Health and Place 53 (2018) 210–218

Contents lists available at ScienceDirect

Health & Place

journal homepage: www.elsevier.com/locate/healthplace

Heatwave and health impact research: A global review

Sharon Campbell[a], Tomas A. Remenyi[b], Christopher J. White[b,c,d,e], Fay H. Johnston[a,*]

[a] Menzies Institute for Medical Research, University of Tasmania, 1 Liverpool St, Hobart, Tasmania 7000, Australia
[b] Antarctic Climate and Ecosystems Cooperative Research Centre, University of Tasmania, 20 Castray Esplanade, Hobart, Tasmania 7000, Australia
[c] School of Engineering, University of Tasmania, Private Bag 65, Hobart, Tasmania 7001, Australia
[d] Department of Civil and Environmental Engineering, University of Strathclyde, James Weir Building, 75 Montrose Street, Glasgow G1 1XJ, United Kingdom
[e] European Centre for Environment and Human Health, University of Exeter, Knowledge Spa, Royal Cornwall Hospital, Truro, Cornwall TR1 3HD, United Kingdom

ARTICLE INFO

Keywords:
Heatwave
Extreme heat
Mortality
Morbidity
Population health

ABSTRACT

Background: Observed increases in the frequency and intensity of heatwave events, together with the projected acceleration of these events worldwide, has led to a rapid expansion in research on the health impacts of extreme heat.
Objective: To examine how research on heatwaves and their health-related impact is distributed globally.
Methods: A systematic review was undertaken. Four online databases were searched for articles examining links between specific historical heatwave events and their impact on mortality or morbidity. The locations of these events were mapped at a global scale, and compared to other known characteristics that influence heat-related illness and death.
Results: When examining the location of heatwave and health impact research worldwide, studies were concentrated on mid-latitude, high-income countries of low- to medium-population density. Regions projected to experience the most extreme heatwaves in the future were not represented. Furthermore, the majority of studies examined mortality as a key indicator of population-wide impact, rather than the more sensitive indicator of morbidity.
Conclusion: While global heatwave and health impact research is prolific in some regions, the global population most at risk of death and illness from extreme heat is under-represented. Heatwave and health impact research is needed in regions where this impact is expected to be most severe.

1. Introduction

Climate change has been described as ‘the biggest global health threat of the 21st Century’, putting the ‘lives and wellbeing of billions of people at increased risk’ (Costello et al., 2009, p. 1693). Furthermore, the projected effects of climate change have been described as representing ‘an unacceptably high and potentially catastrophic risk to human health’ (Watts et al., 2015). The World Health Organization (WHO) recognises the overall health impacts of a changing climate as overwhelmingly negative, with regions exhibiting the poorest health infrastructure being the least able to adapt, prepare and respond to the variety of increased health risks likely in a changing climate (World Health Organization, 2017).

As a result of human-induced changes in climate, global mean surface air temperature shows a rising trend over the last 100 years (Intergovernmental Panel on Climate Change, 2013). This has led to a worldwide increase in frequency, intensity and duration of extreme heat events or heatwaves (Perkins et al., 2012) (noting these terms are used interchangeably in this paper). The Intergovernmental Panel on Climate Change 5th Assessment Report indicates an increase in frequency, length and intensity of heatwaves will be ‘very likely over most land areas’ well into the future (Intergovernmental Panel on Climate Change, 2013, p. 135).

It is widely accepted that increased exposure to heat has a detrimental effect on human health, resulting in increased mortality (death) and morbidity (illness) across a variety of geographical locations (Anderson and Bell, 2011; Haines et al., 2006; Loughnan et al., 2010; Martiello and Giacchi, 2010; Zeng et al., 2016). This effect has been demonstrated by a number of extreme heat events worldwide, including in Chicago, USA in 1995 (Whitman et al., 1997), the European-wide heatwave in 2003 (Kosatsky, 2005) and in South-East Australia in 2009 (Nitschke et al., 2011). Furthermore, a relationship between increasing

* Corresponding author.
E-mail addresses: sharon.campbell@utas.edu.au (S. Campbell), tom.remenyi@utas.edu.au (T.A. Remenyi), chris.white@utas.edu.au (C.J. White), fay.johnston@utas.edu.au (F.H. Johnston).

https://doi.org/10.1016/j.healthplace.2018.08.017
Received 10 February 2018; Received in revised form 7 July 2018; Accepted 22 August 2018
1353-8292/ © 2018 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/BY-NC-ND/4.0/).

temperature and increasing mortality and morbidity has been found across several global locations (Michelozzi et al., 2009; Stafoggia et al., 2006; Sugg et al., 2016; Sung et al., 2013), demonstrating that heat illness and death can occur irrespective of absolute temperature and outside a designated extreme event.

While all sectors of the population are at risk of illness and death when exposed to increased heat, and especially extreme heat, particular sub-groups are more vulnerable than others. However, relationships between temperature and health impacts are neither uniform nor predictable, influenced by a number of complex and interacting factors including biological, environmental, medical, social and geographical factors (Klinenberg, 2002; Uejio et al., 2011; Yihan et al., 2013).

While the elderly appear more likely than other age groups to experience illness and death as a result of extreme heat events—as demonstrated in a number of locations around the world including Europe, Australia and China (Bai et al., 2014; Cerutti et al., 2006; Fouillet et al., 2006; Johnson et al., 2005; Schaffer et al., 2012)—a small number of studies show no direct relationship between heat-related deaths or illness and age (Bustinza et al., 2013; Dalip et al., 2015), suggesting social factors may be of influence at a local level. Heat-related mortality also appears to be associated with a range of pre-existing chronic health conditions, including cardiovascular, cerebrovascular, respiratory, endocrine, genitourinary, nervous system conditions and mental health disorders (Fouillet et al., 2006; Haines et al., 2006), and at different rates in different global locations (Astrom et al., 2015; Yin and Wang, 2017). Other identified sub-groups with increased vulnerability to heat-related illness include those working outdoors or in non-cooled environments (Hanna et al., 2011; Yin and Wang, 2017) and those using particular medications (Beggs, 2000). Furthermore, populations living in regions already experiencing hot weather may experience temperatures rated as non-survivable for humans in the future (Im et al., 2017; Pal and Eltahir, 2016), making their existing vulnerabilities more urgent to address.

Social determinants contribute substantially to an increased risk of heat-related mortality and morbidity. Those living in isolation, in low socio-economic situations, those who are homeless or living in unsafe communities, and those living in regions with low access to urban green space are also more vulnerable to the effects of heat (Bambrick et al., 2011; Klinenberg, 2002; Loughnan et al., 2013). The urban heat island (UHI) effect—where temperatures increase in urban areas as a result of man-made structures and activities—may also increase the risk of illness and death for vulnerable residents in major cities (Tomlinson et al., 2011). The UHI effect has been shown to be associated with an increasing impact of heatwaves on populations, in both Europe (Laaidi et al., 2012; Ward et al., 2016) and China (Tan et al., 2010), and appears to be more likely in cities with a growing population, rather than cities with a stable population (Yee Yong et al., 2017). This poses a major risk to rapidly urbanising regions, especially for populations in developing countries experiencing multiple vulnerabilities.

The nature of systematic reviews examining the impact of heatwaves on mortality and morbidity varies considerably. Some reviews examine the impact of heatwaves on mortality (for example, Xu et al. (2016) and Hajat and Kosatky (2010)) or on morbidity (for example Li et al. (2015)) exclusively. A number of reviews examine the breadth and depth of heatwave and health research across specific populations (for example, Astrom et al. (2011) and Benmarhnia et al. (2015)); for specific medical conditions (for example, Bhaskaran et al. (2009), Phung et al. (2016a, 2016b) and Turner et al. (2012)); and for specific climates (for example, Burkart et al. (2014)).

