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Impact of extreme temperature on hospital admission in Shanghai, China

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A B S T R A C T

No previous study exists in China examining the impact of extreme temperature on morbidity outcomes. In this study, we investigated the impact of heat waves and cold spells on hospital admission in Shanghai, China. Daily hospital admission data between January 1, 2005 and December 31, 2008 were collected from the Shanghai Health Insurance Bureau. The heat wave was defined as a period of at least 7 consecutive days with daily maximum temperature above 35.0 °C and daily average temperatures above the 97th percentile during the study period. The cold spell was defined as a period of at least 7 consecutive days with daily maximum temperature and daily average temperatures below the 3rd percentile during the study period. We calculated excess cases of hospitalization and rate ratios (RRs) to estimate the impacts of both heat wave and cold spell on hospital admission. We identified one heat wave period (from 24 July to 2 August, 2007) and one cold spell period (from 28 January to 3 February, 2008) between 2005 and 2008. The heat wave was associated with 2% (95% CI: 1%–4%), 8% (95%CI: 5%–11%), and 6% (95%CI: 0%–11%) increase of total, cardiovascular and respiratory hospital admission. The cold spell was associated with 38% (95%CI: 35%, 40%), 33% (95%CI: 28%, 37%) and 32% (95%CI: 24%, 40%) increase of total, cardiovascular and respiratory hospital admission. The differences between heat wave and cold spell-related hospital admission were statistically significant for all causes and cardiovascular causes, but not for respiratory causes. In conclusion, both heat wave and cold spell were associated with increased risk of hospital admissions in Shanghai. Cold spell seemed to have a larger impact on hospital admission than heat wave. Public health programs should be tailored to prevent extreme temperature-related health problems in the city.

1. Introduction

There is near unanimous scientific consensus that the world's climate is warming and most of the warming is attributable to human activities (IPCC, 2007). As the largest developing country, China's economic expansion during the past decades is largely driven by fossil fuels, which leads to increasing emissions of greenhouse gasses (GHGs) dramatically. Although per capita emissions in China are at the global average, China surpassed the United States as the country emitting the most carbon dioxide (CO_2) in 2007 (International Energy Agency, 2009).

As in other parts of the world, climate in China has experienced noticeable changes over the past 100 years (China National Development and Reform Commission, 2007). For example, annual average air temperature has increased by 0.5–0.8 °C during the past 100 years, which is slightly higher than the average global temperature rise (China National Development and Reform Commission, 2007). Temperature has long been recognized as a physical hazard, and is associated with a wide range of effects on health (Basu and Samet, 2002). However, compared with developed countries, the evidence for the health impact of climate change is quite limited in China (Zhang et al., 2010). Consideration of the health impact of climate change is important because it can help the Chinese government take actions with appropriate urgency.

Previously, associations between extreme temperature and hospital admission have been extensively reported in North America (Knowlton et al., 2009; Lin et al., 2009; Weisskopf et al., 2002) and Europe (Johnson et al., 2005; Kovats et al., 2004; Tataru et al., 2006; Vanhems et al., 2003). There remains a need for replicating the findings of developed countries in China, where socio-demographic status of local residents (e.g. disease pattern, age structure, and socioeconomic characteristics) may be different.

The present study aims to examine the associations between extreme temperature, including both heat waves and cold spells, and hospital admission between 2005 and 2008 in Shanghai, China.

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2. Materials and methods

2.1. Data

Our study area, Shanghai, is situating at the tip of the Yangtze River Delta in east China. The city features a moderate subtropical climate, with four distinct seasons and abundant rainfall. Shanghai has a total area of 6341 square kilometers (km^2), with a population of 13.5 million at the end of 2008, representing 1% of China's total.

Daily hospital admission data between January 1, 2005 and December 31, 2008 (1461 days) were collected from the database of Shanghai Health Insurance Bureau (SHIB). SHIB is the government agency in charge of the Shanghai Health Insurance System. The Shanghai Health Insurance System, which provides compulsory universal health insurance, covers most of the residents in Shanghai (the coverage rate was 95% in 2008). Computerized records of daily hospital admission are available for 770 contracted hospitals. All the hospitals must submit standard claim documents for medical expenses on a computerized form that includes the date of hospital admission, identification number, gender, birthday, and the diagnostic for each admission. Several previous epidemiologic analyses have used the SHIB database (Chen et al., 2010; Ge et al., 2011). The causes of hospital admission were coded according to International Classification of Diseases, Revision 10 (ICD 10): all non-accidental causes (A00-R99), cardiovascular diseases (I00-I99), and respiratory diseases (J00-J98).

