (PC 6.03%, 95% CI= 4.63, 7.43%)	Not analyzed	Non-institutional deaths in summer (PC 6.10%, 95% CI= 5.31, 7.12%)	Not analyzed	Not analyzed
Tran et al. (2013) (43)	India/ Ahmedabad	Lower-Middle Income Country	Cross-sectional survey/2007	Extreme heat	300 houses	Young (<5); Elderly (>60) ; All other ages (5 ≤ age ≤ 60)	No provided	Vulnerability and morbidity	Mean and maximum temperature	<60 years. Composite outcome (Adjusted OR 1.90, 95% CI= 1.97, 3.37)*****	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Work outdoor Composite outcome (Ajusted OR 1.86, 95% CI= 1.09, 3.16)*
Rathi et al. (2021) (35)	India/ Kolkata, Angul, Ongole and Karimnagar	Lower-Middle Income Country	Analytical cross-sectional study/2007	Extreme heat	2014 households	mean age of the household	Male, female and Transgender.	Vulnerability	Maximum temperature	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Leone et al. (2013) (55)	Tunisia/Tunis	Lower-Middle Income Country	Time series/1991-2007	High temperature	983.861 people	0-14 years old, 15-64 years old, 65-74 years old, 75+ years old.	No provided	Mortality	Maximum apparent temperature (Tappmax)	0-14 age group (PC 7.1%, 95% CI= 3.1 - 10.9)	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Phung et al. (2015) (53)	Vietnam/ Ho Chi Minh City	Lower-Middle Income Country	Time series/2004-2013	High temperature	129.014 hospital admissions	0-64 years old, 65-84 years old and 85+ years old.	Male and female	Morbidity	- ≥2 consecutive days - ≥99th percentile of daily mean temperatures	people aged 0-64 (RR= 1.22; 95%CI= 1.00-1.49)	Males (RR =1.2; 95% CI= 0.98-1.47)	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Ngo et al. (2021) (52)	Vietnam/ Ho Chi Minh City	Lower-Middle Income Country	Time series/2013-2017	High temperature	77.670 hospital admissions	<3 years old and 3-5 years old.	No provided	Morbidity	High maximum temperature in combination with minimu, maximum and average temperature (°C)	3–5 years old (lag3) (RR= 1.03; 95% CI= 0.98-1.07)	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Can et al.(2019) (49)	Instanbul/Turkey	Upper-Middle Income Country	Time series/2013 and 2017	Heat wave	73.028.266 people	0–14 years old, 15–64 years old, 65–74 years old, and ≥75 years old.	Male and Female	Mortality	-daily average of the mean temperature above percentiles 95 -3 consecutive days -3 more lag days	≥75 age group **Heat Wave 1** in 2015 (RR= 1.16; CI=95% 1.06–1.27) and **Heat Wave 3** in 2017 (RR= 1.38; CI=95% 1.26–1.52)	Female - **Heat Wave 1** in 2015 (RR= 1.25; CI=95% 1.15–1.37)#, **Heat Wave 3** in 2016 (RR=1.29; CI 95% 1.18–1.42)#	Not analyzed	Not analyzed	Not analyzed	Not analyzed

* means statistically significant (p < 0.05)

\# means statistically significant (p < 0.01)

PC= Percentage change PI= Percental increase cRR = cumulative Relative Risk

Table 2. (continued)

Reference	City/country	World Bank Classification	Study design/time	Exposure concept	Population/ Sample size	Age	Sex	Study outcome	Heat wave definition / parameters	Main results / Sociodemographic characteristics					
										Age	Sex	Education level	Socioeconomic status	Race	Employment
Wang et al. (2018) (57)	Henfei / China	Upper-Middle Income Country	Time series/2005-2014	Extreme heat	17,744 hospital admissions	0-20 years, 21-40 years, 41-60 years and more 61 or equal years	Male and female	Morbidity	Mean, maximum and minimum temperature, and relative humidity.	21-40 years old (RR=1.07; 95% CI=1.02-1.12)* p<0.05. Significant lag 0-2, lag 0-3, lag 0-4, lag 0-5 and lag 0-6.	Males (RR =1.10; 95%CI= 1.05-1.15) p<0.05. Significant lag 0-1, lag 0-2, lag 0-3, lag 0-4, lag 0-5 and lag 0-6.	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Yang et al. (2018) (58)	31 cities / China	Upper-Middle Income Country	Time series/2007-2013	Temperature variability	259,900,000 permanent citizens	0-64 years and 65-74 years	Male and female	Mortality	Daily minimum and maximum temperature.	>65 years old (non significant)	Males and Females (Non-significant)	**Primary school** (PC= 1.16%; 95% CI= 0.66 - 1.67) **Secondary or higher** (PC= -0.12%, 95% CI= -0.47 - 0.23)	Not analyzed	Not analyzed	Not analyzed
Silveira et al. (2020) (56)	Rio de Janeiro/ Brazil	Upper-Middle Income Country	Case-Crossover/ 2001 - 2018	High temperature	260.874 death records	30-64 years and 65 or more	Male and female	Mortality	Mean temperature and mean relative humidity.	>60 years old (RR= 1.40; 95% CI= (1.24–1.59)	Female (RR: 1.47; 95% CI=1.27–1.70)	**Non study leve**l (RR= 1.63; 95% CI=1.11–2.40), **Primary** (RR= 1.37; 95% CI= 1.17-1.59)	Dead outside hospital (RR:1.59; 95% CI= 1.33–1.90)	**White** (RR=1.34; 95% CI= 1.17 - 1.52) **Non-white** (RR= 1.31; 95% CI= 1.10-1.57)	Not analyzed
Zhang et al. (2015) (34)	Jinan/ China	Upper-Middle Income Country	Case-Crossover/ 2012–2013	Heat wave	17.126 death records	0–64 years; 65–74 yearsand over 75 years	Male and female	Mortality	Chinese Metereological Administration ≥3 consecutive days T. higher 35°C degrees	>75 years old (OR= 1.21; 95% CI= (1.64–1.39)	Males and Females (Non-significant)	Not analyzed	Dead outside hospital (OR:1.13; 95% CI= 1.00–1.29)	Not analyzed	Not analyzed
Yang et al. (2019) (50)	31 cities / China	Upper-Middle Income Country	Time series / 2007 and 2013	Heat wave	259 million permanent residents	0–64 years, 65–74 years and 75 years old or above	Male and female	Mortality	15 HW definitions percentiles of 90, 92.5, 95 and 97.5 and 99 ≥2 consecutive days	>75 years old (RR= 1.08; 95% CI= (1.01, -1.15)	Female (RR, 1.05; 95% CI= 1.01 - 1.09)	Primary school (RR= 0.95; 95% CI= 0.90-0.99) Secondary or higher (RR=0.94 95% CI= -0.90 - 0.98)	Not analyzed	Not analyzed	Not analyzed
Li et al. (2014) (41)	Harbin, Nanjing, Shenzhen and Chongqing/ China	Upper-Middle Income Country	Time series/Harbin 2008-2010, Nanjing 2004-2010, Schenzhen 2004-2010 and Chongquing 2011-2012	High temperature	1.8 million population	0-14 years,, 0-5 years, 15-29 years, 30-54 years, 55-64 years, 65-74 years and >- 75 years	Male and female	Mortality	Daily maximum, mean and minimum temperature (°C), and daily mean relative humidity.	over 55 and 65 years old significant 3 cities (Harbin, Nanjing, Chingquing)	Males and females (4 cities) (Harbin, Nanjing, Shenzhen and Chongquing)	Not analyzed	Not analyzed	Not analyzed	Not analyzed
Zhou et al.(2017) (59)	12 cities of Jiangsu Province, China	Upper-Middle Income Country	Time series / 2009-2013	Heat exposure	74 million people	0–64 years, 65–74 years, and ≥75 years old	Male and female	Mortality	Daily temperature and relative humidity.	>75 years old (RR= 1.67; 95% CI= 1.54-1.82) Total stroke	Female (RR=1.71, 95% CI= 1.57, 1.87) Total stroke	low education level (RR=1.60, 95% CI=1.49, 1.72)	Dead outside hospital (RR=1.60, 95% CI= 1.49, 1.73)	Not analyzed	Not analyzed
Yin et al. (2017) (33)	Bejing, China	Upper-Middle Income Country	Time series/ 2010-2013	Heat wave	24,169 death records	<65 years (younger) and ≥65 years (older)	Male and female	Mortality	Chinese Metereological Administration ≥3 consecutive days T. higher 35°C degrees	≥65 years (PI=94%; 95%CI=60.2-134.3)*	Females (PI= 111%; 95% CI= 61 - 175)*	Not analyzed	Not analyzed	Not analyzed	Outdoor workers (PI= 149%, 95% CI = 87.1 - 230.5)
Li et al. (2019) (51)	16 chinese mega cities, China	Upper-Middle Income Country	Time series/2007-2013	Extreme heat	509,585 death records	0–64 years and 65+ years	Male and female	Mortality	Daily minimum, mean amd maximum temperatures (°C)	≥65 years (non-significant)	Females - **Moderate heat** (PC= 3.65%; 95% CI= 2.25 - 5.08)$^{\#}$ / **extreme heat** (PC=5.54; 95% CI= 3.63 - 7.49)$^{\#}$	**Primary school or lower:** (PC= 2.84%, 95% CI= 1.66,4.03) **Extreme heat** (PC= 4.82%, 95% CI= 3.16,6.50)	Not analyzed	Not analyzed	Not analyzed
Bai et al.(2014) (60)	Lhsa, China	Upper-Middle Income Country	Time series/2005-2012	High temperature	82,491 hospital admissions and 159,139 emergency rooms	0–15 years, 16-44 years, 45–64 years, and ≥65 years old	Male and female	Morbidity	Maximum temperature	≥65 years **Lag 0** (cRR 1.221; 95% CI= 1.02-1.45); **Lag 0-2** (RR 1.15; 95% CI= 1.00-1.32)	Male Lag 0-14 (cRR =1.166, 95% CI= 1.00–1.46)*	Not analyzed	Not analyzed	Not analyzed	Not analyzed