A small number of studies examining extreme heat and human health impact consider geographical factors in the methodology. For example, Bao et al. (2016) examine cities in China across differing latitudes; Medina-Ramon and Schwartz (2007) examine how mortality differs in response to temperature across multiple US cities with different climates; and Na et al. (2013) examine the relationship between heat-related illness and temperature across cities in Korea differing in regionality and latitude. However, there are no studies examining heatwave and health impact research at a global scale, and how research concentration and spread differs when examined through a vulnerability lens. This review seeks to address this gap.

The aim of this study is to describe heatwave and health impact research at a global scale, using information gathered from previously published studies on this topic. This study does not include research characterising the broad relationship between air temperature and population health outcomes.

The objectives of this study are: (1) to examine the distribution of heatwave and health impact research globally, (2) to examine changes in the regional origin of heatwave and health impact publications over time, (3) to examine these publications in relation to different health outcomes (the use of mortality and/or morbidity outcomes), and (4) to determine if this body of research is meeting the needs of the global population at risk of poor health outcomes due to extreme heat, as defined by socio-economic status, population density, acclimatisation capability and physical vulnerability to heatwaves.

2. Methods

Four online databases (PubMed, Scopus, Web of Science and CINAHL) were searched for heatwave and health impact peer-reviewed English language articles published to May 2017. No start date was used in order to capture all historical publications. The following search terms were used in examining keywords, titles and abstracts: ('extreme heat' OR 'heat wave*' OR 'heatwave*') AND ('mortality' OR 'morbidity' OR 'hospital*' OR 'ambulanc*' OR 'emergenc*' OR 'death').

Articles were included which examined human mortality and/or morbidity rates (including ambulance dispatches and/or hospital admissions) with respect to specific heatwave events, and where the main objective of the study was to determine if a change in these indicators had occurred during the period of the heatwave. Studies examining both cold waves and heatwaves were included. Both whole population level studies and partial population level studies (e.g. the elderly) were included. Furthermore, mortality and morbidity studies examining all-cause and cause-specific cases (e.g. cardiovascular disease) were included. Some studies examined the effectiveness of different methodologies, for example, Kalkstein (1991), and while assessing the impact of heatwaves on a population was not the intent of the study, the aim of the study necessitated this. These types of studies were included in this review.

As stated earlier, studies examining ambient temperature (i.e. the influence of temperature gradients on health) were not included. Studies which examined other impacts on health were extremely rare, and included the impact of extreme heat on pre-term birth (Kent et al., 2014) and years of life lost (Huang et al., 2012). These were not included in this review. Studies evaluating interventions aimed at reducing the public health impact of heatwaves were not included.

For each of these included articles, the location or locations of the study were determined by examining the title, abstract or full text, and then recorded in a spreadsheet. Where multiple locations were studied in one article, all study locations were recorded. For two articles (Bobb et al., 2014; Wang et al., 2016), study locations were not specified, and therefore not included or recorded. For one article (Ma et al., 2015) only a partial list of locations were supplied, and these locations were included.

If the studied locations were regions (for example, counties, states or provinces), the largest two cities in those regions were recorded. Where research involved whole countries, the largest three cities in those countries were recorded as representative of the country. This approach enabled populations to be highlighted as the focus of the research, rather than geographical regions which may be large or dispersed.

Data on global wealth was sourced from Shorrocks et al. (2016), and data on global population density was sourced from the Center for

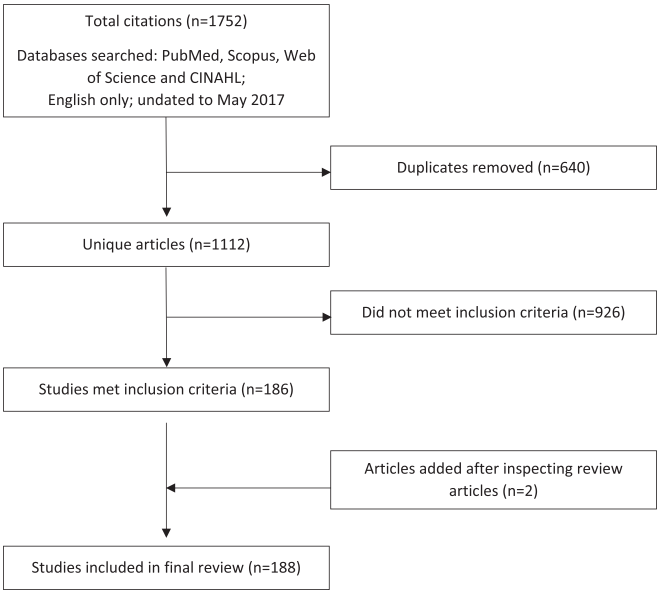

Fig. 1. Flow diagram showing search strategy and results.

International Earth Science Information Network (2016).

The articles included in the systematic review were examined in three ways. Firstly, the global distribution of study locations was mapped and tabled, including a publication date. Secondly, articles were scanned to assess which health outcome indicator was used. Finally, research locations were examined in relation to the needs of populations at risk of poor health outcomes from extreme heat events.

3. Results and discussion

3.1. Search criteria

Of 1752 papers initially retrieved, 188 were eligible for inclusion, after removal of duplicates and review of content against the inclusion criteria (see Fig. 1).

3.2. Global distribution of study locations

From the 188 articles included in the review, 854 locations were identified where the health impact of heatwaves had been researched. This reduced to 292 unique values. (For a full list of included articles and their study locations, see supplementary data.) These locations were then categorised into continents (see Table 1) and plotted on a world map (see Fig. 2).

A concentration of research effort was evident in the mid-latitude temperate zones of North America and southern Europe, followed by eastern China and southern Australia. Very few studies were found elsewhere, including tropical and high altitude zones. Almost no studies covered South and Central America, central and south-east Asia, eastern and far northern Europe, Africa and the Middle East.

Table 1
Study locations by continent.

Continent	No. of study sites	No. of unique locations
Africa	0	0
South America	1	1
Australia	34	5
Asia	91	53
Europe	144	64
North America	584	167
TOTAL	**854**	**292**

Studies varied widely in style and methodological approach, making broad comparisons between studies difficult and not included in the scope or objectives of this review. Despite heterogeneity between study locations and health outcome measured, studies found that heatwave events had a significant impact on ambulance and hospital load in varying geographical regions. For example, Turner et al. (2013) found a 18.8% increase in total ambulance calls during defined heatwave events in Brisbane, Australia, while Phung et al. (2017) found a 2.5% increase in all-cause admissions in Vietnam hospitals during heatwaves. Ghumman and Horney (2016) showed that residents of Karachi, Pakistan were 17 times more likely to die of a heat-related illness during a defined heatwave period when compared with a non-heatwave reference period, while Isaksen et al. (2016) found a 10% increase in the risk of death on a heatwave day versus a non-heatwave day, for all causes and ages in the Seattle region, USA. Some studies identified social risk factors impacted health outcomes during heatwave events. For example, Madrigano et al. (2015) demonstrated that heat-related deaths were more likely among poor black populations, especially those living in areas with relatively less green space. Vanhems et al. (2003) found those living in socially isolated conditions with limited access to health care and health information were most likely to be affected. Other studies highlighted the importance of this type of research in influencing government policy and procedures in the management of and response to heatwave events, for example, Wang et al. (2015) and Bustinza et al. (2013).

While it is evident that heatwave research is lacking in several regions across the world (for example, Africa and South America), this may be attributable in some part to the lack of research funding in these areas, a dearth of active researchers located within the study areas, and issues with data availability. For example, a lack of resources and infrastructure needed for adequate and robust data collection methods, enabling data of good quality to be available to researchers, may not be paramount in locations where general health infrastructure is poor. To address the paucity of research in areas of high heatwave and health impact risk, emphasis must be placed on developing access to reliable datasets.

While out of the scope of this paper, heatwave and health impact research may potentially constitute one case study of several highlighting research funding inequities between richer and poorer regions.

3.3. Publication date

The publication year of each article, along with the continent of study location, was recorded and charted. For this analysis only, studies from 2017 were eliminated to allow for complete years of analysis, leaving 177 publications (see Fig. 3).

