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Short Communication

The impact of the 2003 heat wave on mortality in Shanghai, China

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ABSTRACT

In 2003, Shanghai recorded the hottest summer in over 50 years. We investigated the impact on the mortality of a heat wave in 2003 in Shanghai. We calculated excess mortality and rate ratios (RRs) during the heat wave (July 19–August 6, 2003) compared to a reference (non-heatwave) period (June 28–July 9, and August 16–August 22). During the heat wave, the RR of total mortality was 1.13 (95% CI: 1.06–1.20), and the impact was greatest for cardiovascular (RR = 1.19, 95% CI: 1.08–1.32) and respiratory (RR = 1.23, 95% CI: 1.02–1.48) mortality. Gender did not make a statistically significant difference for the heat-wave impact. Elderly people (over 65 years) were most vulnerable to the heat wave. Our analysis showed that the 2003 heat wave had a substantial effect on mortality in Shanghai. Public health programs should be implemented to prevent heat wave-related health problems in the city.

1. Introduction

Globally, urbanization is proceeding at a quickening pace, with now, half of the world population living in cities or large towns. Many cities in China are undergoing rapid urbanization which is affecting the local climate (such as increasing the urban heat island effect) as well as the quality of housing and the urban infrastructure. Temperature has long been recognized as a physical hazard, and is associated with a wide range of effects on health (Basu and Samet, 2002; Kovats and Hajat, 2008). The rapid buildup of greenhouse gases is expected to increase both mean temperature and temperature variability around the world (Schar et al., 2004). This added urgency to the need of better understanding the relationship between temperature and health events.

Heat wave has been associated with increased mortality in the United States (Knowlton et al., 2009; Balbus and Malina, 2009; O'Neill et al., 2003) and Europe (Schar et al., 2004; Brucker, 2005; Hajat et al., 2006; Huynen et al., 2001). Increased mortality during heat waves has been attributed mainly to cardiovascular illness and diseases of the cerebrovascular and respiratory systems (Kilbourne, 1999), especially among the elderly (Kovats and Kristie, 2006). Heat stress can rapidly become life threatening, especially among those with limited access to immediate medical attention (Mastrangelo et al., 2006). However, there have been relatively few studies examining the adverse health effects of heat wave in Asian developing countries.

In July and August 2003, an extended heat wave resulted in above-average temperatures throughout Europe (Brucker, 2005). The summer of 2003 was also unusually hot across much of Asia, and Shanghai recorded the hottest summer in over 50 years (Tan et al., 2004). The heat-wave event offered an opportunity to study heat-related mortality patterns in a large Chinese city.

2. Materials and methods

2.1. Data

Shanghai comprises nine urban and ten suburban districts, with a total area of 6341 square kilometres (km^2), and had a population of 13.2 million at the end of 2000, representing 1% of China's total. Our study area includes the nine urban districts of Shanghai (289 km^2). The target population includes all permanent residents living in the area, around 6.3 million in 2000. In the target population, the male/female ratio was 100.9%, and the elderly (over 65) accounted for 11.9% of the total.

The daily mortality of residents living in the nine urban districts in the 2003 summer (15 June–15 September) was obtained from the database of the Shanghai Municipal Center of Disease Control and Prevention. Causes of deaths were coded according to the International Classification of Diseases, Revision 10 (ICD 10), and classified into deaths due to total non-accidental causes (A00-R99), cardiovascular diseases (I00-I99) (including subcategories such as stroke and heart diseases), and respiratory diseases (J00-J98) [including subcategories such as chronic obstructive pulmonary disease (COPD) and acute respiratory infection (ARI)]. The temperature data were measured at a fixed-site station located in the Xuhui District of

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Shanghai. Air pollution data were obtained from six monitoring stations in urban Shanghai and the average values across stations were used.

2.2. Definition of heat-wave period

Many methods exist for characterizing the definition of a heat wave (Hajat et al., 2006). We used the Chinese Meteorological Administration's definition of a “heat day”, defined as a day with maximum temperature exceeding 35 °C. We defined a heat wave as a period with at least three consecutive “heat days”. We therefore identified 19 July–6 August as the heat-wave period. To minimize potential time-varying confounding effects, we selected a near-term summer reference period of the same duration (19 days) and with the same distribution of days of the week for the analysis: June 28–July 9, and August 16–August 22 in the same year. The reference period did not include the days immediately after the heat wave because some heat mortality studies have found that the number of deaths caused by heat waves is partially offset by a temporary reduction in death rates in subsequent weeks (Huynen et al., 2001; Braga et al., 2001).

2.3. Statistical analysis

Assuming that the Shanghai population changed little over the course of one summer, and selecting the reference period with the same number of days and distribution of days of the week as the heat-wave period, the person–time units in the denominators of the two rates were equivalent. This allowed us to compare the ratio of the numbers of cases in the two time periods to indicate the relative impact of the heat events (Rothman and Greenland, 1998). We calculated excess deaths as the difference in the numbers of deaths in the two periods. We calculated the rate ratios (RRs) as the ratios between the death numbers in the heat-wave period and in the reference period, and calculated exact 95% confidence intervals (95% CIs) for the RRs using the method of Daly (1992). A similar approach was used by Knowlton et al. (2009) to estimate the impacts of the 2006 California heat wave on hospitalizations and emergency department visits.

Both total non-accidental and cause-specific mortality were assessed. We were able to stratify by gender and age only for total mortality. We tested the statistical significance of differences between effect estimates of the strata of a potential effect modifier (e.g. the difference between females and males) by calculating the 95% CI as $(\hat{Q}_1-\hat{Q}_2) \pm 1.96\sqrt{S\hat{E}_1 + S\hat{E}_2}$, where $\hat{Q}_1$ and $\hat{Q}_2$ are the estimates for the two categories, and $S\hat{E}_1$ and $S\hat{E}_2$ are their respective standard errors (Zeka et al., 2006).