* means statistically significant (p < 0.05)

\# means statistically significant (p < 0.01)

PC= Percentage change PI= Percental increase cRR = cumulative Relative Risk

5 Discussion

This systematic review summarized the most recent and relevant evidence regarding heat-related mortality and/or morbidity in cities located in LMICs, an approach not undertaken in literature prior to this thesis.

Geographical location

This thesis highlights the lack of research in the first and second group of countries by economic power according to the World Bank (37). The first group, Low-Income Countries, compounded by 27 countries, presents no publications between heat exposure and mortality and/or morbidity. The second group, Lower-Middle Income Countries, presents 55 countries in total but was represented in this systematic review by only 4 countries (7%) with identified literature in the proposed topic. Among these 2 countries' classification per the World Bank, 9 articles were identified, not enabling a clear understanding of the heat impact in the cities located in such underrepresented countries. It became evident that with the inclusion of the third category, Upper-Middle Income Countries (UMICs), a vast number of articles would be included in the final search, enabling a broader analysis to be performed. These results have demonstrated a significant research gap in LMICs, a finding also displayed in several articles by Ellena et al. (6), Alizadeh et al. (11), Green et al. (10), and Dimitrova et al. (23).

Out of the 20 papers which have fulfilled the inclusion criteria, nine were from China (33,34,41,50,51,57–60). This finding leads to the assumption that this country is more advanced in the research about the association of heat and mortality/morbidity than other countries in this review. Moreover, the high prevalence of Chinese articles increased the number of studies in the Middle-Income Countries classification. The quantity of articles published by China has proven as a systematic mapping of global research, finding that the number of publications in UMICs and HICs was similar as most of the evidence was from China (27).

Most of the evidence encountered in the literature tackling heat related impacts is centered in High-Income Countries in Europe and in America, reflecting the interest and capacity to conduct different research about the effects of climate change on health, an issue that threatens public health worldwide (4,10,21). Papers such as the ones from Alizadeh et. al (11) and Campbell et al. (4) have demonstrated that due to the strength in research, adaptation mechanisms in early warning systems, infrastructure improvement, electricity, and increasing awareness, the capacity to adapt to a changing climate is stronger in HICs than LMICs, decreasing the impact on mortality and morbidity rates in HICs as countries in this category can act on time. However, it should be noticed that heat wave metrics have increased during the past years especially in Low-Income Countries compared with other economic groups, increasing the heat-stress inequality. These countries do not have enough economic resources to implement heat wave warning systems, doing necessary international help or research of interest in Low-Income Countries, which has been an important element of discussion in articles of LMICs (10,21) and in the 2020 World Development and Climate Change report per World Bank (62).

Heat exposure

The heat definition heterogeneity intensifies its ambiguity and broadens its variations, thus limiting the reader's understanding. A systematic review performed by Song et al. (63) suggested reaching a consensus regarding the variety of heat definitions which arises due to each author's preferences and location. During the process of searching and inclusion criteria, the heterogeneity of heat definition became highly ambiguous as 30% of reviewed papers refer to heat in their titles but their methods and discussion presented another word, hindering readers' understanding who are investigating and looking for information on this topic.

Besides the heat definition ambiguity, there is also a lack of universal definition of heat wave. Heat waves were vastly addressed in this systematic review, as well as its differentiation in three elements (temperature metric, intensity, and duration). The studies included in this review used various definitions; some were based on meteorological data while others used a definition according to governmental definitions.

The exposure to a higher heat wave percentile does not necessarily mean generating the worst consequences, thus a strict heat wave definition following just one percentile (e.g., 4 days and 99 percentile) would underestimate heat waves exposure outcomes. Xu et al. (7)present a similar opinion by pointing out that designing appropriate heat wave thresholds is essential for the development of a heat wave definition and early warning systems, despite the fact that the selection of the right parameters for a heatwave threshold temperature still remains controversial. Nevertheless, is necessary that local authorities with support from institutions and meteorological departments create a local threshold temperature in order to mitigate the heat impacts in the population, taking into account regional differences, local characteristics, and the vulnerable population.

It was also observed that heat waves' behavior changes even if they have similar parameters in the same country. In the study conducted by Yan et al. (50), different heat wave definitions were created and tested across 31 Chinese cities, and the authors concluded that a heat wave lasting for 3 days with a daily maximum temperature is the best model to estimate heat related mortality impacts. However, in the study performed by Zhang et al.(34), heat waves lasting at least 4 days at a specific temperature of 36°C resulted in higher casualties. Regarding these findings, Oudin et al. (64) point of view in their article converged with the findings, mentioning that impacts between locations will change even if the study is only in one country.

Climate

There were four studies performed in countries fully located in tropical zones. Those studies showed evidence about the effect of high temperatures on mortality, but evidence regarding hospital admissions was less conclusive. Campbell et al.(4) discovered that populations at higher latitudes experience greater health outcomes due to heat exposure, while the results from the included studies in this thesis suggest that countries located in tropical zones in lower latitudes have higher heat related impacts. However, the relationship between heat exposure and main outcomes in tropical countries needs further investigation as there is no sufficient evidence. In this matter, approximately 80% of all research tackling the association between heat wave and health related impact are from developed countries (4).