The number of published studies per year demonstrates an overall increase from around 2002. Although relatively consistent from 2002 to 2011, there was a marked increase from 2012. The total number of studies published in the five years between 2012 and 2016 was 84, compared to 93 studies published in the previous 48 years combined.

Examining research publications by both date and region of origin uncovers two noteworthy points. Firstly, the marked increase in publications in 2005–2006 (when compared to previous years) was accounted for by studies examining the severe European heatwave in 2003. Similarly, the severe heatwave in south-east Australia in 2009 preceded a number of Australian studies published in 2010, accounting for a publication spike in this year. While small in number, these two examples may suggest that specific severe heatwave events increase the number of published studies in subsequent years. Examination of this trend in the future would be worthwhile, especially as the frequency and severity of heatwave events worldwide continues to rise (Intergovernmental Panel on Climate Change, 2013).

Secondly, prior to 2002 studies concentrating on locations in North America (primarily the United States) were almost three times more common than those covering locations in Europe, and over ten times

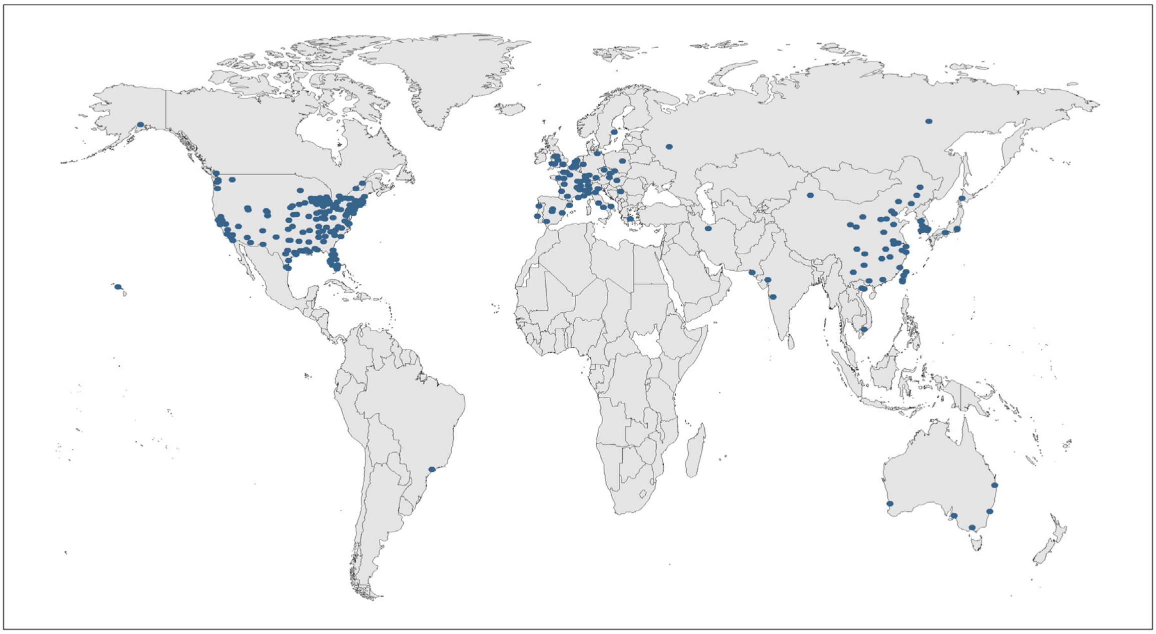

Fig. 2. Locations of heatwave and health impact research, 1964–2017.

more common than those covering locations in Asia. In the period 2002–2011, the balance shifted to a greater proportion of studies located in Europe, now three times more likely than studies located in North America. Australian studies were first represented in this period also. Studies in Asia (primarily in China) became prominent after 2010, and by 2016 represented almost 40% of the worldwide studies for that year. The rapidly changing nature of heatwave and health impact research region of origin indicates that investigator capacity is growing and changing in response to a growing identified risk in more vulnerable regions. Taken together with the rise in research output after a specific heatwave event, these trends may suggest that researchers are strongly responsive to the demands and interests of policy-makers and society in this particular field.

3.4. Evaluated health outcomes

Included articles represented both mortality and morbidity studies (hospital admissions and ambulance/emergency medical services (EMS) call outs), including those with a mix of these outcomes. Of the 188 articles, mortality studies were most highly represented at 61% (n = 114), followed by hospital admission studies at 21% (n = 40), mixed studies at 13% (n = 24), and ambulance/EMS call out studies at 5% (n = 10) (see Fig. 4).

Mortality was assessed as the main outcome measure more than all other types combined. This may potentially be a practicality of the studies in question, as mortality data are usually available for large-scale population level studies. However, as an early sign of heatwave impact on a population, mortality is a blunt measure of population-

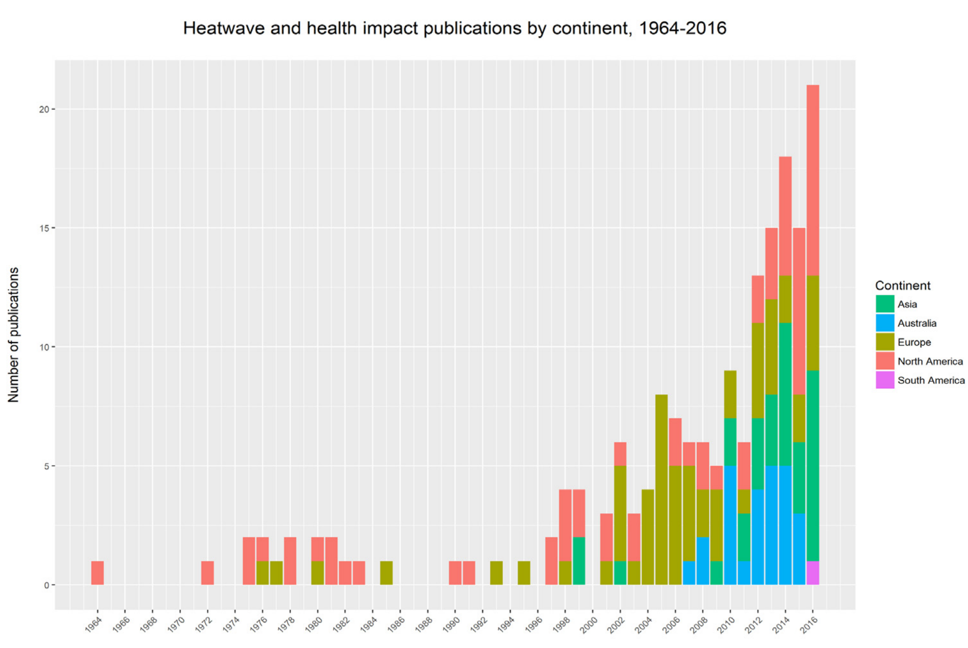

Fig. 3. Number of published heatwave and health impact research articles per year, by continent (1964–2016).

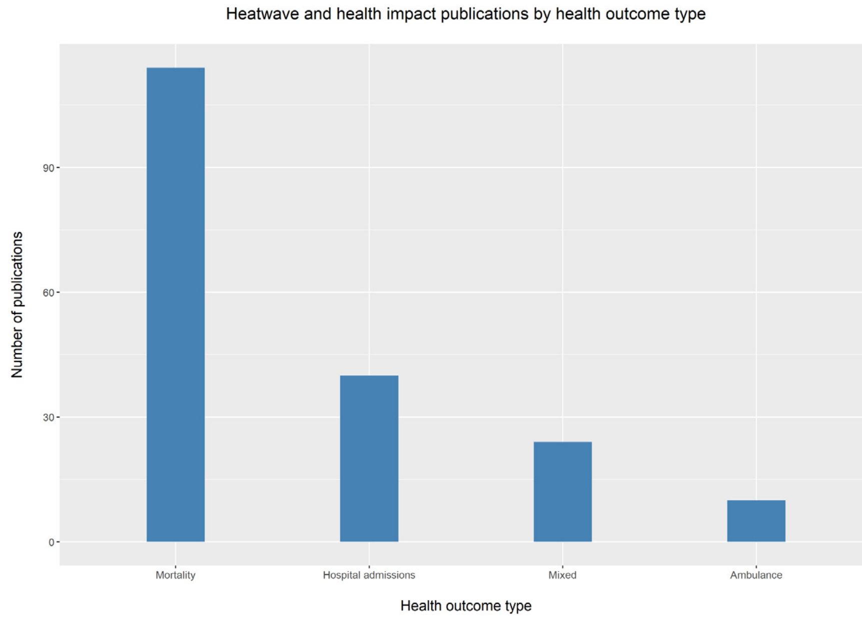

Fig. 4. Heatwave and health impact publications by health outcome type.