3. Results and discussion

The average daily maximum temperatures during the heat-wave and summer reference periods in Shanghai were 36.3 °C and 32.3 °C, respectively. The hottest day of the heatwave occurred on July 25, 2003, with a maximum temperature of 39.0 °C.

An increase in daily mortality was observed during the heat wave (Fig. 1). Consistent with previous studies (O'Neill et al., 2003; Kilbourne, 1999), the impact of heat wave was apparent across a wide range of mortality outcomes including both total and cardiopulmonary mortality (Table 1). The excess deaths number during the heat-wave period in this population was approximately 258 in the study population. The heat wave caused a short term increase in total mortality of 13% (95% CI: 6% to 20%). The heat waves caused an increase in deaths from cardiovascular causes (RR = 1.19, 95% CI: 1.08–1.32), particularly stroke (RR = 1.21, 95% CI: 1.06–1.39), coronary heart disease events (RR = 1.20, 95% CI: 1.02–1.40). Respiratory deaths also increased during the heat wave (RR = 1.23, 95% CI: 1.02–1.48), although ARI mortality did not increase significantly (RR = 0.83, 95% CI: 0.42–1.65). There was no significant difference between the RRs of cardiovascular and respiratory mortality in the heat-wave period.

The RRs varied by gender or age group (Table 2). The effect of heat wave on total mortality in males was slightly higher than in females, but the difference was not statistically significant. This finding is consistent with a previous study showing no differences of temperature health effects across genders (O'Neill et al., 2003).

Like a few other studies (O'Neill et al., 2003; Brucker, 2005), we found the elderly (over 65 years) were most vulnerable to the heat wave (RR = 1.13, 95% CI: 1.06–1.21) (Table 2). We did not observe significant effects of heat wave in residents aged under 64. For the elderly, the ability to regulate body temperatures is reduced, and sweating thresholds are generally elevated in comparison with younger people (Foster et al., 1976; Kenney and Hodgson, 1987). In that case, the cardiorespiratory system could not adjust well to the outside temperature change, especially for those persons with preexisting cardiorespiratory diseases. However, it should be noted that since most deaths occur over age 65, there is more power to find associations in this age group.

In short, our work suggested that the 2003 heat wave had a substantial effect on mortality in Shanghai. The effect seemed to be

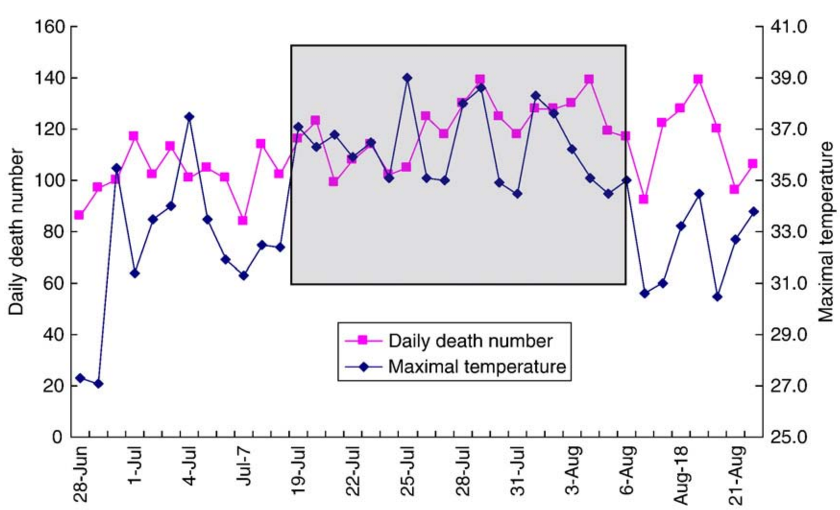

Fig. 1. Daily death number and maximal temperature during the heat-wave period (July 19–August 6, 2003) and summer reference period (June 28–July 9, and August 16–August 22) in Metropolitan Shanghai (the rectangle in gray indicates the heat-wave period).

Table 1
Total and cause-specific mortality during the 2003 Shanghai heat-wave period (July 19–August 6, 2003), versus the summertime reference period (June 28–July 9, and August 16–August 22).

Mortality	Reference period	Heat-wave period	RR (95% CI) [a]
Total	2025	2283	1.13 (1.06, 1.20)*
Cardiovascular	691	825	1.19 (1.08, 1.32)*
Stroke	371	450	1.21 (1.06, 1.39)*
CHD	283	339	1.20 (1.02, 1.40)*
Respiratory	201	247	1.23 (1.02, 1.48)*
COPD	167	199	1.19 (0.97, 1.46)
ARI	18	15	0.83 (0.42, 1.65)

[a] RRs were calculated as ratios between the death numbers in the heat-wave period and in the reference period.
* $p<0.05$.

Table 2
Sex and age-stratified total mortality during the 2003 Shanghai heat-wave period (July 19–August 6, 2003), versus the summertime reference period (June 28–July 9, and August 16–August 22).

Mortality	Reference period	Heat-wave period	RR (95% CI)
Sex			
Male	1053	1217	1.16 (1.06, 1.26)*
Female	972	1066	1.10 (1.01, 1.20)*
Age (years)			
0–4	9	6	0.67 (0.24, 1.87)
5–44	62	71	1.15 (0.81, 1.61)
45–64	292	325	1.11 (0.95, 1.30)
≥65	1662	1881	1.13 (1.06, 1.21)*

* $p<0.05$.

limited to older adults. Public health programs should be implemented to prevent heat wave-related health problems in the city.

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