Measures of association

Due to the heterogeneity of estimate effects such as Relative Risk (RR), Odds Ratio (OR), Percentage Increase (PI), among others, pooling effect and meta-analysis cannot be performed effectively as authors present results in different units. For this reason, Li et al. (65) suggested in their paper that it is important to evaluate different methods to determine the most appropriate one in detecting heat impacts on mortality and morbidity, and to compare studies conducted in different regions worldwide. However, most of the meta-analysis performed in the heat sphere used Relative Risks (RR) as the most adequate indicator to explain a strong association between heat and health outcomes (7,23).

Via the examination of study periods in research publications, there was an increase in publications in 2019 evaluating the impact of heat waves in India in 2010 and Istanbul, Turkey between 2013 and 2017, of which India's 2010 one was the most powerful one, resulting in a steep increase of 41% in all-cause mortality. Therefore, the 2019 publication spike may have been a consequence of such harmful heat wave periods in India and Turkey.

Urban Heat Island (UHI)

Literature has demonstrated that heat waves increase cities' mortality due to Urban Heat Island phenomena (UHI), and population density in urban areas is associated with the UHI effect (4,32). Green surfaces and vegetation could reduce such heat exposure as those create a cooling effect, as demonstrated by Li et al. (51) in this systematic review. This finding coincides with Sera et al. (66) which also found out that green spaces could reduce heat impact. An aggravating factor in UHI mitigation is the lack of research in cities located in LMICs, not allowing academia and local governments to better understand such an effect and to identify who are the most vulnerable populations to UHI. Per Tong et al. (14), mortality rates associated with heat in Europe will increase about 50 times by 2100 due to climate change generated by urban expansion, which raises the urgency to tackle UHI as soon as possible.

Health outcomes

Regarding health outcomes, the ones resulting from heat exposure presented in this thesis are in line with other systematic reviews tackling LMICs which also displayed significant associations between mortality and/or morbidity with cardiovascular and respiratory health outcomes (10,23). The heat impacts in cardiovascular and respiratory systems are the most documented outcomes in epidemiological literature. Yet, results from this thesis evidence an expansion of men's schizophrenia hospital admissions during extreme heat periods between lag 0 to 2 days. A study performed in Adelaide, Australia also noticed a rise of schizophrenia hospital admissions during heat waves (67), a conclusion that coincides with this systematic review's findings.

Four studies in this thesis detected a relationship between circulatory system, ischemic and hemorrhagic strokes, and mortality and morbidity rates resulting from heat exposure (50,57,59,60). Likewise, a cross-over study conducted in three cities across three Latin American countries uncovered elevated temperatures resulting in higher mortality rates attributed to cardiovascular and respiratory causes (68). Both this thesis results and Bell et al.(68) study agreed that days with a higher risk of mortality in a period with high temperatures would be between 0-2 days. There are also well-documented evidence of hospital admissions and mortality rates increases for suicide, preterm birth, and stillbirth, although most of these studies were performed in HICs and LMICs countries rather than cities, which narrows down the number of studies investigating heat exposure in the population living in cities (63,69,70).

Sociodemographic characteristics

Concerning sociodemographic characteristics, in this systematic review people over 60 years have been identified as the most vulnerable age group to mortality and morbidity heat effects. Similarly, Smith et al. (22) showcased in their article that people over 60 years are more susceptible to heat than other groups due to physiological mechanisms, homeostasis, and changes in the thermoregulatory responses. In addition, one specific article in this systematic review identified that children between 3-5 years were more susceptible to hospital admissions related to lower respiratory infection (ALRI) (52), while Xu et al. (71) evidenced that mortality due to heat wave exposure increased in children between 0–4 years old. However, even though Xu et al. (71) findings are in line with the ones from this systematic review concerning children, the results are not significant enough to draw conclusions. It is important to highlight that most of the authors who evaluated the relationship between age and mortality discovered a group with higher exposure. On the other hand, for Egondi et al. (54), a heat wave exposure did not generate any variation in the evaluated age groups.

In relation to sex, the results from this systematic review infer that female tend to be more vulnerable to heat exposure for mortality while males tend to be more vulnerable for morbidity. Equivalently, Tong (67) identified females as being more vulnerable to death linked to high temperature exposure due to physiological differences between males and females.

Other socio demographic aspects were evaluated in this systematic review, most notably educational level. A low level of education associated with low socio-economic status influenced mortality risk per four reviewed articles. This finding is supported by Bell et al. (68) who exposed mortality risk being higher for those with low education levels.

Continuing the socio-economic theme, Silveira et al. (56) and Zhou et al. (59) affirmed that people outside hospitals tend to have a higher risk of death by cardiovascular and stroke outcomes due to socioeconomic status and lower education, while for Singh et al. (48) the risk is just related to socioeconomic status. Gronlund (72) agreed with all those authors' points of view which were part of this systematic review.

In relation to race, the finding from Silveira et al. (56) suggested more vulnerability in white people. Yet, according to Gronlund (72), heat tolerance differences by race or due to genetic differences is inconclusive. Such discrepancy highlights that race is a topic not so addressed by literature investigating heat exposure impacts.

5.1 Limitations

This systematic review was not able to perform risk of bias evaluation due to the lack of a checklist for a time-series study. Among the systematic reviews checked on this topic, two scenarios were identified. First, the quality of studies was not measured, and second, the authors adapted some domain risk of bias tools to evaluate proper domains.

Concerning heat exposure, most of the evidence found during the database search was focused on countries, metropolitan areas, or municipalities rather than cities, which limited the search results. One of the search purposes was to find relevant evidence about Urban Heat

Island (UHI) effect, nonetheless, the two identified articles in this systematic review mentioned it superficially.

Concerning sociodemographic characteristics, a great variety of classifications was found specially in age and level of education, limiting a proper understanding of each group at higher risk of mortality and morbidity because some age ranges or education levels overlap. Hence, a proper classification and standardization of this data is necessary to perform future studies.

Finally, it was not possible to conduct a thorough analysis about the link between tropical climates and heat related impacts as the articles included in this thesis' systematic review do not tackle such a relationship with sufficient details.

6 Conclusion

This systematic review infers that heat exposures are harmful events with consequences on mortality and morbidity outcomes, mostly in cardiovascular and respiratory systems. Women, elderly, people working outdoors, and people with low educational level and disadvantaged socioeconomic status need protection as these were the most vulnerable populations in cities located in LMICs observed in this review. Public health adaptation and prevention programs in LMICs could be useful to develop response plans and to enhance health care systems in the adaptation to extreme weather events. Moreover, a clear definition of all heat concepts, including heat waves, may need to be developed and standardized as a prerequisite to create early warning systems and disaster preparedness based on defined temperature thresholds.

This thesis findings suggest exposure to heat waves are likely to become more frequent and intense as climate change takes effect, consequently further investigation tackling morbidity and Urban Heat Island effect in cities located in LMICs is needed as there is limited evidence for these countries. Heterogeneity for the measure the relationship between the outcome were found, limiting the possibility of meta-analysis for future research and present the results more accurate. A checklist to evaluate time-series environmental studies currently does not exist, limiting the possibility to evaluate how the study was conducted and described.

6.1 Recommendations

More investigation tackling morbidity and heat exposure is needed as most of the research is centered on mortality outcomes. The usage of technologies such as machine learning could be used to support future research as demonstrated in a study performed by Berrang-Ford (27), This technology would also help in the decision-making process about climate change mitigation and adaptation responses among researchers and policymakers seeking to performed new research at cities located in in LMICs with the support of their governments or non-governmental institutions.