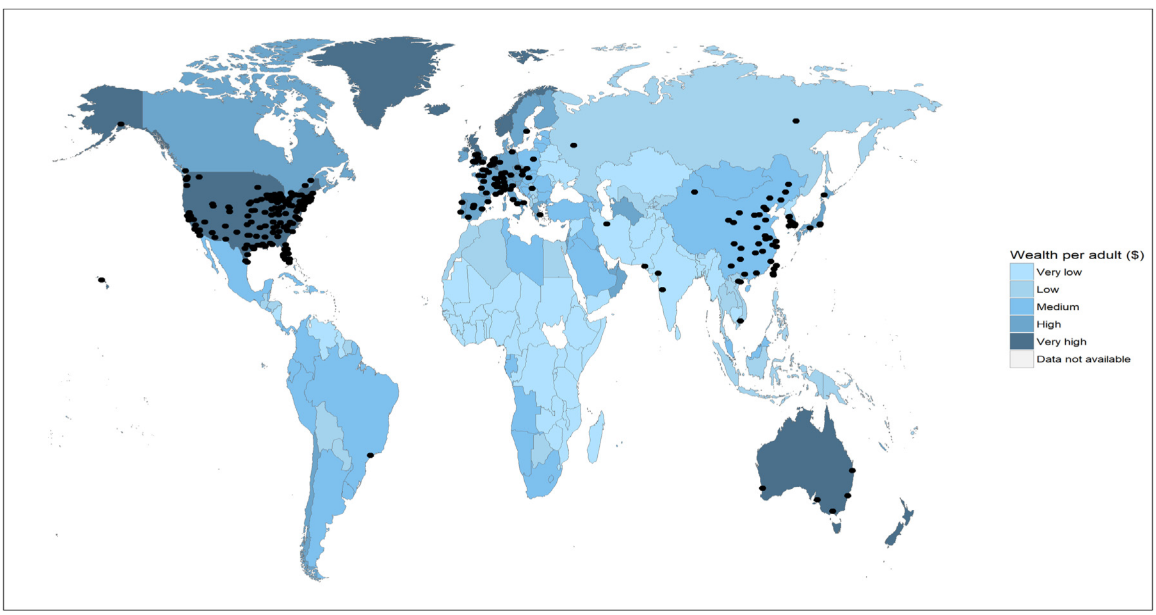

Fig. 5. Global average wealth per adult 2016, adapted from Shorrocks et al. (2016), with locations of heatwaves and health impact research.

wide heat impact (Chan et al., 2001), with morbidity a more subtle measure (Bi et al., 2011). A focus on mortality rather than morbidity as an indicator of heatwave impact tends to overshadow impacts that are less extreme than death, yet also significant to the narrative that explains extreme heat and health-related impact on a population. For example, research on how extreme heat impacts productivity or output for outdoor workers remains relatively unexplored, but has the potential to impact the economy (Hanna et al., 2011). These more nuanced but important measures of extreme heat impact remain a critical part of research, discussion and public policy concerning heatwaves.

The global distribution of research by health outcome type was generally consistent with the overall distribution, with no one region displaying a predominance of any particular health outcome study type.

3.5. *Vulnerable populations*

The distribution of heatwave and health impact research leads to a comparison with other types of global distribution mapping approaches, such as wealth distribution and population density. Comparisons can also be made across the spread of latitudes represented by heatwaves and health impact research.

By examining global wealth distribution alongside global heatwave and health impact research distribution, an understanding of how social constructs may influence research delivery is gained. Low-income regions, or regions experiencing high poverty, are less likely to have comprehensive data collection systems, inhibiting detection and evaluation of extreme events, and less capacity to adapt and respond to these threats when they do occur (Olsson et al., 2014). Poorer countries are less likely to have active researchers located within the country, and have less access to research funds. Furthermore, extreme climatic events, including heatwaves, tend to exacerbate existing poverty due to impacts on water resources, agriculture and livelihood (Olsson et al., 2014).

While still impacted by heatwaves as a result of geography and meteorological conditions, high-income countries tend to have access to resources and strategies to reduce this impact. These may include (but not be limited to) the implementation of alert and warning systems (Lowe et al., 2011), access to community-wide prevention strategies, for example, the provision of public cool spaces (Eisenman et al., 2016), and adequate medical care for those experiencing heat-related illness.

In mapping wealth distribution alongside the location of heatwave and health impact research across the globe, it can be seen that this research tends to be concentrated in high- to very high-income countries. With the exception of China, relatively few or no studies examine the impact of heatwaves in middle- to low-income regions (see Fig. 5). This effect is consistent with expected social influences on research, and is not isolated to extreme heat research. A similar distribution is noted by Schmitt et al. (2016) in a review of the economic evaluations of health impacts in other weather-related extreme events.

China's research response to extreme heat events is notable as the only low- to middle-income country with a major research effort on heatwaves. Given the high number of people affected, overall climate change impacts in China are recognised as the greatest in absolute population terms, with significant social and health impacts as a result of melting glaciers, rising sea levels and an increase in natural disasters (Lai, 2009). China's top-down approach to policy-making in the climate change sector (known as 'authoritarian environmentalism') has resulted in public mandates associated with energy efficiency and transport, with research to develop and direct these policy mandates considered key to the process (Gilley, 2012).

Mapping population density alongside global heatwave and health impact research distribution allows further insight into how social influences shape research outcomes. While there is some concentration of heatwave and health impact research in areas of medium to high population density (for example, United States, southern Europe and eastern China), there is a paucity of research covering other highly population-dense regions. These include Central America, central Africa, eastern Europe, the Middle East, India, Bangladesh, Pakistan and south-east Asia, especially Indonesia (see Fig. 6).

Heatwaves have been shown to have an increased mortality effect on communities with higher relative population densities (Medina-Ramon and Schwartz, 2007). Furthermore, the population density of urban areas is closely linked to the UHI effect (Elsayed, 2012), where increased urban infrastructure and development create significantly warmer ground temperatures than experienced in less developed areas.

While strength of association between global wealth, population density and research distribution is out of scope for this study, this area is worthy of further research to extend these initial findings.

Heatwave and health impact research was concentrated in regions in the mid-latitudes (approximately between 25° and 55° either side of the equator), with a lack of research apparent in the tropics (within 25° either side of the equator) and at higher latitudes (over 55° either side of the equator) (see Fig. 7). The bulk of high-income countries are situated in the mid-latitudes, with locations in the European and North American continents representing approximately 80% of all heatwave and health-related research (see Table 1).

Tropical climates are notably under-represented in heatwave and health impact research. The small number of studies located in tropical regions evaluated in this review found links between heatwaves and all-cause hospitalisation in Vietnam (10°-23°N) (Phung et al., 2017), heatwaves and all-cause mortality in Ahmedabad, India (23°N) (Azhar et al., 2014) and Guangzhou, China (23°N) (Yang et al., 2013) and heatwaves and mortality from non-infectious diseases in Vadu, India (18°N) (Ingole et al., 2015). The few studies that covered tropical regions, while examining specific causes, specific populations or high ambient temperatures, found elevated rates of cardiovascular hospital admissions during high temperatures in Vietnam (10°-23°N) (Phung et al., 2016a); elevated mortality for stroke and cardiovascular disease during high temperatures in Puerto Rico (18°N) (Mendez-Lazaro et al., 2016); and higher mortality rates during the hottest season in Burkina Faso (10°-15°N) (Kynast-Wolf et al., 2010). The combined results of these studies tend to suggest that tropical regions are prone to extreme heat health-related impacts, but better characterising of the risks is needed.

