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Short Report

Mortality–temperature thresholds for ten major population centres in rural Victoria, Australia

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ABSTRACT

Mortality–temperature relationships in small regional towns in Victoria, Australia, were used to ascertain whether the effects of high ambient temperatures documented in the literature for major population centres in Europe and America are also noted in small rural communities in Australia. The establishment of threshold temperatures in all major rural regions of Victoria indicate that hot weather results in an increase in mortality in persons aged 65 years and older. This adds considerable strength to the argument that human populations are vulnerable to heat events regardless of location. Heat alerts can be issued through local health and welfare agencies, to increase awareness of 'hot' weather as a health hazard for elderly people by providing education campaigns involving local authorities based on these simple thresholds.

1. Introduction

The high mortality associated with the European heatwave of 2003 (Dhainaut et al., 2004; Fouillet et al., 2006; Laaidi et al., 2006; Vandentorren et al., 2006) and recent heatwaves in the US (Golden et al., 2008; Luber and McGeehin, 2008), as well as predicted increases in summer temperature associated with climate change (IPCC., 2007), has led to an increased awareness of hot weather as an environmental hazard. Exposure to extreme heat is already a significant public health problem and a major cause of weather-related mortality in the U.S.A. (Kinney et al., 2008; Kovats and Hajat, 2008). Many large cities around the world have now implemented heat alert systems (Weisskopf et al., 2002; Kalkstein et al., 1996) including Melbourne, Australia (Nicholls et al., 2008). However, heat alerts for smaller regional cities or large towns do not feature prominently in the literature. The research described here examines whether similar mortality–temperature thresholds to those found for Melbourne also apply to rural Victorian population centres. The Melbourne heat alert system is based on the identification of this mortality–temperature threshold (Nicholls et al., 2008) and relies on readily available temperature forecasts from the Bureau of Meteorology (BoM). If temperature thresholds, above which excess deaths occur, can be identified for rural population centres, then similar daily weather forecasts could be used to develop an operational heat alert system for most population centres in the State.

2. Data and methods

Data for daily observed maximum and minimum temperature were purchased from the BoM for 1990–2006. This data set provided data for two weather stations with data covering the study period for each of the five rural Victorian health regions defined by the Department of Health, Victoria (DoH). Fig. 1 shows the locations of the weather stations and the health regions. Daily mortality data for persons aged 65 years and older were purchased from the Australian Bureau of Statistics (ABS) for the study period. The ABS data were provided for Statistical Districts (SDs). Each DoH health region is comprised of two ABS Statistical Districts the locations of which are also shown in Fig. 1. For privacy reasons the ABS is restricted from publishing information in situations where fewer than five deaths occur; therefore daily data at a high spatial resolution in rural areas with small populations, could not be obtained. Due to low numbers of daily deaths in rural areas the mortality numbers were summed every two days, thereby representing deaths over a 48 h period, with the exception of the Geelong (Barwon) region where numbers of deaths were sufficient to allow daily analyses. Days missing from the data set because of this restriction accounted for 1.3–2.5% of the data in each region. The majority of days with missing data were during the summer months. However days with missing data did not coincide with days that exceeded the heat thresholds in any of the regions studied.

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The relationships of maximum (T_{max}), minimum (T_{min}), and average temperature (Mean-T) with total 2-day mortality and anomalous mortality were investigated. In order to determine the mortality anomaly it is necessary to remove the long-term trend, the seasonal variation and any shorter-term cycles from the mortality time series. A multiplicative decomposition model was used to remove the trend, seasonal variation, and any cyclic behaviour in mortality (death rate=trend × cycle × seasonal factor × anomaly). The mortality time series was decomposed using exponential smoothing, in SPSS version 14. The mortality anomaly for each time unit (1 or 2 days depending on the region) over the study period was then calculated as the deviation of the actual death rate for that day(s) from the smoothed death rate (mortality anomaly=actual death rate/smoothed death rate). This is the same method as was used to determine the threshold temperatures for Melbourne (Nicholls et al., 2008).