It is also essential that local governments with the support of international organizations implement heat warning systems in LICs and LMICs during heat waves or extreme periods of high temperatures aiming to protect vulnerable groups such as children, females, elderly, and people with disadvantage socioeconomic situation, who are most exposed to this phenomenon (10,29,63). One of the groups who required more attention are the elderly people as current demographic projections per United Nations affirmed world population over 65 years and older will increase from 9% to 16% by 2050 (73). To facilitate the implementation of such actions, it is crucial to establish an interdisciplinary effort combining public health surveillance, stakeholders, government agencies, meteorological institutions, and researchers' as well as to recurrently collect citizens information via census for follow-up purposes to evaluate the actions that will be taken and to determine the viability of public health policies implementation in order to reduce health impacts and strengthen resilient populations as a consequence of the impacts of climate change on health.

Investigations performed in HICs could not be extrapolated to LMICs as they have different economic resources, weather conditions, technology, among other differences. Health outcomes would be different as well due to people's different socioeconomic status and demographic characteristics. Thus, investigation and preventive measures in cities located in LMICs might be performed by themselves to identify which are the most vulnerable populations and to create a deeper understanding of opportunities and challenges extreme temperatures can generate.

It has been demonstrated that green spaces, green roofs, and other construction materials rather than asphalt strengthen the cooling effect, resulting in heat diminution of the absorbed energy (32,66). Governments and Public Health programs can also help in the reduction of UHI through development of local pilot projects, education of the community, implementation of cooling spaces, and improvement of health care systems capacity during extreme weather events to protect the most vulnerable populations from this harmful effect.

Finally, research tackling vulnerability in the context of climate change has significantly improved, nevertheless, more investigation is recommended to identify mitigation strategies using the risk concept proposed by the IPCC with the elements of hazard and vulnerability, with the ultimate goal of reducing vulnerabilities.

6.2 Implications

It is the first systematic review tackling heat related impacts in cities located in Low- and Middle-Income Countries (LMICs). This is useful for future research as it has unveiled the current research gaps in those locations in topics like Urban Heat Island mitigation, heat related morbidity, early warning systems necessity, heat and/or heat waves concise and clear definition, association between heat and tropical climates.

The results of the systematic review with the help of public health professionals in LMICs countries or cities facilitating the creation of public health policies that will allow the creation of preventive strategies to avoid the progression of UHIs. It is vital to raise awareness in affected population of how heat affects different age groups, populations regardless of their sex, socioeconomic level, race, and level of education aiming to create equity in the protection of this harmful effect.

The main findings presented in this systematic review may support the creation of new climate change policies in LMICs, facilitating the achievement of goals number 10 (reducing inequalities) and 13 (climate action) from the UN’s 2030 Agenda for Sustainable Development as well as the alignment of national plans implementing climate agreements which need to be rolled out together.

References

1. Rossati A. Global Warming and Its Health Impact. Int J Occup Environ Med [Internet]. 2017; 8:7–20. Available from: www.theijoem.com
2. Roberts D, Pidcock R, Chen Y, Connors S, Tignor M. Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change. 2018.
3. Turek-Hankins LL, Coughlan de Perez E, Scarpa G, Ruiz-Diaz R, Schwerdtle PN, Joe ET, et al. Climate change adaptation to extreme heat: a global systematic review of implemented action. Oxford Open Climate Change. 2021;1(1):1–13.
4. Campbell S, Remenyi TATAA, White CJCJ, Johnston FHFHH. Heatwave and health impact research: A global review. Health and Place [Internet]. 2018 Sep 1; 53:210–8. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85052861346&doi=10.1016%2Fj.healthplace.2018.08.017&partnerID=40&md5=37f91ea38de5c8636e5d960b65975eb1
5. Vicedo-Cabrera AM, Scovronick N, Sera F, Royé D, Schneider R, Tobias A, et al. The burden of heat-related mortality attributable to recent human-induced climate change. Nature Climate Change. 2021;11(6):492–500.
6. Ellena M, Breil M, Soriani S. The heat-health nexus in the urban context: A systematic literature review exploring the socio-economic vulnerabilities and built environment characteristics. Urban Climate [Internet]. 2020;34(April):100676. Available from: https://doi.org/10.1016/j.uclim.2020.100676
7. Xu Z, FitzGerald G, Guo Y, Jalaludin B, Tong S. Impact of heatwave on mortality under different heatwave definitions: A systematic review and meta-analysis. Environment International [Internet]. 2016;89–90:193–203. Available from: http://dx.doi.org/10.1016/j.envint.2016.02.007
8. Seneviratne SI, Nicholls N, Easterling D, Goodess CM, Kanae S, Kossin J, et al. Changes in climate extremes and their impacts on the natural physical environment. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change. 2012; 9781107025:109–230.
9. United Nations Office for Disasters Risk Reduction. Economic losses, poverty & disasters 1998-2017. Centre for Research on the Epidemiology of Disasters (CRED). Brussels, Belgium; 2017. 01–30 p.
10. Green H, Bailey J, Schwarz L, Vanos J, Ebi K, Benmarhnia T. Impact of heat on mortality and morbidity in low and middle income countries: A review of the epidemiological

evidence and considerations for future research. Environmental Research [Internet]. 2019 Apr; 171:80–91. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L2001465622&from=export
11. Alizadeh MR, Abatzoglou JT, Adamowski JF, Prestemon JP, Chittoori B, Akbari Asanjan A, et al. Increasing Heat-Stress Inequality in a Warming Climate. Earth's Future. 2022;10(2):1–11.
12. The World Bank, UN, EU. Guidelines for Assessing the Human Impact of Disasters. 2019;50.
13. Ebi KL, Capon A, Berry P, Broderick C, de Dear R, Havenith G, et al. Hot weather and heat extremes: health risks. The Lancet [Internet]. 2021;398(10301):698–708. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L2014134348&from=export
14. Tong S, Prior J, McGregor G, Shi X, Kinney P. Urban heat: An increasing threat to global health. The BMJ [Internet]. 2021;375(375): n2467. Available from: http://www.bmj.com/
15. He C, Ma L, Zhou L, Kan HD, Zhang Y, Ma WC, et al. Exploring the mechanisms of heat wave vulnerability at the urban scale based on the application of big data and artificial societies. Environment International [Internet]. 2019 Jun 1; 127:573–83. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L2001805591&from=export
16. IPCC 2007. Climate Change 2007 Synthesis Report. Intergovernmental Panel on Climate Change [Core Writing Team IPCC [Internet]. 2007 [cited 2022 Apr 12];104. Available from: https://www.ipcc.ch/report/ar4/syr/
17. Sutton MA, van Grinsven H, Billen G, Bleeker A, Bouwman AF, Bull K, et al. Climate change 2014: Impacts, Adaption and Vulnerability. Summary for policy makers. Intergovernmental Panel on Climate Change [Core Writing Team IPCC. 2014.
18. Ebi KL and WHO. Climate Change and Health. Vulnerability and adaptation assessment. Vols. 2021-Janua, Issues in Environmental Science and Technology. 2021. 353–369 p.
19. Carmen P, Jim M, Ruiz-chico J, Rafael A. Analysis of Research on the SDGs: The Relationship between Climate Change, Poverty and Inequality. Applied sciences. 2021;11(8947).
20. Phung D, Chu C, Rutherford S, Nguyen HLTHLT, Do CMCMM, Huang C. Heatwave and risk of hospitalization: A multi-province study in Vietnam. Environmental Pollution [Internet]. 2017; 220:597–607. Available from:

https://www.embase.com/search/results?subaction=viewrecord&id=L613437513&from=export