While regions at higher latitudes tend to have relatively cooler maximum summer temperatures and experience heatwaves less often when compared to regions in mid and lower latitudes, a number of studies indicate that populations at higher latitudes still experience significant heat-related health risks. Multi-city or nationwide studies demonstrated this effect in the United States (Curriero et al., 2002),

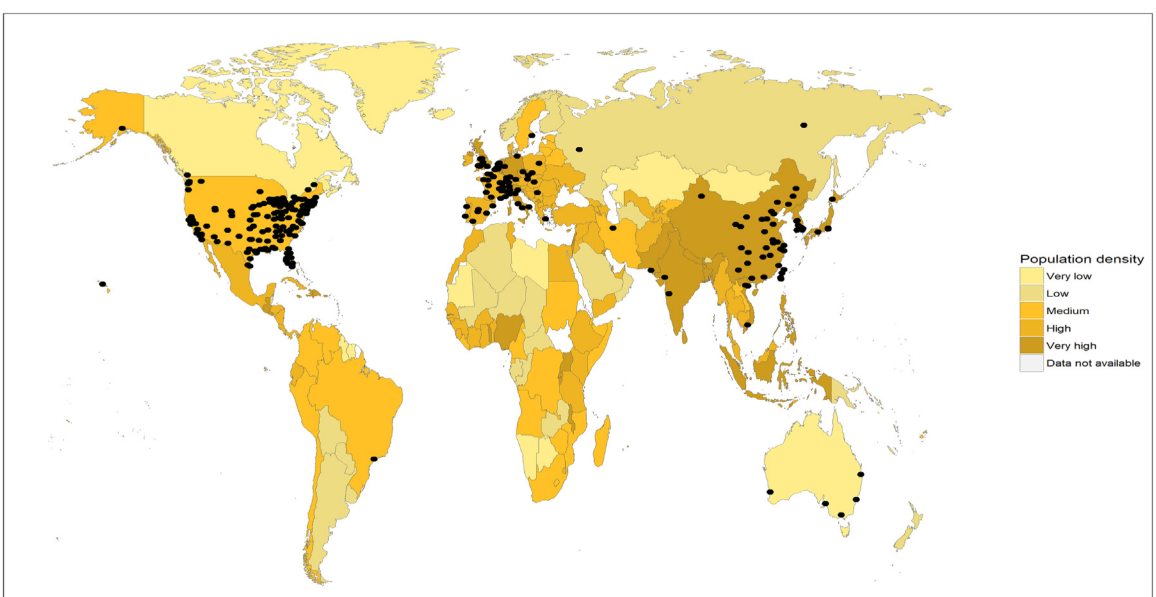

Fig. 6. Global population density 2016, adapted from the Center for International Earth Science Information Network (2016), with locations of heatwaves and health impact research.

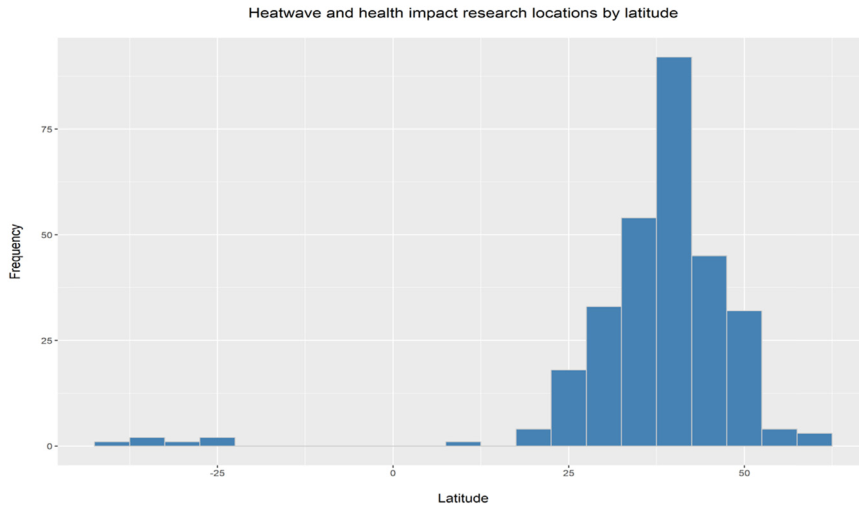

Fig. 7. Heatwave and health impact research locations by latitude.

South Korea (Na et al., 2013), Vietnam (Phung et al., 2017) and Europe (Ward et al., 2016), while studies in the United States demonstrate larger heatwave impacts in cities with milder summers (Medina-Ramon and Schwartz, 2007). A similar pattern was noted in a multi-city study from Europe, the United States and Australia, where cities with lower mean summer temperatures had a significantly lower threshold at which heat-related mortality began to occur (Gosling et al., 2007).

This may plausibly be explained through a lack of acclimatisation to hotter weather from individuals residing in cooler regions, and therefore a heightened impact to extreme heat events when they do occur. Exceedance of an absolute temperature for a specified time (for example, a daily mean exceeding 28 °C for three or more days) does not necessarily define an extreme heat event, as the population at that location will be adapted to the 'normal' temperatures for that region. This acclimatisation phenomenon is taken into account by Nairn and Fawcett (2015) when calculating the Australian Bureau of Meteorology's National Heatwave Service using the Excess Heat Factor (EHF) methodology. EHF has been shown to be a better measure of health service utilisation and demand following an extreme heat event than other definitions of heatwaves that do not account for acclimatisation (Scalley et al., 2015).

3.6. Risks associated with projected future impact

Climate change projections of heatwave frequency and severity show that specific regions around the world are at greater future risk than others. Research by Mora et al. (2017) shows that when compared to other regions, Central and South America, Africa, India, south-east Asia and northern Australia are more likely to experience a greater number of days per year when weather conditions are above a survivable human threshold. These conditions remain valid using any of three future greenhouse gas concentration scenarios or Representative Concentration Pathways (further described by Intergovernmental Panel on Climate Change (2013: 29)). Similarly, Im et al. (2017) demonstrate high risk to populations from exceedances in survivable wet bulb temperatures (temperature readings which take humidity into account) in the Middle East, Pakistan, India, Bangladesh, eastern China and northern Australia, while Pal and Eltahir (2016) show regions in the Middle East are likely to exceed critical survivable threshold temperatures in the future.

The majority of these regions are significantly under-represented in current heatwave and health impact research, while regions most heavily researched were not identified in the regions most at risk in future scenarios. The one exception to this observation is eastern China.

3.7. Study strengths and limitations

Strengths of this study include the wide range of health outcomes examined over a relatively long time period. Cross-checking studies identified for inclusion with similar review studies ensured as many studies as possible were captured in the process.

Limitations included restriction to articles in English, which may partly explain fewer studies in non-English speaking regions such as South America, South-East Asia and Africa. However, a similar examination of heatwave and health-related research by Mora et al. (2017) yielded comparable results, while also including studies in Spanish, French, Japanese and Chinese.

This study was restricted to mortality and morbidity data, using health outcomes from three sources (death data, hospital data and ambulance data). While acknowledging that health impact from heat exposure is a continuum from mild to severe and therefore may not always be captured in these datasets, this study sought to aggregate a sufficient number of publications to enable comment on global research distribution. The health outcomes chosen were considered most likely to enable this depth of investigation.

This review would benefit from ongoing updates as further heatwave and health impact research is developed, particularly in regions more vulnerable to the impact of heat-related illness. Further research examining more novel heat-related health outcomes (for example, GP presentations, workplace illness and injury) would enhance the understanding of this issue.