Meteorological data (daily average, maximal, and minimal temperature; and relative humidity) were obtained from the database of Shanghai Meteorological Bureau. The weather data were measured at a fix-site station located at the center of Shanghai.

2.2. Definition of heat waves and cold spells

There are no operational definitions of heat waves or cold spells for health studies in China, and various approaches were adopted in literatures (Huang et al., 2010; Tan et al., 2007; Tong and Kan, 2011; Tong et al., 2010). We used the Chinese Meteorological Administration's definition of a “heat day”, defined as a day with maximum temperature exceeding 35 °C. In our study, heat wave was defined as a period of at least 7 consecutive days with daily maximum temperature above 35.0 °C and daily average temperatures above 97th percentile during the study period. Cold spell was defined as a period of at least 7 consecutive days with daily maximum temperature and daily average temperatures below 3rd percentile during the study period.

To control potential time-varying confounding effects, we selected a near-term summer/winter reference period of the same duration, with the same distribution of days of the week (DOW) for the analysis. A similar definition of reference period was used to estimate the impacts of the 2006 California heat wave on hospitalizations and emergency department visits (Knowlton et al., 2009). The reference periods did not include the days immediately after the heat wave/cold spell because some studies have found that the number of deaths caused by heat wave/cold spell was partially offset by a temporary reduction in death rates in subsequent weeks (Basu and Samet, 2002).

2.3. Statistical analysis

Assuming that the Shanghai population changed little during one summer/winter, and selecting the reference period with the same number of days and distribution of DOW as the heat wave/cold spell periods, 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/cold events. We calculated excess hospital visits as the difference in the numbers of hospital admission in the two periods. We then calculated the rate ratios (RRs) between the hospital visit numbers in the heat wave/cold spell period (a) and in the reference period (b), and calculated exact 95% confidence intervals (CIs) for the RRs using the formula $\left[\exp\left(LnRR \pm 1.96\sqrt{\frac{1}{a}+\frac{1}{b}}\right)\right]$ (Rothman et al., 2008).

We tested the statistical significance of differences between effect estimates of heat waves and cold spells by calculating the 95% CI as $\left(\widehat{Q}_1-\widehat{Q}_2\right) \pm 1.96\sqrt{\left(S\widehat{E}_1\right)^2+\left(S\widehat{E}_2\right)^2}$, where $\widehat{Q}_1$ and $\widehat{Q}_2$ are the estimates for the two categories, and $S\widehat{E}_1$ and $S\widehat{E}_2$ are their respective standard errors (Zeka et al., 2006).

Table 1
Summary statistics of daily average, minimal and maximal temperature in Shanghai (2005–2008, °C).

	Mean	Min.	3%	Median	97%	Max.
Daily average temperature	17.7	−3.1	1.5	18.8	31.2	34.1
Daily minimal temperature	14.6	−5.8	−1.8	15.1	28.1	30.7
Daily maximal temperature	21.3	−0.4	4.8	22.5	35.8	38.8

3. Result

During our study period (2005–2008), the mean daily average temperature was 17.5 °C, reflecting the subtropical climate in Shanghai (Table 1). During the summer (June–August) and winter (December–February), the mean daily average temperature was 26.3 °C and 4.7 °C, respectively, in the city. Between 2005 and 2008, we identified one heat wave period (from 24 July to 2 August, 2007) and one cold spell period (from 28 January to 3 February, 2008).

An increase in hospital admission was observed during the heat wave period (Table 2). The impact of heat wave on hospital admission was significant for both all non-accidental and cardiopulmonary causes. The number of excess hospital admissions during the heat wave period was 352 in Shanghai. The heat wave caused a short term increase in total hospital admission of 2% (95% CI: 1%–4%). The heat wave also caused an 8% (95%CI: 5%–11%) increase of hospital admission from cardiovascular causes, and 6% (95%CI: 0%–11%) increase of hospital admission from respiratory causes.

During the cold spell period, excess hospitalizations reached 3725 cases (Table 3). Hospital admission due to all causes, cardiovascular causes and respiratory causes increased to 38% (95%CI: 35%, 40%), 33% (95%CI: 28%, 37%) and 32% (95%CI: 24%, 40%), respectively.

The differences between cold spell and heat wave-related hospital admission were statistically significant for all causes ($p<0.01$), cardiovascular causes ($p<0.01$), but not for respiratory causes ($p>0.05$).

Table 2
Hospital admission during the heat wave period (24 July–2 August, 2007), versus the summer reference period (10 July–16 July, 7 August–9 August, 2007).