21. Cheng W, Li D, Liu Z, Brown RD. Approaches for identifying heat-vulnerable populations and locations: A systematic review. Science of the Total Environment [Internet]. 2021 Dec 10 [cited 2022 May 18];799. Available from: https://sci-hub.se/10.1016/j.scitotenv.2021.149417
22. Smith KR, Woodward A, Campbell-Lendrum D, Chadee DD, Honda Y, Liu Q, et al. Human health: Impacts, adaptation, and co-benefits. Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects. 2015;709–54.
23. Dimitrova A, Ingole V, Basagaña X, Ranzani O, Milà C, Ballester J, et al. Association between ambient temperature and heat waves with mortality in South Asia: Systematic review and meta-analysis. Environment International. 2021;146.
24. Rajib Shaw, Yong Luo TSC. IPCC WGII Sixth Assessment Report Chapter 10. IPCC. 2021;10-1-10–172.
25. Nori-Sarma A, Benmarhnia T, Rajiva A, Azhar GSS, Gupta P, Pednekar MSS, et al. Advancing our understanding of heat wave criteria and associated health impacts to improve heat wave alerts in developing country settings. International Journal of Environmental Research and Public Health [Internet]. 2019;16(12). Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L2002156002&from=export
26. Zander KK, Cadag JR, Escarcha J, Garnett ST. Perceived heat stress increases with population density in urban Philippines. Environmental research letters. 2018;13(8):84009.
27. Berrang-Ford L, Sietsma AJ, Callaghan M, Minx JC, Scheelbeek PFD, Haddaway NR, et al. Systematic mapping of global research on climate and health: a machine learning review. The Lancet Planetary Health [Internet]. 2021 Aug 1 [cited 2022 Mar 24];5(8): e514–25. Available from: http://dx.doi.org/10.1016/S2542-5196(21)00179-0
28. Gasparrini A, Guo Y, Hashizume M, Lavigne E, Zanobetti A, Schwartz J, et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. The lancet [Internet]. 2015;386(9991):369–75. Available from: www.lancet.com
29. Nori-Sarma A, Anderson GBB, Rajiva A, ShahAzhar G, Gupta P, Pednekar MSMS, et al. The impact of heat waves on mortality in Northwest India. Environmental Research [Internet]. 2019;176. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85067659192&doi=10.1016%2Fj.envres.2019.108546&partnerID=40&md5=9d981bebc2f02a77938b57b4ea5b2686

30. Dang TN, Honda Y, Do D van, Pham ALT, Chu C, Huang C, et al. Effects of extreme temperatures on mortality and hospitalization in Ho Chi Minh City, Vietnam. International Journal of Environmental Research and Public Health. 2019;16(3).
31. Morello-Frosch R, Zuk M, Jerrett M, Shamasunder B, Kyle AD. Understanding the cumulative impacts of inequalities in environmental health: implications for policy. Health Aff. 2011;30(5):879–87.
32. Fernandez Milan B, Creutzig F, Milan BF, Creutzig F. Reducing urban heat wave risk in the 21st century. Current Opinion in Environmental Sustainability. 2015 Jun 1; 14:221–31.
33. Yin Q, Wang J. The association between consecutive days' heat wave and cardiovascular disease mortality in Beijing, China. BMC Public Health. 2017 Feb 23;17(1):223.
34. Zhang JJ, Liu S, Han J, Zhou L, Liu Y, Yang L, et al. Impact of heat waves on nonaccidental deaths in Jinan, China, and associated risk factors. Int J Biometeorol [Internet]. 2016 Sep 1;60(9):1367–75. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L615599388&from=export
35. Rathi SKSK, Chakraborty S, Mishra SKSK, Dutta A, Nanda L. A heat vulnerability index: Spatial patterns of exposure, sensitivity and adaptive capacity for urbanites of four cities of india. International Journal of Environmental Research and Public Health [Internet]. 2022 Dec;19(1). Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L2015106344&from=export
36. Ebi KL, Hess JJ. Health risks due to climate change: Inequity in causes and consequences. Health Affairs. 2020;39(12):2056–62.
37. The World Bank. World Bank Country and Lending Groups [Internet]. 2022. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups
38. OECD iLibrary. Cities in the World: A new perspective on Urbanisation [Internet]. 2020. Available from: https://www.oecd-ilibrary.org/sites/8976b9c2-en/index.html?itemId=/content/component/8976b9c2-en
39. Bambrick HJ, Capon AG, Barnett GB, Beaty RM, Burton AJ. Climate change and health in the urban environment: adaptation opportunities in Australian cities. Asia Pacific Journal of Public Health. 2011;23(2_suppl):67S-79S.
40. McMichael AJ. The urban environment and health in a world of increasing globalization: issues for developing countries. Bulletin of the world Health Organization. 2000; 78:1117–26.

41. Li Y, Cheng Y, Cui G, Peng C, Xu Y, Wang Y, et al. Association between high temperature and mortality in metropolitan areas of four cities in various climatic zones in China: A time-series study. Environmental Health: A Global Access Science Source [Internet]. 2014;13(1). Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L600014193&from=export
42. Leal Filho W, Quasem Al-Amin A, Nagy GJ, Azeiteiro UM, Wiesböck L, Ayal DY, et al. A Comparative Analysis of Climate-Risk and Extreme Event-Related Impacts on Well-Being and Health: Policy Implications. Int J Environ Res Public Health [Internet]. 2018; 15:331. Available from: www.mdpi.com/journal/ijerph
43. Tran K v, Azhar GS, Nair R, Knowlton K, Jaiswal A, Sheffield P, et al. A cross-sectional, randomized cluster sample survey of household vulnerability to extreme heat among slum dwellers in Ahmedabad, India. International Journal of Environmental Research and Public Health [Internet]. 2013;10(6):2515–43. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L369169943&from=export
44. Munn Z, Stern C, Aromataris E, Lockwood C, Jordan Z. What kind of systematic review should i conduct? A proposed typology and guidance for systematic reviewers in the medical and health sciences. BMC Medical Research Methodology. 2018;18(1):1–9.
45. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. The BMJ. 2021;372.
46. Muka T, Glisic M, Milic J, Verhoog S, Bohlius J, Bramer W, et al. A 24-step guide on how to design, conduct, and successfully publish a systematic review and meta-analysis in medical research. European Journal of Epidemiology [Internet]. 2020;35(1):49–60. Available from: https://doi.org/10.1007/s10654-019-00576-5
47. Ottawa Hospital Research Institute [Internet]. [cited 2022 May 18]. Available from: http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp
48. Singh N, Mhawish A, Ghosh S, Banerjee T, Mall RKK. Attributing mortality from temperature extremes: A time series analysis in Varanasi, India. Science of the Total Environment [Internet]. 2019; 665:453–64. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85061528440&doi=10.1016%2Fj.scitotenv.2019.02.074&partnerID=40&md5=d7a57f0c1dda6f9d58cf6ae6fb6078ed
49. Can G, Şahin Ü, Sayılı U, Dubé M, Kara B, Acar HCC, et al. Excess mortality in istanbul during extreme heat waves between 2013 and 2017. International Journal of Environmental Research and Public Health [Internet]. 2019;16(22). Available from:

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85074632763&doi=10.3390%2Fijerph16224348&partnerID=40&md5=37be795b49728588c05702fab97cec2d

50. Yang J, Yin P, Sun J, Wang B, Zhou M, Li M, et al. Heatwave and mortality in 31 major Chinese cities: Definition, vulnerability and implications. Science of the Total Environment [Internet]. 2019; 649:695–702. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L2001070833&from=export

