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The Effects of Extreme Heat on Human Mortality and Morbidity in Australia: Implications for Public Health

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Abstract

Most regions of Australia are exposed to hot summers and regular extreme heat events; and numerous studies have associated high ambient temperatures with adverse health outcomes in Australian cities. Extreme environmental heat can trigger the onset of acute conditions, including heat stroke and dehydration, as well as exacerbate a range of underlying illnesses. Consequently, in the absence of adaptation, the associated mortality and morbidity are expected to increase in a warming climate, particularly within the vulnerable populations of the elderly, children, those with chronic diseases, and people engaged in physical labour in noncooled environments. There is a need for further research to address the evidence needs of public health agencies in Australia. Building resilience to extreme heat events, especially for the most vulnerable groups, is a priority. Public health professionals and executives need to be aware of the very real and urgent need to act now.

Keywords

extreme heat, health, morbidity, mortality, temperature

Introduction

Climate change is already having an impact in Australia. Average surface temperatures have increased by 0.9°C since 1950,[1] and recent summer seasons have been characterized by unprecedented extreme heat events in southeastern Australia. Best estimates for average temperatures

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for 2070 suggest a rise of between 1.8°C (1.0°C to 2.5°C) for a low emissions scenario, to 3.4°C (2.2°C to 5.0°C) for a high emissions scenario.[1] The effect of elevated temperatures and more frequent heat waves on population health in Australia is a growing public health concern. The aim of this review is to investigate the evidence for heat-related mortality and morbidity in Australia and to discuss the projected impacts from a warming climate.

Evidence for Heat-Related Mortality in Australia

There have been numerous published studies investigating the relationship between high ambient temperatures and adverse health outcomes in Australia. Most studies use mortality as an outcome, indicating an increase in mortality associated with increasing temperature (summarized in Table 1). The role of air pollutants as confounders in this relationship is less clear and needs further study.

In recognition that multiple weather elements may influence health, some studies have examined the effects of exposure to different synoptic categories, which incorporate thermal and moisture properties of air masses, wind conditions, and cloud cover. Guest et al[2] estimated a combined average of 83 excess deaths each summer was associated with oppressive synoptic clusters in Adelaide, Melbourne, Brisbane, and Sydney. Vaneckova et al[6] found the hot and dry and warm and humid synoptic categories were associated with higher all-cause, circulatory, and cerebrovascular mortality in Sydney, especially for the 65 years and older age group and women.[6]

The effect of exposure to heat waves, or cumulative heat exposure, has also been investigated for several Australian cities, using local criteria to define a "heat wave" in each location. Mortality estimates associated with a heat wave event may also include estimates of any mortality deficit in the post–heat event period. These estimates quantify any mortality displacement, or hastening of death of those individuals who would have been expected to die shortly (in days to weeks) regardless of the weather. Mortality displacement during early summer can leave a more "robust" population to face heat episodes later in the season. In a 4-day heat wave in Sydney during January 1994 (daily maximum temperatures exceeding 32°C), there were 110 excess deaths, with a short-term mortality displacement of 59% for this event.[7] This suggested that the heat effects in Sydney might be predominantly mortality displacement (although morbidity data also need to be analyzed), with the remaining population being well acclimatized to the heat.[7] In contrast, a heat wave in February 2004 was associated with 75 excess deaths in Brisbane, with no evidence of short-term mortality displacement.[15]

For the week spanning the 2009 heat wave in Melbourne, which included 3 days with temperatures >43°C, there was a 62% increase in total all-cause mortality when compared with the average for the same period from the previous 5 years.[16] Although the greatest number of deaths occurred in those 75 years or older, there was a 46% increase in deaths in the 65- to 74-year age group and a 55% increase in the 5- to 64-year age groups, corresponding to 46 and 64 excess deaths in these age groups, respectively. This extraordinary increase among young people needs urgent additional research. Were these healthy people who were overexposed to heat and died, or did they have preexisting disease? Were these deaths associated with high alcohol consumption, accidents, or drowning?