	Heat wave	Reference period	Excess cases	RR[a] (95%CI)
Total	17,593	17,241	352	1.02 (1.01, 1.04)*
Cardiovascular disease	4051	3752	299	1.08 (1.05, 1.11)*
Respiratory disease	1361	1289	72	1.06 (1.00, 1.11)*

[a] Rate ratios (RRs) were calculated as ratios between the hospital admission numbers in the heat wave period and in the reference period.
* $p<0.05$.

Table 3
Hospital admission during the cold spell period (28 January–3 February, 2008), versus the winter reference period (17 January–20 January, 11 February–13 February, 2008).

	Cold spell	Reference period	Excess cases	RR[a] (95%CI)
Total	13,669	9944	3725	1.38 (1.35, 1.40)*
Cardiovascular disease	3154	2380	774	1.33 (1.28, 1.37)*
Respiratory disease	1097	833	264	1.32 (1.24, 1.40)*

[a] Rate ratios (RRs) were calculated as ratios between the hospital admission numbers in the cold spell period and in the reference period.
* $p<0.05$.

4. Discussion

In this analysis, both heat waves and cold spells were associated with increased risk of hospital admissions in Shanghai. Our finding is consistent with previous studies reporting the effect of extreme temperature on hospital admission worldwide (Johnson et al., 2005; Knowlton et al., 2009; Kovats et al., 2004; Lin et al., 2009; Tataru et al., 2006; Vanhems et al., 2003; Weisskopf et al., 2002). Interestingly, the cold spell seemed to have a larger impact on hospital admission than the heat wave in Shanghai. To our knowledge, this is the first study in China examining the relationship between extreme temperature and morbidity outcomes.

The rapid built up of greenhouse gasses is expected to increase both mean temperature and temperature variability around the world. This change added urgency to the need of better understanding of the health impact of extreme temperature, including not only heat waves but also cold spells. Previously, the impacts of heat waves on mortality were examined in several Chinese cities, including Shanghai (Huang et al., 2010; Tan et al., 2007) and Beijing (Chung et al., 2009). However, few Chinese cities have established city-wide morbidity reporting system, and consequently existing data on the association between extreme temperature and morbidity outcomes are quite scarce in the country.

Our study found that both heat waves and cold spells were associated with increased risk of hospitalization in Shanghai. Interestingly, cold spells had a larger impact on hospitalization than heat waves. Exposure patterns may contribute to the observed difference. In the summer, Shanghai residents use air conditioning more frequently due to the relatively higher temperature and humidity, thus reducing their exposure to high temperate. For example, in a survey of 1106 families in Shanghai, 32.7% of the families in the winter versus 3.7% in the summer never turn on air conditioner (Long et al., 2007). In addition, frequent rain in the summer in Shanghai may reduce time outdoors and thus personal exposure. In contrast, the winter in Shanghai is drier and less variable, so people are more likely to go outdoors.

In this analysis, we used daily maximum and average temperature to define the heat waves and cold spells. Generally, daily average temperature mirrors average level of exposure to temperature for 24 h (Diaz et al., 2005). Daily maximum temperature generally occurs in the daytime when people have more activities than in the evening, suggesting that daily maximum temperature might reflect the real exposure level of urban residents. In contrast, minimal temperature is usually recorded around 6 a.m. when little human activity occurs outdoors (Diaz et al., 2005).

Our study has limitations. As in other studies in this field, we used available outdoor monitoring data to represent the population exposure to extreme temperature. Also, it should be noted that our assessment of weather conditions was derived entirely from one monitoring station. Measurement error may have substantial implications for interpreting epidemiologic studies on extreme temperature. We were not able to obtain the hospital-specific number of admissions. Of course, our analysis is preliminary and exploratory; therefore we could not exclude the possibility of a spurious finding or confounding due to unmeasured factors that are associated with both extreme temperature and hospital admission. Also, due to the ecological nature of our data, we do not have individual information that allows us to conduct a more thorough examination of relationship with both extreme temperature and hospital admission. Further research will be needed to understand the modification of individual socio-demographic characteristics on extreme temperature health effects. Alternative definition of reference periods might have impact on the estimated effect of extreme temperature. Moreover, our study focused on the aggregate effects of extreme temperature upon population morbidity, so the normally used time-series analysis was not appropriate. Finally, the duration of an extreme weather period may affect the magnitude of the health effects on a population. The cold spell we examined lasted 10 days while the heat wave lasted 8 days. Although we were careful to compare only the RR for the two events but not absolute numbers, the duration of the event itself might have an impact.

In summary, exposure to extreme temperature was associated with an increased risk of hospital admissions in Shanghai. Public health programs should be tailored to prevent extreme temperature-related health problems in the city. More studies are needed in China to better understand the health impact of extreme weather events associated with global climate change.

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The authors declare they have no competing financial interests.

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