4. Conclusion

In this review of studies of health impacts of heatwaves, a mismatch was identified between research effort (as measured by the number and location of studies) and need (as suggested by several indicators of population level vulnerability).

The global distribution of research into heatwaves and their impact on human health is not uniform, and tends to cluster in regions with high levels of resources and income. Furthermore, as a risk associated with heatwave mortality and morbidity, global population density does not match the location of current heatwave and human health studies.

Our analysis shows significant gaps in tropical and high-latitude regions, with additional gaps across South America, Africa, Eastern Europe and the Middle East. Countries in parts of Asia are also under-represented. These regions contain significant heat-vulnerable populations, and inhabitants at high risk from other climate-related impacts. The regions most covered by heatwave and health impact research are not necessarily matched by those regions most at risk in future climate scenarios.

Furthermore, this type of research appears skewed towards mortality rather than morbidity outcomes, which may give a better picture of heatwave impact in a population.

As the likelihood of extreme heat events increases into the future, heatwave and health impact research is urgently needed across regions where the impact of these events will be felt more acutely.

Acknowledgements

Dr Grant Williamson, School of Biological Sciences, University of Tasmania for additional assistance with mapping.

Funding source

This work was supported by the Menzies Institute for Medical Research (University of Tasmania) and the Antarctic Climate and Ecosystems Cooperative Research Centre. The funding source had no involvement in the study's design, data collection, interpretation of data and writing of the article.

Competing financial interests

None declared.

Conflicts of interest

None declared.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.healthplace.2018.08.017.

References

Anderson, B., Bell, M., 2011. Heat waves in the United States: mortality risk during heat waves and effect modification by heat wave characteristics in 43 U.S. Communities. Environ. Health Perspect. 119 (2), 210–218.

Astrom, D.O., Forsberg, B., Rocklov, J., 2011. Heat wave impact on morbidity and mortality in the elderly population: a review of recent studies. Maturitas 69 (2), 99–105.

Astrom, D.O., Schifano, P., Asta, F., Lallo, A., Michelozzi, P., Rocklov, J., Forsberg, B., 2015. The effect of heat waves on mortality in susceptible groups: a cohort study of a mediterranean and a northern European City. Environ. Health 14.

Azhar, G.S., Mavalankar, D., Nori-Sarma, A., Rajiva, A., Dutta, P., Jaiswal, A., Sheffield, P., Knowlton, K., Hess, J.J., 2014. Heat-related mortality in India: excess all-cause mortality associated with the 2010 Ahmedabad heat wave. PLoS One 9 (3), e91831.

Bai, L., Ding, G., Gu, S., Bi, P., Su, B., Qin, D., Xu, G., Liu, Q., 2014. The effects of summer temperature and heat waves on heat-related illness in a coastal city of China, 2011–2013. Environ. Res 132, 212–219.

Bambrick, H.J., Capon, A.G., Barnett, G.B., Beaty, R.M., Burton, A.J., 2011. Climate change and health in the urban environment: adaptation opportunities in Australian Cities. Asia-Pac. J. Public Health 23 (2 suppl), 67S–79S.

Bao, J., Wang, Z., Yu, C., Li, X., 2016. 'The influence of temperature on mortality and its Lag effect: a study in four Chinese cities with different latitudes'. BMC Public Health 16 (1).

Beggs, P., 2000. Impacts of climate and climate change on medications and human health. Aust. N. Z. J. Public Health 24, 630–632.

Benmarhnia, T., Deguen, S., Kaufman, J.S., Smargiassi, A., 2015. Vulnerability to heat-related mortality: a systematic review, meta-analysis, and meta-regression analysis. Epidemiology 26 (6), 781–793.

Bhaskaran, K., Hajat, S., Haines, A., Herrett, E., Wilkinson, P., Smeeth, L., 2009. Effects of ambient temperature on the incidence of myocardial infarction. Heart 95 (21), 1760–1769.

Bi, P., Williams, S., Loughnan, M., Lloyd, G., Hansen, A., Kjellstrom, T., Dear, K., Saniotis, A., 2011. The effects of extreme heat on human mortality and morbidity in Australia: implications for public health. Asia Pac. J. Public Health 23 (2 SUPPL).

Bobb, J.F., Obermeyer, Z., Wang, Y., Dominici, F., 2014. Cause-specific risk of hospital admission related to extreme heat in older adults. J. Am. Med. Assoc. 312 (24), 2659–2667.

Burkart, K., Khan, M.M.H., Schneider, A., Breitner, S., Langner, M., Krämer, A., Endlicher, W., 2014. The effects of season and meteorology on human mortality in tropical climates: a systematic review. Trans. R. Soc. Trop. Med. Hyg. 108 (7), 393–401.

Bustinza, R., Lebel, G., Gosselin, P., Belanger, D., Chebana, F., 2013. Health impacts of the July 2010 heat wave in Quebec, Canada. BMC Public Health 13 (1), 56.

Center for International Earth Science Information Network, 2016. Gridded Population of the World, Version 4 (GPWv4): Population Density, NASA Socioeconomic Data and Applications Center (SEDAC), Palisades, NY, 20170803, 〈http://dx.doi.org/10.7927/H4NP22DQ〉.

Cerutti, B., Tereanu, C., Domenighetti, G., Cantoni, E., Gaia, M., Bolgiani, I., Lazzaro, M., Cassis, I., 2006. Temperature related mortality and ambulance service interventions during the heat waves of 2003 in Ticino (Switzerland). Int. J. Public Health 51 (4), 185–193.

Chan, N.Y., Stacey, M.T., Smith, A.E., Ebi, K.L., Wilson, T.F., 2001. An empirical mechanistic framework for heat-related illness. Clim. Res. 16 (2), 133–143.

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., Friel, S., Groce, N., Johnson, A., Kett, M., Lee, M., Levy, C., Maslin, M., McCoy, D., McGuire, B., Montgomery, H., Napier, D., Pagel, C., Patel, J., de Oliveira, J.A.P., Redclift, N., Rees, H., Rogger, D., Scott, J., Stephenson, J., Twigg, J., Wolff, J., Patterson, C., 2009. Managing the health effects of climate change. Lancet 373 (9676), 1693–1733.

Curriero, F.C., Heiner, K.S., Samet, J.M., Zeger, S.L., Strug, L., Patz, J.A., 2002. Temperature and mortality in 11 cities of the eastern United States. Am. J. Epidemiol. 155 (1), 80–87.

Dalip, J., Phillips, G.A., Jelinek, G.A., Weiland, T.J., 2015. Can the elderly handle the heat? A retrospective case-control study of the impact of heat waves on older patients attending an inner city Australian emergency department. Asia Pac. J. Public Health 27 (2), NP1837–NP1846.

Eisenman, D.P., Wilhalme, H., Tseng, C.H., Chester, M., English, P., Pincetl, S., Fraser, A., Vangala, S., Dhaliwal, S.K., 2016. Heat Death Associations with the built environment, social vulnerability and their interactions with rising temperature. Health Place 41, 89–99.

Elsayed, I.S.M., 2012. Effects of Population Density and Land Management on the Intensity of Urban Heat Islands: A Case Study on the City of Kuala Lumpur, Malaysia. In: Alam, B.M. (Ed.), Application of Geographic Information Systems. InTech, Rijeka. https://doi.org/10.5772/47943.

Fouillet, A., Rey, G., Laurent, F., Pavillon, G., Bellec, S., Guihenneuc-Jouyaux, C., Clavel, J., Jougla, E., Hémon, D., 2006. Excess mortality related to the August 2003 heat wave in France. Int. Arch. Occup. Environ. Health 80 (1), 16–24.

Ghumman, U., Horney, J., 2016. Characterizing the impact of extreme heat on Mortality, Karachi, Pakistan, June 2015. Prehosp. Disaster Med. 31 (3), 263–266.

Gilley, B., 2012. Authoritarian environmentalism and China's response to climate change. Environ. Polit. 21 (2), 287–307.