Temperature variables were fitted to the 2-day mortality data by selecting the maximum value of daily maximum (T_{max}), daily minimum (T_{min}), and daily average (Mean-T, the average of T_{max} and T_{min} over the 9 am–9 pm period) temperature observed over the 48 h period. Thus 2-day total mortality was related to the highest temperature (T_{max}, T_{min}, and Mean-T) observed during the 2-day period. This method was considered appropriate as heat related mortality typically peaks either on the day of extreme heat or the day following the heat event, and mortality heat relationships in Melbourne (Nicholls et al., 2008) have demonstrated that the effects of hot weather are immediate and there is little or no mortality displacement. The DoH analysis of the January 2009 heatwave in Victoria also demonstrated that mortality peaked with temperature and declined as temperatures decreased. Heatwaves in Victoria are typically of short duration but are intense (http://www.health.vic.gov.au/chiefhealthofficer/downloads/heat_impact_rpt.pdf, 2009). Examination of the French heatwave in 2003 also found mortality peaked during the event and declined sharply as temperature subsided (Fouillet et al., 2006; Laaidi et al., 2006; Pascal et al., 2006). This is not always the case and mortality peaks 3–4 days or longer following the heat event have been reported (Hajat et al. 2006; Johnson et al. 2005). Peaks in mortality following heatwaves may show some temporal variability depending upon heatwave duration and intensity as well as differences in how deaths are recorded. Nicholls et al. (2008) found that high minimum temperatures were a good predictor of excess mortality in Melbourne, so one of the variables examined in this study is the highest minimum temperature observed over the 2-day period.

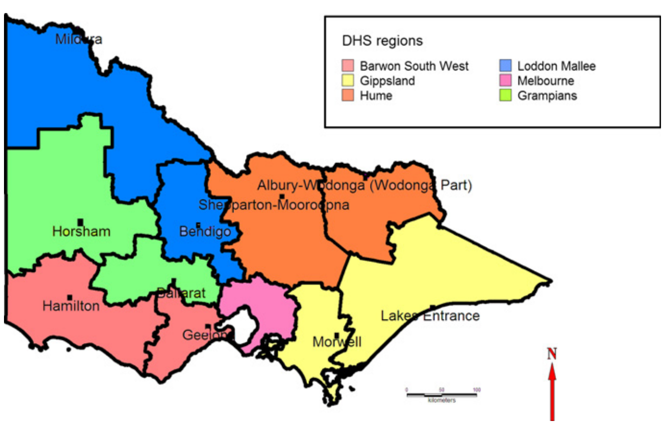

Fig. 1. The Department of Human Services delivers services through its eight health regions (three of these are in Melbourne and are omitted from the figure and from this study). Each region is comprised of two statistical districts (SD) each of which includes one major population centre. The population centres and names of the SDs in each region are listed in Table 1. The BoM weather stations are located in each of the major centres.

Box plots were prepared for 'bins' of maximum, minimum, and average temperature and 48 h mortality. Temperature bins were selected to represent 2 °C increments. In the case of one region (Geelong/Barwon), where data were available to undertake the analysis using daily data rather than 2-day accumulations, the best relationship was with temperatures from the day before the mortality data.

3. Results

The median, upper, and lower quartiles and range of 2-day total mortality anomalies (i.e., with the long-term trend and seasonal cycles removed) for persons aged 65 years and older versus the maximum value of the selected temperature variable (T_{max}, T_{min}, or Mean-T) over the same 48 h period were calculated. The results presented for the Geelong/Barwon region used daily data. The results of the threshold temperature analysis for all the major centres are summarised in Table 1. Table 1 details the major centre and SD, the threshold temperature for T_{max}, T_{min}, and Mean-T (the number of episodes exceeding the threshold in each area), the percentage increase in median mortality associated with threshold exceedance.

4. Discussion and conclusions

This study has demonstrated that in all major rural population centres across Victoria an increase in mortality in persons aged 65 years and older takes place when hot weather exceeding a specific threshold occurs. The clearest thresholds are, in general, with

Table 1
Threshold temperatures (°C) for rural Victorian centres. Numbers of episodes exceeding thresholds during the study period are listed in parentheses. The percentage increase in mortality on days exceeding the threshold is also shown for each threshold.

Major centre (SD)	Threshold temperature					
	T_{max}		T_{min}		Mean-T	
Bendigo (Loddon)	40 (14)	8%	22 (18)	5%	32 (23)	18%
Wodonga (Hume)	40 (16)	20%	28 (4)	5%	None identified	None identified
Latrobe Valley (Gippsland)	36 (41)	16%	22 (8)	22%	30 (25)	18%
Horsham (Grampians)	38 (103)	10%	None identified	None identified	32 (33)	10%
Hamilton (Western District)	42 (6)	5%	24 (10)	7%	34 (2)	7%
Lakes Entrance (East Gippsland)	38 (21)	15%	23 (24)	7%	30 (10)	7%
Geelong (Barwon)	40 (19) 1 day lag	10%	20 (11)	4%	28 (39)	15%
Shepparton (Goulburn)	43 (3)	36%	26 (8)	15%	30 (23)	15%
Ballarat (Central highlands)	32 (13)	5%	18 (65)	10%	28 (16)	18%
Mildura (Mallee)	44 (7)	18%	27 (16)	10%	35 (20)	10%