51. Li M, Zhou M, Yang J, Yin P, Wang B, Liu Q. Temperature, temperature extremes, and cause-specific respiratory mortality in China: a multi-city time series analysis. Air Quality, Atmosphere and Health [Internet]. 2019;12(5):539–48. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85060927204&doi=10.1007%2Fs11869-019-00670-3&partnerID=40&md5=b94652001c232fa8bdd532366ff8d87b

52. Ngo HKTT, Luong LMTT, Le HHTCHHTC, Dang TN, le Pham A, Phung D, et al. Impact of temperature on hospital admission for acute lower respiratory infection (ALRI) among pre-school children in Ho Chi Minh City, Vietnam. International Journal of Biometeorology [Internet]. 2021;65(7):1205–14. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L634640416&from=export

53. Phung D, Guo Y, Thai P, Rutherford S, Wang X, Nguyen M, et al. The effects of high temperature on cardiovascular admissions in the most populous tropical city in Vietnam. Environmental Pollution [Internet]. 2016; 208:33–9. Available from: http://dx.doi.org/10.1016/j.envpol.2015.06.004

54. Egondi T, Kyobutungi C, Rocklöv J. Temperature variation and heat wave and cold spell impacts on years of life lost among the urban poor population of Nairobi, Kenya. Int J Environ Res Public Health [Internet]. 2015 Mar;12(3):2735–48. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84927591622&doi=10.3390%2Fijerph120302735&partnerID=40&md5=aa04db48f5c18210d486bcad795f362f

55. Leone M, D'Ippoliti D, de Sario M, Analitis A, Menne B, Katsouyanni K, et al. A time series study on the effects of heat on mortality and evaluation of heterogeneity into European and Eastern-Southern Mediterranean cities: Results of EU CIRCE project. Environmental Health: A Global Access Science Source [Internet]. 2013;12(1). Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84880432765&doi=10.1186%2F1476-069X-12-55&partnerID=40&md5=b3cba7953913be059390476946c0d819

56. Silveira IHIH, Cortes TRTRR, Oliveira BFAFABFA, Junger WLWL. Temperature and cardiovascular mortality in Rio de Janeiro, Brazil: Effect modification by individual-level and neighbourhood-level factors. Journal of Epidemiology and Community Health [Internet]. 2021 Jan 1;75(1):69–75. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85097870561&doi=10.1136%2Fjech-2020-215002&partnerID=40&md5=75dc0a1e97bdd423165b3a1e20b0d27c
57. Wang S, Zhang X, Xie M, Zhao D, Zhang H, Zhang Y, et al. Effect of increasing temperature on daily hospital admissions for schizophrenia in Hefei, China: a time-series analysis. Public Health [Internet]. 2018; 159:70–7. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85044100887&doi=10.1016%2Fj.puhe.2018.01.032&partnerID=40&md5=160ccec0b78fe85a2cf3a78f5eb8392c
58. Yang J, Zhou M, Li M, Liu X, Yin P, Sun Q, et al. Vulnerability to the impact of temperature variability on mortality in 31 major Chinese cities. Environ Pollut. 2018 Aug; 239:631–7.
59. Zhou L, Chen K, Chen X, Jing Y, Ma Z, Bi J, et al. Heat and mortality for ischemic and hemorrhagic stroke in 12 cities of Jiangsu Province, China. Science of the Total Environment [Internet]. 2017 Dec;601–602:271–7. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L616379052&from=export
60. Bai L, Cirendunzhu, Woodward A, Dawa, Zhaxisangmu, Chen B, et al. Temperature, hospital admissions and emergency room visits in Lhasa, Tibet: a time-series analysis. Sci Total Environ [Internet]. 2014 Aug 15; 490:838–48. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L373236901&from=export
61. Yang J, Yin P, Sun J, Wang B, Zhou M, Li M, et al. Heatwave and mortality in 31 major Chinese cities: Definition, vulnerability and implications. Sci Total Environ. 2019 Feb; 649:695–702.
62. The World Bank. World development report: development and climate change. Vol. 47, Choice Reviews Online. 2010. 47-5609-47–5609 p.
63. Song X, Wang S, Hu Y, Yue M, Zhang T, Liu Y, et al. Impact of ambient temperature on morbidity and mortality: An overview of reviews. Science of the Total Environment [Internet]. 2017;586(222):241–54. Available from: http://dx.doi.org/10.1016/j.scitotenv.2017.01.212
64. Oudin Åström D, Åström C, Forsberg B, Vicedo-Cabrera AM, Gasparrini A, Oudin A, et al. Heat wave–related mortality in Sweden: A case-crossover study investigating effect

modification by neighbourhood deprivation. Scandinavian Journal of Public Health [Internet]. 2020;48(4):428–35. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85059658931&doi=10.1177%2F1403494818801615&partnerID=40&md5=e8264981b2e0cdd78f6c321ef1e9b59e

65. Li M, Gu S, Bi P, Yang J, Liu Q. Heat waves and morbidity: Current knowledge and further direction-a comprehensive literature review. International Journal of Environmental Research and Public Health [Internet]. 2015;12(5):5256–83. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L604639618&from=export

66. Sera F, Armstrong B, Tobias A, Vicedo-Cabrera AMM, Åström C, Bell MLL, et al. How urban characteristics affect vulnerability to heat and cold: A multi-country analysis. International Journal of Epidemiology [Internet]. 2019;48(4):1101–12. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L628953364&from=export

67. Tong S, Wang XY, Yu W, Chen D, Wang X. The impact of heatwaves on mortality in Australia: A multicity study. BMJ Open. 2014;4(2):1–7.

68. Bell ML, O'Neill MS, Ranjit N, Borja-Aburto VH, Cifuentes LA, Gouveia NC. Vulnerability to heat-related mortality in Latin America: a case-crossover study in Sao Paulo, Brazil, Santiago, Chile and Mexico City, Mexico. Int J Epidemiol [Internet]. 2008 Aug;37(4):796–804. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L352088511&from=export

69. Gao J, Cheng Q, Duan J, Xu Z, Bai L, Zhang Y, et al. Ambient temperature, sunlight duration, and suicide: A systematic review and meta-analysis. Science of the Total Environment [Internet]. 2019; 646:1021–9. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L2000986182&from=export

70. Ha S. The Changing Climate and Pregnancy Health. Curr Environ Health Rep. 2022 Jun;9(2):263–75.

71. Xu Z, Sheffield PE, Su H, Wang X, Bi Y, Tong S. The impact of heat waves on children's health: A systematic review. International Journal of Biometeorology. 2014;58(2):239–47.

72. Gronlund CJJ. Racial and socioeconomic disparities in heat-related health effects and their mechanisms: a review. 2015;1(3):165–73.

73. de Schrijver E, Bundo M, Ragettli MS, Sera F, Gasparrini A, Franco OH, et al. Nationwide Analysis of the Heat-and Cold-Related Mortality Trends in Switzerland between 1969 and 2017: The Role of Population Aging. Environmental Health Perspectives. 2022;130(3):1–9.

Appendix

Appendix 1: PRISMA checklist

Section/topic	#	Checklist item	Reported on page # /section
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Title
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	Abstract section
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	1-5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	NA
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	9
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	39-45
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	8
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	9

Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	40
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	9
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	22-23
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

Appendix 2: Bibliographic search record

Databases	References retrieved
PUBMED	343
Scopus	657
Embase	505
TOTAL with duplicates	1505
Duplicates	414
TOTAL	**1091**

Population: LMICs.