Heat-Related Indices of Morbidity and Physiological Effects

In terms of the impact of extreme heat on population health, morbidity should be a more sensitive index than mortality. For Adelaide heat waves during the period 1993 to 2006, defined as 3 or more days of 35°C or above, a 4% increase in ambulance transports was observed compared to non–heat wave periods.[14] There were significant increases in all-age renal and mental hospital

Table 1. Overview of Published Studies Quantifying Heat-Related Mortality in Australian Cities

Study Location	Study Period	Age Group (Years)	Effect on All-Cause Mortality Outcome	Reference
Perth, Adelaide Melbourne, Sydney Brisbane	1979-1990	65+	Combined total of 175 excess annual deaths above 28°C	Guest et al[2]
Perth, Darwin, Brisbane, Cairns, Townsville, Sydney, Canberra, Melbourne, Adelaide, Hobart	1997-1999	65+	Estimated annual heat-related deaths for this period: 1115 from the 7 temperate cities; 6 from the 3 tropical cities (Darwin, Cairns, Townsville)	McMichael et al[3]
Sydney	1993-2004	0-64 and 65+	4.5% to 12.1% increase per 10°C increase in daily maximum temperature, depending on mortality cause and age group	Vaneckova et al[4]
Sydney	1994-2004	All ages	0.9% increase (95% confidence interval = 0.6% to 1.3%] per 1°C increase in daily maximum temperature; 7.8% when maximum temperature above 32°C	Hu et al[5]
Sydney	1993-2001	0-64 and 65+	Warmest synoptic categories associated with higher mortality, especially for older age group	Vaneckova et al[6]
Sydney	1988-2003	All ages	Heat-related death rate of 1.8 (per 100 000 per year)	Gosling et al[7]
Sydney	1993-2004	65+	Spatial analysis identified geographical patterns of heat-related mortality within the metropolitan area	Vaneckova et al[8]
Brisbane	1984-1985	All ages	Positive association between summer heat and acute myocardial infarction deaths	Auliciems and Skinner[9]
Brisbane	1981-1985	<5, 5-64, and 65+	Deaths (stroke, heart attack, and respiratory failure) are affected by weather and the dominant relationship is with air temperature	Auliciems et al[10]
Brisbane	1986-1995	All ages and 65+	7% increase per 1°C increase in monthly mean minimum temperature for 65+ group	Bi et al[11]
Brisbane	1996-2001	All ages	Adverse effects of increasing minimum temperature most apparent at higher levels of PM_{10}	Ren et al[12]
Melbourne	1979-2001	65+	15% to 17% increase in average daily mortality when mean daily temperature exceeds 30°C; 19% to 21% when minimum temperature exceeds 24°C	Nicholls et al[13]
Adelaide	1993-2004	All ages	All age mortality not affected by heat waves (at least 3 days of 35°C or above)	Nitschke et al[14]

admissions (7% and 13%, respectively) and an 8% increase in ischemic heart disease admissions in the 65- to 74-year age group.[14,17,18] For the population of Melbourne, hospital admissions for acute myocardial infarction were increased by 37.7% on days when the 3-day average temperature exceeded 27°C.[19] During the 2009 Melbourne heat wave, emergency department presentations showed a 12% overall increase and a 37% increase in those 75 years or older, compared with the average for the same period for the previous 5 years.[16] Compared with the same period in 2008, ambulance emergency cases increased by 46% over the 3 hottest days in Melbourne.[16]

Heat exposure is of great importance to the physiological functions of the body. Physiology based effects of heat include heat exhaustion, heat collapse, and more serious heat stroke,[20] and they are associated with internal heat production during physical work. As these effects are most often temporary, they are seldom reported in health statistics, but the impacts on the immediate sense of well-being and on daily productivity of working people can be of great importance. This is of increasing concern in relation to local climate change, as discussed in the article by Hanna et al[21] in this issue.

In addition to the direct health effects of heat exposure, some of the secondary characteristics of heat events that are often overlooked are increased rates of injury, trauma, crime, and domestic violence.[22,23]

Vulnerable Population Groups: Evidence From Australia and Overseas

The public health outcomes of heat waves depends on the level of exposure (timing, frequency, intensity, and duration of the heat wave), and the demographic profile of the exposed population, population sensitivity, and the prevention measures in place.[24] Identifying populations at greatest risk enables health authorities to plan and target interventions accordingly.

Epidemiological investigations following major heat waves in the Northern Hemisphere in the past 2 decades have markedly increased our understanding of susceptibility to heat. In August 2003, Europe experienced its hottest summer for several hundred years with almost 15 000 heat-related deaths occurring in France alone.[25] Most of the deaths—as well as heat stroke, hyperthermia, and dehydration—were among persons aged 75 years and older. The main causes of excess mortality were diseases of the cardiovascular, respiratory, genitourinary, and nervous systems as well as endocrine and mental disorders.[25]

Clinical, epidemiological, and physiological evidences suggest that chronic disease increases the risk of heat stress. In addition to the aforementioned diseases, this includes cognitive impairment, diabetes, cancer, and obesity.[26] The use of some medications, such as anticholinergics and certain antipsychotics, also increases the risk of heat stress.[27,28] Hospital inpatients and nursing home residents are at high risk of heat-related mortality despite being under the care of professionals.[24]

