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The mortality burden of hourly temperature variability in five capital cities, Australia: Time-series and meta-regression analysis

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ABSTRACT

Background: Unstable weather, such as intra- and inter-day temperature variability, can impair the health and shorten the survival time of population around the world. Climate change will cause Earth's surface temperature rise, but has unclear effects on temperature variability, making it urgent to understand the characteristics of the burden of temperature variability on mortality, regionally and nationally.
Objectives: This paper aims to quantify the mortality risk of exposure to short-term temperature variability, estimate the resulting death toll and explore how the strength of temperature variability effects will vary as a function of city-level characteristics.
Methods: Ten-year (2000–2009) time-series data on temperature and mortality were collected for five largest Australia's cities (Sydney, Melbourne, Brisbane, Perth and Adelaide), collectively registering 708,751 deaths in different climates. Short-term temperature variability was captured and represented as the hourly temperature standard deviation within two days. Three-stage analyses were used to assess the burden of temperature variability on mortality. First, we modelled temperature variability-mortality relation and estimated the relative risk of death for each city, using a time-series quasi-Poisson regression model. Second, we used meta-analysis to pool the city-specific estimates, and meta-regression to explore if some city-level factors will modify the population vulnerability to temperature variability. Finally, we calculated the city-specific deaths attributable to temperature variability, and applied such estimates to the whole of Australia as a reflection of the nation-wide death burden associated with temperature variability.
Results: We found evidence of significant associations between temperature variability and mortality in all cities assessed. Deaths associated with each 1 °C rise in temperature variability elevated by 0.28% (95% confidence interval (CI): 0.05%, 0.52%) in Melbourne to 1.00% (95%CI: 0.52%, 1.48%) in Brisbane, with a pooled estimate of 0.51% (95%CI: 0.33%, 0.69%) for Australia. Subtropical and temperate regions showed no apparent difference in temperature variability impacts. Meta-regression analyses indicated that the mortality risk could be influenced by city-specific factors: latitude, mean temperature, population density and the prevalence of several chronic diseases. Taking account of contributions from the entire time-series, temperature variability was estimated to account for 0.99% to 3.24% of deaths across cities, with a nation-wide attributable fraction of 1.67% (9.59 deaths per 100, 000 population per year).
Conclusions: Hourly temperature variability may be an important risk factor of weather-related deaths and led to a sizeable mortality burden. This study underscores the need for developing specific and effective interventions in Australia to lessen the health consequences of temperature variability.

1. Introduction

The impact of non-optimum temperature exposure on human health remains a major public health issue worldwide (Hajat et al., 2010; Gasparrini et al., 2015), partly due to concerns about anthropogenic greenhouse gas emissions catalyzing the changes in global climate (IPCC, 2014). One of the most pronounced health consequences arising from climate change is increasing mortality rates associated with adverse temperatures (Hajat et al., 2010). A number of studies over the past decades have provided robust evidence that many countries already have experienced considerable weather-related mortality from either heat or cold or both (Gasparrini et al., 2015; Yang et al., 2016;

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Vardoulakis et al., 2014). The non-linear temperature-mortality relations of U, V or J-pattern, and acute effects of heat and delayed effects of cold have also been extensively reported (Gasparrini et al., 2015; Guo et al., 2014).

In addition to cold and heat, unstable weather, such as rapid temperature fluctuations within a certain period, represents an extra risk factor of human health. For example, time-series studies involved in regions of Asia, America, Australia and Europe revealed short-term temperature variability (e.g., temperature change within one day or two days) in relation to daily mortality (Guo et al., 2016; Kim et al., 2016; Zhan et al., 2017; Zhang et al., 2017; Kan et al., 2007; Lin et al., 2013). Several cohort studies in UK and USA even observed that temperature variability could reduce the long-term survival among population, and increases in temperature variability can have similar effects on longevity as increases in mean temperature (Zanobetti et al., 2012; Shi et al., 2015). These findings highlight the important role of temperature variability in affecting human health. While a few studies have investigated the premature mortality attributable to cold and heat (Gasparrini et al., 2015; Yang et al., 2016; Vardoulakis et al., 2014), none so far have offered evidence on mortality attributable to temperature variability. Climate change will continue to increase the Earth's surface temperature throughout the 21st century (IPCC, 2014) and possibly produce changes to regional temperature variability, with unclear effects on global temperature variability (Huntingford et al., 2013). There is also some evidence of progressive acclimatization to warming climate within a given population (Todd and Valleron, 2015; Åström et al., 2016), while unstable weather may be more difficult for society to adapt to (Huntingford et al., 2013; Shi et al., 2015). This makes it urgent to understand the burden of temperature variability on mortality, regionally and nationally (Shi et al., 2015).