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Exposure:

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Outcome

(“socioeconomic” OR vulnerability” OR “disparities” OR “inequalities” OR “inequi*” OR “health impacts”) AND (“morbidity” OR “mortality” OR “excess death” OR “hospital admissions”)

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"serbians"[Text Word] OR "surinamese"[Text Word] OR "sudanese"[Text Word] OR "thai"[Text Word] OR "turkmenistan"[Text Word] OR "tonga"[Text Word] OR "turk"[Text Word] OR "turkish"[Text Word] OR "turkmen"[Text Word] OR "tuvaluan"[Text Word] OR "tuvaluans"[Text Word] OR "venezuelan"[Text Word] OR "venezuelans"[Text Word] OR "samoan"[Text Word] OR "samoans"[Text Word] OR "kosovo"[Text Word] OR "south africa"[Text Word])) AND ("extreme heat"[Text Word] OR "heat extreme"[Text Word] OR "urban heat"[Text Word] OR "urban heat island"[Text Word] OR "heat wave"[Text Word] OR "heatwave"[Text Word] OR "heat-waves"[Text Word] OR "heat-waves"[Text Word] OR "heat-health"[Text Word] OR "heat day"[Text Word] OR "global warming"[Text Word] OR "temperature*"[Text Word] OR "heat ind*"[Text Word] OR "extreme-heat event"[Text Word] OR "heat stress"[Text Word] OR "heat vulnerability"[Text Word] OR "hot temperature"[Text Word]) AND (("socioeconomic"[Text Word] OR "vulnerability"[Text Word] OR "disparities"[Text Word] OR "inequalities"[Text Word] OR "inequi*"[Text Word] OR "health impacts"[Text Word]) AND ("morbidity"[Text Word] OR "mortality"[Text Word] OR "excess death"[Text Word] OR "hospital admissions"[Text Word]))

Scopus strategy:

((KEY("developing countr*" OR "developing nation*" OR "developing population*" OR "developing world" OR "less developed countr*" OR "less developed nation*" OR "less developed world" OR "lesser developed countr*" OR "lesser developed nation*" OR "under developed countr*" OR "under developed world" OR "underdeveloped countr*" OR "underdeveloped nation*" OR "underdeveloped population*" OR "underdeveloped world" OR "middle income countr*" OR "middle income nation*" OR "middle income population*" OR "low income countr*" OR "low income nation*" OR "low income population*"

OR "lower income countr*" OR "lower income nation*" OR "lower income population*" OR "underserved countr*" OR "underserved nation*" OR "underserved population*")) OR (KEY("under served population*" OR "deprived countr*" OR "deprived population*" OR "poor countr*" OR "poor nation*" OR "poor population*" OR "poor world" OR "poorer countr*" OR "poorer nation*" OR "poorer population*" OR "developing econom*" OR "less developed econom*" OR "underdeveloped econom*" OR "middle income econom*" OR "low income econom*" OR "lower income econom*" OR "low gdp" OR "low gnp" OR "low gross domestic" OR "low gross national" OR "lower gdp" OR "lower gross domestic" OR "lmic" OR "lmics" OR "third world" OR "lami countr*" OR "transitional countr*" OR "emerging econom*" OR "emerging nation*")) OR (KEY("Afghanistan" OR "burkina Faso" OR "burundi" OR "central african republic" OR "chad" OR "democratic republic of the congo" OR " eritrea" OR "ethiopia" OR "gambia" OR "guinea" OR "guinea bissau" OR "democratic people's republic of korea" OR "liberia" OR "madagascar" OR "malawi" OR "mali" OR "mozambique" OR "niger" OR "rwanda" OR "sierra leone" OR "somalia" OR "south sudan" OR "sudan" OR "syria" OR "togo" OR "uganda" OR "yemen" OR "angola" OR "algeria" OR "bangladesh" OR "belize" OR "benin" OR "bhutan" OR "bolivia" OR "cabo verde" OR "cambodia" OR "cameroon" OR "comoros" OR "cote d'ivoire" OR "djibouti" OR "egypt" OR "el salvador" OR "Eswatini" OR "ghana" OR "haiti" OR "honduras" OR "india" OR "indonesia" OR "iran" OR "kenya" OR "Kiribati" OR "kyrgyzstan")) or (KEY("laos" OR "lesotho" OR "mauritania" OR "micronesia" OR "mongolia" OR "morocco" OR "myanmar" OR "nepal" OR "nicaragua" OR "nigeria" OR "pakistan" OR "papua new guinea" OR "philippines" OR "samoa" OR "sao tome and principe" OR "senegal" OR "solomon island" OR "Sri Lanka" OR "tanzania" OR "tajikistan" OR "timor leste" OR "tunisia" OR "ukraine" OR "uzbekistan" OR "vanuatu" OR "vietnam" OR "West Bank and Gaza" OR "zambia" OR "zimbabwe" OR "africa south of the sahara" OR “"albania" OR "argentina" OR "armenia" OR "american samoa" OR "azerbaijan" OR "bulgaria" OR "bosnia" OR "herzegovina" OR "belarusian" OR "belarusians" OR "byelorussian" OR "byelorusians" OR "belizean" OR "belizeans" OR "beninese" OR "benineses" OR "belizean" OR "belizeans" OR "beninese" OR "benineses" OR "braziliean" OR "brazilians" OR "brasilian" OR "brasilians" OR "botswana" OR "batswana" OR "china" OR "colombia" OR "costa rica" OR "costa rican" OR "costa ricans" OR "dominican" OR "dominicans" OR "ecuadorian" OR "ecuadorians" OR "fiji" OR "gabon" OR "gabonese republic" OR "georgia" OR "georgian" OR "guinea" OR "grenada" OR "guatemala" OR "guyana" OR "guiana" OR "indonesia" OR "iran" OR "iraq" OR "isle of man" OR "jamaica" OR "jordan" OR "kazakhastan" OR "kazakh" OR "lebanon" OR "liberia" OR "libya" OR "Libya" OR "libyan arab jamahiriya" OR "saint lucia" OR "st lucia" OR "Maldives" OR "mexico" OR "marsall islands" OR "macedonia" OR "montenegro" OR "malaysia" OR " namibia" OR "peru" OR " paraguay" OR "russia" OR "russian federation" OR "usrr" OR "sovietic union" OR "serbia" OR "serbians" OR "surinamese" OR "sudanese" OR "surinameses" OR "thai" OR "turkmenistan" OR "tonga" OR "turk" OR "turkish" OR "turkmen" OR "tuvaluan" OR "tuvaluans" OR "venezuelan" OR "venezuelans" OR "samoan" OR "samoans" OR "kosovo" OR "south africa“))) AND (KEY("extreme heat" OR "heat extreme" OR "urban heat" OR "urban heat island" OR "heat wave" OR "heatwave" OR "heat waves" OR "heat-waves" OR "heat-health" OR "heat-health" OR "heat day" OR "global warming" OR "temperature*" OR "heat ind*" OR "extreme-heat event" OR "heat stress" OR "heat vulnerability" OR "hot temperature")) AND ((KEY("socioeconomic" OR "vulnerability" OR "disparities" OR "inequalities" OR "inequi" OR "health impacts")) AND (KEY(("morbility" OR "mortality" OR "excess death" OR "hospital admissions"))))

EMBASE strategy:

