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The effect of ambient temperature on diabetes mortality in China: A multi-city time series study

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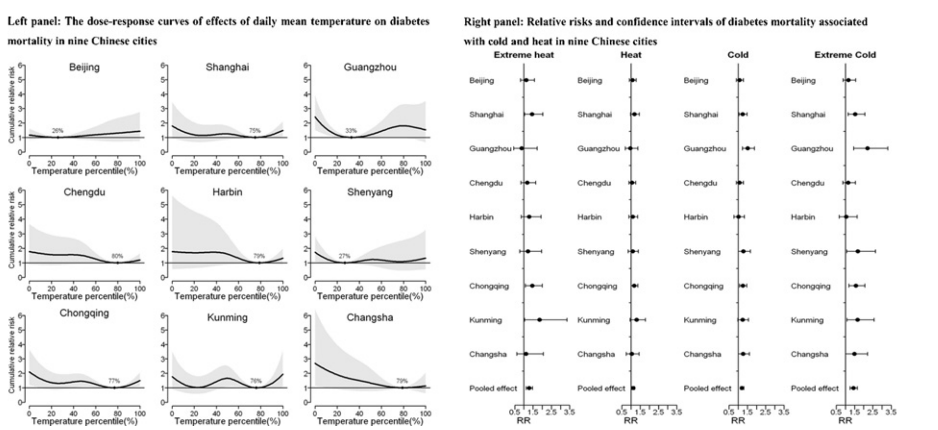
HIGHLIGHTS

- Ambient temperature is an independent risk factor for diabetes mortality.
- Effects of ambient temperature were higher among the elderly and those with no education level.
- This is the first multi-city study examining temperature impact on diabetes mortality in China.

GRAPHICAL ABSTRACT



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ABSTRACT

Few multi-city studies have been conducted to investigate the acute health effects of low and high temperatures on diabetes mortality worldwide. We aimed to examine effects of ambient temperatures on city-/gender-/age-/education-specific diabetes mortality in nine Chinese cities using a two-stage analysis. Distributed lag non-linear model was first applied to estimate the city-specific non-linear and delayed effects of temperatures on diabetes mortality. Pooled effects of temperatures on diabetes mortality were then obtained using meta-analysis, based on restricted maximum likelihood. We found that heat effects were generally acute and followed by a period of mortality displacement, while cold effects could last for over two weeks. The pooled relative risks of extreme high

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(99th percentile of temperature) and high temperature (90th percentile of temperature) were 1.29 (95%CI: 1.11–1.47) and 1.11 (1.03–1.19) over lag 0–21 days, compared with the 75th percentile of temperature. In contrast, the pooled relative risks over lag 0–21 days were 1.44 (1.25–1.66) for extreme low (1st percentile of temperature) and 1.20 (1.12–1.30) for low temperature (10th percentile of temperature), compared to 25th percentile of temperature. The estimate of heat effects was relatively higher among females than that among males, with opposite trend for cold effects, and the estimates of heat and cold effects were particularly higher among the elderly and those with low education, although the differences between these subgroups were not statistically significant ($P > 0.05$). These findings have important public health implications for protecting diabetes patients from adverse ambient temperatures.

1. Introduction

Climate change is associated with increased intensity, frequency and duration of extreme weather events (e.g., heat wave, cold spell and floods) (IPCC, 2012). Therefore, the impacts of climate change on health have led to growing concerns by governments and epidemiologists (Frumkin et al., 2008). Building public health adaptive capacity to temperature extremes and the long-term climate change requires a comprehensive and in-depth understanding of the deleterious effects of ambient temperatures on human health (Frumkin et al., 2008).

Diabetes mellitus, commonly referred to diabetes, is a group of metabolic diseases in which there are high blood sugar levels over a prolonged period (Kitabchi et al., 2009). Its acute complications include diabetic ketoacidosis and nonketotic hyperosmolar coma, and the long-term complications include cardiovascular disease, kidney failure and foot ulcers. The International Diabetes Federation (IDF) has projected that the number of diabetes patients will increase from 382 million in 2013 to 592 million by 2035 globally, with 80% of cases occurring in low- and middle-income countries (International Diabetes Federation, 2013). In China, diabetes is becoming one of the primary causes of morbidity, with a prevalence rate of about 9.7% in Chinese adults, and diabetes mortality accounted for approximately 2.8% of the total mortality of urban residents in 2011 (Chen and Yang, 2014).