Gosling, S.N., McGregor, G.R., Paldy, A., 2007. Climate change and heat-related mortality in six cities part 1: model construction and validation. Int J. Biometeorol. 51 (6), 525–540.

Haines, A., Kovats, R.S., Campbell-Lendrum, D., Corvalan, C., 2006. Climate change and human health: impacts, vulnerability, and mitigation. Lancet 367 (9528), 2101–2109.

Hajat, S., Kosatky, T., 2010. Heat-related mortality: a review and exploration of heterogeneity. J. Epidemiol. Community Health 64 (9), 753–760.

Hanna, E.G., Kjellstrom, T., Bennett, C., Dear, K., 2011. Climate change and rising heat: population health implications for working people in Australia. Asia Pac. J. Public Health 23 (2), 14S–26S.

Huang, C., Barnett, A.G., Wang, X., Tong, S., 2012. Effects of extreme temperatures on years of life lost for cardiovascular deaths: a time series study in Brisbane, Australia. Circ. Cardiovasc. Qual. Outcomes 5 (5), 609–614.

Im, E.-S., Pal, J.S., Eltahir, E.A.B., 2017. Deadly heat waves projected in the densely populated agricultural regions of South Asia. Sci. Adv. 3 (8).

Ingole, V., Rocklov, J., Juvekar, S., Schumann, B., 2015. Impact of heat and cold on total and cause-specific mortality in Vadu HDSS-a rural setting in Western India. Int. J. Environ. Res. Public Health 12 (12), 15298–15308.

Intergovernmental Panel on Climate Change, 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge, United Kingdom.

Isaksen, T.B., Fenske, R.A., Hom, E.K., Ren, Y., Lyons, H., Yost, M.G., 2016. Increased mortality associated with extreme-heat exposure in King County, Washington, 1980–2010. Int. J. Biometeorol. 60 (1), 85–98.

Johnson, H., Kovats, R.S., McGregor, G., Stedman, J., Gibbs, M., Walton, H., Cook, L., Black, E., 2005. The impact of the 2003 heatwave on mortality and hospital admissions in England. Health Stat. Q. 25, 6–11.

Kalkstein, L.S., 1991. A new approach to evaluate the impact of climate on human mortality. Environ. Health Perspect. 96, 145–150.

Kent, S.T., McClure, L.A., Zaitchik, B.F., Smith, T.T., Gohlke, J.M., 2014. Heat Waves and Health Outcomes in Alabama (USA): the importance of heat wave definition. Environ. Health Perspect. 122 (2), 151–158.

Klinenberg, E., 2002. Heat Wave: Social Autopsy of Disaster in Chicago. University of Chicago Press, Chicago.

Kosatsky, T., 2005. The 2003 European heat waves. Eurosurveillance 10 (7–9), 148.

Kynast-Wolf, G., Preuss, M., Sie, A., Kouyate, B., Becher, H., 2010. Seasonal patterns of cardiovascular disease mortality of adults in Burkina Faso, West Africa. Trop. Med. Int. Health 15 (9), 1082–1089.

Laaidi, K., Zeghnoun, A., Dousset, B., Bretin, P., Vandentorren, S., Giraudet, E., Beaudeau, P., 2012. The impact of heat islands on mortality in Paris during the august 2003 heat wave. Environ. Health Perspect. 120 (2), 254–259.

Lai, E.C.-Y., 2009. Climate Change Impacts on China's Environment: Biophysical Impacts. Woodrow Wilson Center, Washington, DC.

Li, M., Gu, S., Bi, P., Yang, J., Liu, Q., 2015. Heat waves and morbidity: current knowledge and further direction-a comprehensive literature review. Int. J. Environ. Res. Public Health 12 (5), 5256–5283.

Loughnan, M., Nicholls, N., Tapper, N., 2010. Mortality-temperature thresholds for ten

