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Heatwave and health impact research: A global review

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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

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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