('developing countr*' OR 'developing nation*' OR 'developing population*' OR 'developing world' OR 'less developed countr*' OR 'less developed nation*' OR 'less developed world' OR 'lesser developed countr*' OR 'lesser developed nation*' OR 'under developed countr*' OR 'under developed world' OR 'underdeveloped countr*' OR 'underdeveloped nation*' OR 'underdeveloped population*' OR 'underdeveloped world' OR 'middle income countr*' OR 'middle income nation*' OR 'middle income population*' OR 'low income countr*' OR 'low income nation*' OR 'low income population*' OR 'lower income countr*' OR 'lower income nation*' OR 'lower income population*' OR 'underserved countr*' OR 'underserved nation*' OR 'underserved population*' OR 'under served population*' OR 'deprived countr*' OR 'deprived population*' OR 'poor countr*' OR 'poor nation*' OR 'poor population*' OR 'poor world' OR 'poorer countr*' OR 'poorer nation*' OR 'poorer population*' OR 'developing econom*' OR 'less developed econom*' OR 'underdeveloped econom*' OR 'middle income econom*' OR 'low income econom*' OR 'lower income econom*' OR 'low gdp' OR 'low gnp' OR 'low gross domestic' OR 'low gross national' OR 'lower gdp' OR 'lower gross domestic' OR 'lmic' OR 'lmics' OR 'third world' OR 'lami countr*' OR 'transitional countr*' OR 'emerging econom*' OR 'emerging nation*' OR 'afghanistan' OR 'burkina faso' OR 'burundi' OR 'central african republic' OR 'chad' OR 'democratic republic of the congo' OR 'eritrea' OR 'ethiopia' OR 'gambia' OR 'guinea' OR 'guinea bissau' OR 'democratic peoples republic of korea' OR 'liberia' OR 'madagascar' OR 'malawi' OR 'mali' OR 'mozambique' OR 'niger' OR 'rwanda' OR 'sierra leone' OR 'somalia' OR 'south sudan' OR 'sudan' OR 'syria' OR 'togo' OR 'uganda' OR 'yemen' OR 'angola' OR 'algeria' OR 'bangladesh' OR 'belize' OR 'benin' OR 'bhutan' OR 'bolivia' OR 'cabo verde' OR 'cambodia' OR 'cameroon' OR 'comoros' OR 'cote divoire' OR 'djibouti' OR 'egypt' OR 'el salvador' OR 'eswatini' OR 'ghana' OR 'haiti' OR 'honduras' OR 'india' OR 'indonesia' OR 'iran' OR 'kenya' OR 'kiribati' OR 'kyrgyzstan' OR 'laos' OR 'lesotho' OR 'mauritania' OR 'micronesia' OR 'mongolia' OR 'morocco' OR 'myanmar' OR 'nepal' OR 'nicaragua' OR 'nigeria' OR 'pakistan' OR 'papua new guinea' OR 'philippines' OR 'samoa' OR 'sao tome and principe' OR 'senegal' OR 'solomon island' OR 'sri lanka' OR 'tanzania' OR 'tajikistan' OR 'timor leste' OR 'tunisia' OR 'ukraine' OR 'uzbekistan' OR 'vanuatu' OR 'vietnam' OR 'west bank and gaza' OR 'zambia' OR 'zimbabwe' OR 'africa south of the sahara' OR “"albania" OR "argentina" OR "armenia" OR "american samoa" OR "azerbaijan" OR "bulgaria" OR "bosnia" OR "herzegovina" OR "belarusian" OR "belarusians" OR "byelorussian" OR "byelorusians" OR "belizean" OR "belizeans" OR "beninese" OR "benineses" OR "belizean" OR "belizeans" OR "beninese" OR "benineses" OR "braziliean" OR "brazilians" OR "brasilian" OR "brasilians" OR "botswana" OR "batswana" OR "china" OR "colombia" OR "costa rica" OR "costa rican" OR "costa ricans" OR "dominican" OR "dominicans" OR "ecuadorian" OR "ecuadorians" OR "fiji" OR "gabon" OR "gabonese republic" OR "georgia" OR "georgian" OR "guinea" OR "grenada" OR "guatemala" OR "guyana" OR "guiana" OR "indonesia" OR "iran" OR "iraq" OR "isle of man" OR "jamaica" OR "jordan" OR "kazakhastan" OR "kazakh" OR "lebanon" OR "liberia" OR "libya" OR "Libya" OR "libyan arab jamahiriya" OR "saint lucia" OR "st lucia" OR "Maldives" OR "mexico" OR "marsall islands" OR "macedonia" OR "montenegro" OR "malaysia" OR " namibia" OR "peru" OR " paraguay" OR "russia" OR "russian federation" OR "usrr" OR "sovietic union" OR "serbia" OR "serbians" OR "surinamese" OR "sudanese" OR "surinameses" OR "thai" OR "turkmenistan" OR "tonga" OR "turk" OR "turkish" OR "turkmen" OR "tuvaluan" OR "tuvaluans" OR "venezuelan" OR "venezuelans" OR "samoan" OR "samoans" OR "kosovo" OR "south africa" AND 'extreme heat' OR 'heat extreme' OR 'urban heat' OR 'urban heat island' OR 'heat wave' OR 'heatwave' OR 'heat waves' OR 'heat-waves' OR 'heat-health' OR 'heat day' OR 'global warming' OR 'temperature*' OR 'heat ind*' OR 'extreme-heat event' OR 'heat stress' OR 'heat vulnerability' OR 'hot temperature' AND ('socioeconomic' OR 'vulnerability' OR 'disparities' OR 'inequalities' OR 'inequi*' OR 'health impacts') AND ('morbidity' OR 'mortality' OR 'excess death' OR 'hospital admissions')

Appendix 3: List of Low- and Middle-Income Countries (LMICs) according to the World Bank 2022.

Low-Income Countries (LICs)			
Afghanistan	Ethiopia	Malawi	South Sudan
Burkina Faso	Gambia	Mali	Sudan
Burundi	Guinea	Mozambique	Syrian Arab Republic
Central African Republic	Guinea-Bissau	Niger	Togo
Chad	North Korea	Rwanda	Uganda
Congo, Dem. Rep.	Liberia	Sierra Leone	Yemen
Eritrea	Madagascar	Somalia	

Lower Middle-Income Countries (LMICs)			
Angola	Egypt Arab Republic	Mauritania	Solomon Islands
Algeria	El Salvador	Fed. States of Micronesia	Sri Lanka
Bangladesh	Eswatini	Mongolia	Tanzania
Belize	Ghana	Morocco	Tajikistan
Benin	Haiti	Myanmar	Timor-Leste
Bhutan	Honduras	Nepal	Tunisia
Bolivia	India	Nicaragua	Ukraine
Cabo Verde	Indonesia	Nigeria	Uzbekistan
Cambodia	Iran, Islamic Rep	Pakistan	Vanuatu
Cameroon	Kenya	Papua New Guinea	Vietnam
Comoros	Kiribati	Philippines	West Bank and Gaza
Congo Republic	Kyrgyz Republic	Samoa	Zambia
Côte d'Ivoire	Lao PDR	São Tomé and Principe	Zimbabwe
Djibouti	Lesotho	Senegal	

Upper Middle-Income Countries (UMICs)			
Albania	American Samoa	Argentina	Armenia
Azerbaijan	Belarus	Bosnia and Herzegovina	Botswana
Brazil	Bulgaria	China	Colombia
Costa Rica	Cuba	Dominica	Dominican Republic
Equatorial Guinea	Ecuador	Fiji	Gabon
Georgia	Grenada	Guatemala	Guyana
Iraq	Jamaica	Jordan	Kazakhstan
Kosovo	Lebanon	Libya	Malaysia
Maldives	Marshall Islands	Mauritius	Mexico
Moldova	Montenegro	Namibia	North Macedonia
Panama	Paraguay	Peru	Romania
Russia	Serbia	South Africa	St. Lucia
St Vicent and Grenadines	Suriname	Thailand	Tonga
Turkey	Turkmenistan	Tuvalu	

Source: World Bank Country and Lending Groups – World Bank Data Help Desk [Internet]. Datahelpdesk.worldbank.org. 2022.