Conventionally, previous studies have usually investigated the effects of intra-day temperature variability (diurnal temperature range) or inter-day temperature variability (temperature change between two neighboring days), separately (Cheng et al., 2014; Kim et al., 2016; Zhan et al., 2017). Until recently, few studies attempted to account for both intra- and inter-day temperature variability by calculating the standard deviation of temperature within two days (Guo et al., 2016; Zhang et al., 2017). These studies have consistently shown increased mortality associated with temperature variability, whereas temperature variability calculations merely rely on very few temperature values (i.e., maximum, minimum and mean temperatures). Since temperature observation time and type can influence estimates of temperature-related mortality (Davis et al., 2016), overlooking the temporal variation in temperature may introduce an exposure measurement error and bias health effect estimates of temperature variability. Theoretical results suggested that the regression estimates obtained from less aggregated series are more efficient if there are sufficient data (Jacobsen and Dannenburg, 2003). Because reliable estimation of the health burden of temperature variability is essential to support evidence based government policy, we argue that using finer temperature monitoring (e.g., hourly records) could better capture the variable temperature within a short period of time, as well as provides a complementary method for health risk assessment.

The purpose of this study is to quantify the effects of short-term temperature variability on mortality, estimate the mortality attributable to temperature variability, and explore whether the temperature variability-mortality relation will vary as a function of city-level characteristics in five metropolitan cities in Australia.

2. Methods

2.1. Setting

This study was performed in the five largest cities in Australia (Sydney, Melbourne, Brisbane, Perth and Adelaide), respectively representing the capital of five states that are home to approximately 95% of Australia population during 2000–2009 (ABS, 2014a). The population of the five cities together account for over 60% of Australia population (Table 1), and cover different climates. Fig. 1 presents the study regions across Australia.

Table 1
Characteristics of population, mean temperature, temperature variability, and mortality in the five largest cities of Australia, 2000–2009.

	Yearly population size (count)[a]	Daily mean temperature (°C)[b]	Daily temperature variability (°C)[b]	Daily mortality (count)[a]
Adelaide	1,137,452	16.7 (6.3–36.8)	3.3 (0.6–8.9)	22.7 (7–43)
Brisbane	1,805,157	20.7 (6.1–33.0)	3.3 (0.8–7.3)	26.1 (5–68)
Melbourne	3,676,322	14.4 (4.6–35.4)	3.5 (0.7–9.4)	57.4 (13–127)
Perth	1,490,515	18.1 (6.6–33.2)	4.2 (1.1–12.8)	21.4 (4–41)
Sydney	4,255,616	18.4 (8.3–33.1)	2.7 (0.5–9.0)	66.4 (20–114)
Australia[c]	20,330,256	NA	NA	367.8

NA = not available.
Mean temperature was calculated as the average of hourly temperature records for each day, with corresponding range in parentheses.
Temperature variability was calculated as the standard deviation of hourly temperature records within two neighboring days, with corresponding range in parentheses.
[a] Data from Australian Bureau of Statistics.
[b] Data from Australian Bureau of Meteorology.
[c] The whole country.

2.2. Data collection

2.2.1. Mortality and weather data

We obtained daily mortality counts on all causes for the above five cities from Australian Bureau of Statistics (ABS) between 1 January 2000 and 31 December 2009. The study period is identical across all cities. In light of well-documented evidence of harmful effects of temperature change on both accidental and non-accidental mortality (Kim et al., 2015; Gasparrini et al., 2012), we used all-cause mortality in our analysis, which is helpful for the estimation of practical overall death burden related to temperature variability.

Daily temperature (hourly) for each city was provided by Australia Bureau of Meteorology (ABM) for the years 2000–2009. Mean temperature was calculated by the average of hourly temperature within a day (24 h). As motivated by previous studies (Guo et al., 2016; Zanobetti et al., 2012; Shi et al., 2015), short-term temperature variability was captured and generated from the standard deviation of hourly temperature within two days, accounting for both intra- and inter-day temperature variability. Other weather data such as relative humidity were collected for two cities (Brisbane and Sydney) and air pollutants for one city (Brisbane), which served as the sensitivity analysis to check the robustness of research findings (Gasparrini et al., 2015; Guo et al., 2016).

2.2.2. Climate zones, geographic location, demographic, health-related, behavioral and socioeconomic data

According to the Köppen classification method, there are a total of six major types of climate in Australia (ABM, 2017), and most of Australia population actually dwell in the subtropical and temperate zones (ABS, 2014b). As a city may cover different climates, the final climate zone for each city was determined based on their geographic location (central business district coordinates). Geographic data on longitude and latitude of each city was also derived from corresponding central business district coordinates.

Short-term temperature variability (e.g., diurnal temperature range) within a region can be influenced by the urbanization process (Cheng et al., 2014; Mohan and Kandya, 2015), and changes to population density that partly address the heterogeneous susceptibility to adverse temperature in a country would occur accordingly (Medina-Ramón and