In addition to biophysical reasons for increased risk, social factors are also important. There is good evidence for the importance of social networks as being protective for heat wave mortality.[29,30] Elderly persons living alone are at a greater risk, as are those who are living in areas of low socioeconomic status.[31,32] Other factors associated with increased vulnerability include homelessness,[33] poor English language skills among migrants,[34] living in rural and remote communities, especially remote indigenous communities,[35-37] and participating in strenuous outdoor activities.[38] In urban areas, the urban heat island can increase the latent heat load; this can be exacerbated by poor building design and urban planning, resulting in high-density housing with limited green space.[39-41] These issues are described further in the article by Bambrick et al in this issue.[42]

An area of particular concern is occupational heat stroke risk during heat waves. It was observed during heat waves in Adelaide that men in the working age range (35 to 64 years) had a particularly increased hospital admission rate for kidney diseases.[17] The authors considered occupational heat exposure as a potential cause. Very similar phenomena were also observed in the 2003 heat wave in France, when men aged 35 to 64 years were affected, possibly because of occupational heat exposure.[43]

To date, there are very few Australian studies characterizing those people hospitalized or dying during periods of heat. In addition, few studies have focused on the populations from rural and remote regions. Further research in these areas will contribute to a better understanding of the vulnerable subgroups in Australia and to more precise estimates of future climate change impacts. There is a limited opportunity to improve the biophysical thermal capacity of humans; however, exposure to extreme heat can be mitigated through behavioral adaptation and technological change. Issues of adaptation and resilience to extreme heat are another important focus for future research.

Heat Health Warning Systems

As a result of the public health impact of heat waves, many European and US cities have introduced Heat Health action plans and heat wave warning systems, as suggested by the World Health Organization.[44] Useful insights into best practice formulations can be gained from these and similar frameworks applied in the Australian setting. Defining heat threshold temperatures, above which mortality and/or morbidity increase, can inform the development of threshold-based alert systems. Heat thresholds for mortality have been estimated for major Australian cities.[4,13,45] A mean daily temperature threshold for Melbourne estimated by Nicholls et al[13] has been incorporated into a Victorian heat alert system.[13] Guidance for health-based maximum heat exposure in workplaces is available in international standards.[46]

Projections for Heat-Related Morbidity and Mortality in Australia

In addition to predicted increases in average temperatures for Australian cities, the average number of days per year of maximum temperatures exceeding 35°C is expected to rise as a consequence of climate change.[1] In Darwin (Northern Territory) the change may be drastic, with the Commonwealth Scientific and Industrial Research Organisation predicting the annual average of days with temperatures >35°C to increase from the current 11 days to between 141 and 308 days in 2070, under a worst case emissions scenario.[1] In contrast, in Hobart (Tasmania) there will be little change with the current average of 1.4 days >35°C per year increasing up to 3.4 days by 2070 under a worst case scenario. There is also a projected strong increase in frequency of warm nights.[1] Extreme heat events with little overnight respite are widely considered to be the most challenging for health.[47]

There are several levels of uncertainty inherent in projecting the impact of increasing temperatures on population health. These are related to temperature projections, temperature–mortality models, potential acclimatization of the population, the effectiveness of mitigation strategies, and the influence of future air quality.

In light of many uncertainties, projections of the impact of climate change on population health should be presented as a range of plausible outcomes. The Garnaut Review reported that annual net temperature-related deaths (winter and summer) for the unmitigated climate change scenario would increase by 1250 deaths in 2070, and 8628 deaths in 2100, nationally, compared with the no climate change scenario.[45] The greatest negative impacts were predicted for Queensland, Northern Territory, and Western Australia.

Other studies have predicted annual heat-related deaths for the combined temperate capital cities in the range of 2300 to 2500 in 2020 and 4300 to 6300 in 2050.[3] For the tropical cities of Darwin, Townsville, and Cairns, an estimated 58 to 186 annual heat-related deaths by 2050 has been predicted, compared with 6 per year at baseline.[3] By 2100, it has been estimated that heat-related deaths combined for all cities will be in the range of 4200 to 15 100;[48] and for Sydney, a 344% increase from current mortality (1961-1990) has been predicted for 2050.[49] Whereas most impact assessments to date have made predictions based on change in mean summer temperature, Gosling et al[49] also considered changes in temperature variability, and possible adaptation, in their assessment of future heat-related mortality. This approach may provide new directions for future impact assessments. However, such assessments also need to include morbidity, the incidence of activity limiting physiological effects (eg, heat exhaustion during work), and the economic and social impacts of preventive interventions.