major population centres in rural Victoria, Australia. Health Place 16 (6), 1287–1290.
Loughnan, M., Tapper, N., Phan, T., Lynch, K., McInnes, J., 2013. A Spatial Vulnerability Analysis of Urban Populations During Extreme Heat Events in Australian Capital Cities. National Climate Change Adaptation Research Facility, Gold Coast.
Lowe, D., Ebi, K.L., Forsberg, B., 2011. Heatwave early warning systems and adaptation advice to reduce human health consequences of heatwaves. Int. J. Environ. Res. Public Health 8 (12), 4623–4648.
Ma, W., Zeng, W., Zhou, M., Wang, L., Rutherford, S., Lin, H., Liu, T., Zhang, Y., Xiao, J., Zhang, Y., Wang, X., Gu, X., Chu, C., 2015. The short-term effect of heat waves on mortality and its modifiers in China: an analysis from 66 communities. Environ. Int. 75, 103–109.
Madrigano, J., Ito, K., Johnson, S., Kinney, P.L., Matte, T., 2015. A case-only study of vulnerability to heat wave-related mortality in New York City (2000–2011). Environ. Health Perspect. 123 (7), 672–678.
Martiello, M.A., Giacchi, M.V., 2010. High temperatures and health outcomes: a review of the literature. Scand. J. Public Health 38 (8), 826–837.
Medina-Ramon, M., Schwartz, J., 2007. Temperature, temperature extremes, and mortality: a study of acclimatisation and effect modification in 50 US cities. Occup. Environ. Med. 64 (12), 827–833.
Mendez-Lazaro, P.A., Perez-Cardona, C.M., Rodriguez, E., Martinez, O., Taboas, M., Bocanegra, A., Mendez-Tejeda, R., 2016. Climate change, heat, and mortality in the tropical urban area of San Juan, Puerto Rico, Int. J. Biometeorol.
Michelozzi, P., Accetta, G., De Sario, M., D'Ippoliti, D., Marino, C., Baccini, M., Biggeri, A., Anderson, H.R., Katsouyanni, K., Ballester, F., Bisanti, L., Cadum, E., Forsberg, B., Forastiere, F., Goodman, P.G., Hojs, A., Kirchmayer, U., Medina, S., Paldy, A., Schindler, C., Sunyer, J., Perucci, C.A., 2009. High temperature and hospitalizations for cardiovascular and respiratory causes in 12 European cities. Am. J. Respir. Crit. Care Med 179 (5), 383–389.
Mora, C., Dousset, B., Caldwell, I.R., Powell, F.E., Geronimo, R.C., Bielecki, C.R., Counsell, C.W.W., Dietrich, B.S., Johnston, E.T., Louis, L.V., Lucas, M.P., McKenzie, M.M., Shea, A.G., Tseng, H., Giambelluca, T.W., Leon, L.R., Hawkins, E., Trauernicht, C., 2017. Global risk of deadly heat. Nat. Clim. Change 7 (7), 501–506.
Na, W., Jang, J.Y., Lee, K.E., Kim, H., Jun, B., Kwon, J.W., Jo, S.N., 2013. The effects of temperature on heat-related illness according to the characteristics of patients during the summer of 2012 in the Republic of Korea. J. Prev. Med Public Health 46 (1), 19–27.
Nairn, J.R., Fawcett, R.J.B., 2015. The excess heat factor: a metric for heatwave intensity and its use in classifying heatwave severity. Int. J. Environ. Res. Public Health 12 (1), 227–253.
Nitschke, M., Tucker, G.R., Hansen, A.L., Williams, S., Zhang, Y., Bi, P., 2011. Impact of two recent extreme heat episodes on morbidity and mortality in Adelaide, South Australia: a case-series analysis. Environ. Health 10 (42).
Olsson, L., Opondo, M., Tschakert, P., Agrawal, A., Eriksen, S.H., Ma, S., Perch, L.N., Zakieldeen, S.A., 2014. Livelihoods and Poverty. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Pal, J.S., Eltahir, E.A.B., 2016. Future temperature in southwest Asia projected to exceed a threshold for human adaptability. Nat. Clim. Change 6 (2), 197–200.
Perkins, S.E., Alexander, L.V., Nairn, J.R., 2012. Increasing frequency, intensity and duration of observed global heatwaves and warm spells. Geophys. Res. Lett. 39 (20), L20714.
Phung, D., Chu, C., Rutherford, S., Nguyen, H.L., Do, C.M., Huang, C., 2017. Heatwave and risk of hospitalization: a multi-province study in Vietnam. Environ. Pollut. 220 (Pt A), 597–607.
Phung, D., Guo, Y., Thai, P., Rutherford, S., Wang, X., Nguyen, M., Do, C.M., Nguyen, N.H., Alam, N., Chu, C., 2016a. The effects of high temperature on cardiovascular admissions in the most populous tropical city in Vietnam. Environ. Pollut. 208 (Pt A), 33–39.
Phung, D., Thai, P.K., Guo, Y., Morawska, L., Rutherford, S., Chu, C., 2016b. Ambient temperature and risk of cardiovascular hospitalization: an updated systematic review and meta-analysis. Sci. Total Environ. 550, 1084–1102.
Scalley, B.D., Spicer, T., Jian, L., Xiao, J.G., Nairn, J., Robertson, A., Weeramanthri, T., 2015. Responding to heatwave intensity: Excess Heat Factor is a superior predictor of health service utilisation and a trigger for heatwave plans. Aust. N. Z. J. Public Health 39 (6), 582–587.
Schaffer, A., Muscatello, D., Broome, R., Corbett, S., Smith, W., 2012. Emergency department visits, ambulance calls, and mortality associated with an exceptional heat wave in Sydney, Australia, 2011: a time-series analysis. Environ. Health 11 (3).
Schmitt, L.H., Graham, H.M., White, P.C., 2016. Economic evaluations of the health impacts of weather-related extreme events: a scoping review. Int. J. Environ. Res. Public Health 13 (11).
Shorrocks, A., Davies, J., Lluberas, R., Koutsoukis, A., 2016. Global Wealth Report 2016, Credit Suisse Research Institute Zurich, Switzerland.
Stafoggia, M., Forastiere, F., Agostini, D., Biggeri, A., Bisanti, L., Cadum, E., Caranci, N., De'Donato, F., De Lisio, S., De Maria, M., Michelozzi, P., Miglio, R., Pandolfi, P., Picciotto, S., Rognoni, M., Russo, A., Scarnato, C., Perucci, C.A., 2006. Vulnerability to heat-related mortality: a multicity, population-based, case-crossover analysis. Epidemiology 17 (3), 315–323.
Sugg, M.M., Konrad 2nd, C.E., Fuhrmann, C.M., 2016. Relationships between maximum temperature and heat-related illness across North Carolina, USA. Int. J. Biometeorol. 60 (5), 663–675.
Sung, T.I., Wu, P.C., Lung, S.C., Lin, C.Y., Chen, M.J., Su, H.J., 2013. Relationship between heat index and mortality of 6 major cities in Taiwan. Sci. Total Environ. 442, 275–281.
Tan, J., Zheng, Y., Tang, X., Guo, C., Li, L., Song, G., Zhen, X., Yuan, D., Kalkstein, A.J., Li, F., 2010. The urban heat island and its impact on heat waves and human health in Shanghai. Int. J. Biometeorol. 54 (1), 75–84.
Tomlinson, C., Chapman, L., Thornes, J., Baker, C., 2011. Including the urban heat island in spatial heat health risk assessment strategies: a case study for Birmingham, UK. Int. J. Health Geogr. 10 (1), 42.
Turner, L.R., Barnett, A.G., Connell, D., Tong, S., 2012. Ambient temperature and cardiorespiratory morbidity: a systematic review and meta-analysis. Epidemiology 23 (4), 594–606.
Turner, L.R., Connell, D., Tong, S., 2013. The effect of heat waves on ambulance attendances in Brisbane, Australia. Prehosp. Disaster Med. 28 (5), 482–487.
Uejio, C.K., Wilhelmi, O.V., Golden, J.S., Mills, D.M., Gulino, S.P., Samenow, J.P., 2011. Intra-urban societal vulnerability to extreme heat: the role of heat exposure and the built environment, socioeconomics, and neighborhood stability. Health Place 17 (2), 498–507.
Vanhems, P., Gambotti, L., Fabry, J., 2003. Excess rate of in-hospital death in Lyons, France, during the August 2003 heat wave. N. Engl. J. Med. 349 (21), 2077–2078.
Wang, X.Y., Guo, Y., FitzGerald, G., Aitken, P., Tippett, V., Chen, D., Wang, X., Tong, S., 2015. The impacts of heatwaves on mortality differ with different study periods: a multi-city time series investigation. PLoS One 10 (7), e0134233.
Wang, Y., Bobb, J.F., Papi, B., Wang, Y., Kosheleva, A., Di, Q., Schwartz, J.D., Dominici, F., 2016. Heat stroke admissions during heat waves in 1,916 US counties for the period from 1999 to 2010 and their effect modifiers. Environ. Health 15.
Ward, K., Lauf, S., Kleinschmit, B., Endlicher, W., 2016. Heat waves and urban heat islands in Europe: a review of relevant drivers. Sci. Total Environ. 569–570, 527–539.
Watts, N., Adger, W.N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., Chaytor, S., Colbourn, T., Collins, M., Cooper, A., Cox, P.M., Depledge, J., Drummond, P., Ekins, P., Galaz, V., Grace, D., Graham, H., Grubb, M., Haines, A., Hamilton, I., Hunter, A., Jiang, X., Li, M., Kelman, I., Liang, L., Lott, M., Lowe, R., Luo, Y., Mace, G., Maslin, M., Nilsson, M., Oreszczyn, T., Pye, S., Quinn, T., Svensdotter, M., Venevsky, S., Warner, K., Xu, B., Yang, J., Yin, Y., Yu, C., Zhang, Q., Gong, P., Montgomery, H., Costello, A., 2015. Health and climate change: policy responses to protect public health. Lancet 386 (10006), 1861–1914.
Whitman, S., Good, G., Donoghue, E.R., Benbow, N., Shou, W., Mou, S., 1997. Mortality in Chicago attributed to the July 1995 heat wave. Am. J. Public Health 87 (9), 1515–1518.
World Health Organization, 2017. Climate change and health - Fact sheet, viewed 1 August 2017, ⟨www.who.int/mediacentre/factsheets/fs266/en⟩.
Xu, Z., FitzGerald, G., Guo, Y., Jalaludin, B., Tong, S., 2016. Impact of heatwave on mortality under different heatwave definitions: a systematic review and meta-analysis. Environ. Int. 89–90, 193–203.
Yang, J., Liu, H.Z., Ou, C.Q., Lin, G.Z., Ding, Y., Zhou, Q., Shen, J.C., Chen, P.Y., 2013. Impact of heat wave in 2005 on mortality in Guangzhou, China. Biomed. Environ. Sci. 26 (8), 647–654.
Yee Yong, L., Din, M.F.M., Ponraj, M., Noor, Z.Z., Kenzo, I., Chelliapan, S., 2017. Overview of urban heat island (UHI) phenomenon towards human thermal comfort. Environ. Eng. Manag. J. 16 (9), 2097–2111.
Yihan, X., Payam, D., Barrera-Gómez, J., Sartini, C., MarÃ-Dell'Olmo, M., Borrell, C., Medina-Ramón, M., Sunyer, J., Basagaña, X., 2013. Differences on the effect of heat waves on mortality by sociodemographic and urban landscape characteristics... [corrected][published erratum appears in J Epidemiol Community Health 2013 Jul; 67(7): 624]. J. Epidemiol. Community Health 67 (6), 519–525.
Yin, Q., Wang, J.F., 2017. The association between consecutive days' heat wave and cardiovascular disease mortality in Beijing, China. BMC Public Health 17.
Zeng, Q., Li, G.X., Cui, Y.S., Jiang, G.H., Pan, X.C., 2016. Estimating temperature-mortality exposure-response relationships and optimum ambient temperature at the multi-city level of China. Int. J. Environ. Res. Public Health 13 (3).