Relevant Policy in Australia

Policy responses to the overwhelming evidence of the impacts of extreme weather and climate change on population health have varied across jurisdictions in Australia. International experience and expertise provides a wealth of responses to heat waves—from early warning systems and alerts, to more sustainable public health campaigns designed to change behavior over time and assist in adaptation to a phenomenon that will be a feature of countries such as Australia for some time.

Most states in Australia have developed heat wave warning plans; however, these plans are in early stages of implementation and none have been evaluated to date. The Victorian Department of Health "Heatwave Plan for Victoria 2009-2010" is the most comprehensive plan, setting out the roles and responsibilities of the Victorian Government, local councils, emergency management, and the health and community service sector.[50] Among current plans there is a focus on the emergency response to heat waves rather than the need to, perhaps more appropriately, adapt to them as a permanent meteorological phenomenon.

The challenge for public health agencies is to simultaneously develop heat wave plans, as emergency planning and response policies, in the short term, and to develop longer term policies and programs that address exposure through transport, urban planning and building design, changes to behavior, and health education. These 2 approaches, although not mutually exclusive, do represent different areas of health policy and practice. On the one hand there is a need to develop appropriate emergency response systems then can react with efficiency and effectiveness to such an event, and on the other, the need to develop a more prolonged public health campaign, aimed at changing behavior and, as importantly, influencing other systems outside of health services to reduce morbidity and mortality because of these events.

Promotion of "active transport"—walking, cycling, and/or using public transport instead of car travel—is one behavior change that could have dual benefits by providing physical activity and reducing the contribution of motor vehicle transport emissions to climate change.[51] Political will is needed to create environments that facilitate active transport options. Neighbourhoods and communities that have a denser pattern of development, with residential areas and services located together (mixed-use neighborhoods), and good public transport infrastructure linking the communities with employment opportunities, are less dependent on cars and can markedly reduce greenhouse gas emissions.[52]

Urban planning should also address thermal comfort during extreme heat. International research indicates that streets with shade trees, good ventilation, proximity to a water body, and a compact urban form provided the most comfortable human thermal conditions during periods of extreme heat.[53-55] Exploring the spatial distribution of heat-related mortality and morbidity, and the contribution of socioeconomic circumstance, enhances our understanding of the influence of urban form on urban climate. Silva et al[56] identified 4 key mitigation strategies for urban landscapes to reduce urban temperatures and alleviate heat stress in a hot arid climate. These included increasing the overall emissivity, percentage of vegetated area, thermal conductivity, and albedo of the urban environment.

The health sector can influence urban planning and transport policies by providing comprehensive assessments of the impact of transport and urban planning policy options on health. Every effort should be made to give health outcomes an economic value so that they become part of the overall cost benefit analysis for large transport and land use decisions.[57]

In public health terms, the issue of extremes of heat is straightforward simply because the intervention is a relatively simple public health message. However, like many public health messages, the key is to work outside of the health system to best implement such a campaign. Health agencies have considerable work to do to ensure that the population is appropriately informed about the health impacts of extreme heat events and knows what steps to take to reduce or eliminate those impacts. In this context, heat impacts on working people ("occupational health") needs to be considered jointly with other public health effects. Heat warnings and other preventive measures may be particularly important for this population group as the work activities themselves are likely to be affected by the heat as well as by the preventive measures.[38] Deaths during heat waves in recent years among working Australians has highlighted the importance of such warnings.

A further challenge then for health agencies is to ensure that information is taken up and promoted both by health services and nonhealth agencies. Working with local governments, nongovernmental organizations, industries, and other state agencies, to mainstream such basic public health messages into existing policies and programs would go some way to ensuring such messages were promoted. For instance, interruptions to power supplies during heat waves generally occur because of increased electricity demand associated with the use of domestic air conditioners.[58] Preparatory measures and emergency response procedures need to be instigated by power supply companies when forthcoming heat waves are forecast. Certainly, Victoria is leading the way with the "Heatwave Planning Guide for Local Government," which provides local councils with a clear framework to develop local heat wave plans to best respond to local conditions and circumstances.

Translating research into doable and appropriate public health actions is an additional challenge. Although there is considerable Australian research currently being undertaken on health impacts of heat—there appears at times a disjuncture between some of the research and the evidence needs of public health agencies. In addition, the biggest challenge is to convince both public health professionals and executives of the very real and urgent need to act now.

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