To reduce the burden of diabetes, it is urgent to identify modifiable risk factors. It is well-known that individual factors (e.g. aging, obesity, smoking, high fat diet and physical inactivity) and socio-economic factors (e.g. low income and low education level) are potential risk factors in developing diabetes (Haire-Joshu et al., 2003; Mokdad et al., 2003; Yang et al., 2010). In addition, environmental drivers such as air pollution and meteorological factors could also contribute to the increase in diabetes morbidity (Andersen et al., 2012; Basu et al., 2012; Lindstrom et al., 2013; Vaneckova and Bambrick, 2013). However, evidence about environmental determinants of diabetes mortality is limited.

To date, only a few studies have assessed the relationship between ambient temperatures and diabetes mortality, reporting excess diabetes deaths increased during hot weather (Medina-Ramón et al., 2006; Schifano et al., 2009; Schwartz, 2005). Evidence on low temperatures and diabetes mortality is quite unclear. Most recently, Li et al. (2014b) found that the elevated risks of diabetes mortality were associated with both cold and heat in Harbin (in Northern China) and Chongqing (in Central China). This information may have important implications for identifying adverse health consequences resulting from extreme temperatures and guiding mitigating and preventive actions.

Evidence on the relationship between ambient temperatures and diabetes mortality at multi-city level is also limited. In this study, we examined the effects of high and low temperatures on daily diabetes mortality in nine Chinese cities using a standardized analytic method. We also aimed to identify demographic factors (e.g. age, gender and education level) that may increase susceptibility to temperature-related diabetes mortality.

2. Materials and methods

2.1. Data collection

In this analysis, the study population included residents of nine large cities (Beijing, Shanghai, Shenyang, Harbin, Chengdu, Chongqing, Kunming, Changsha and Guangzhou) in China (Fig. 1). Beijing, Shenyang and Harbin are located in northern China, with temperate monsoon climate and cold winter. Shanghai is located in eastern China, with a subtropical monsoon climate and four distinct seasons. Chengdu and Chongqing are located in central China, with subtropical monsoon humid climate, mild winter and hot summer. Kunming, Changsha and Guangzhou are located in southern China, with subtropical climate, warm winter and hot summer. Our study areas were restricted to the urban areas because the Death Registry System had not been well established in rural areas in China.

The daily mortality data of urban residents were collected from the Chinese National Center for Chronic and Noncommunicable Disease Control and Prevention from 1 January 2007 to 31 December 2013. The daily counts for diabetes, coded E10-E14 according to International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10), were used in the analysis. The population data of each city was based on the China's Sixth National Population Census in 2010. This study was approved by the Ethics Committee of Chinese Center for Disease Control and Prevention (No. 201214).

Daily weather data were collected from China Meteorological Data Sharing Service System (http://cdc.nmic.cn/home.do) from one weather monitoring station for each city, including daily mean temperature, daily minimum temperature, daily maximum temperature, daily relative humidity, and daily atmospheric pressure. There are no missing values of these meteorological measures during the study period.

2.2. Statistical analysis

The association between temperature and diabetes mortality was investigated with a 2-stage analysis.

At the first stage, we examined city-specific non-linear and lagged effects of temperatures on daily diabetes death counts. We used distributed lag non-linear model (dlnm) combined with quasi-Poisson regression allowing for over-dispersion. Briefly, we incorporated several covariates in the first-stage model: (1) a natural cubic spline of time variable (1, 2, 3,..., 2557) with 7 degrees of freedom (df) per year to control for long-term trend and seasonality of diabetes mortality; (2) a natural cubic spline with 3 df respectively for barometric pressure and relative humidity to control for their potential confounding effects; (3) day of the week and public holiday as indicator variables. These specifications were in line with previous investigations (Guo et al., 2011; Guo et al., 2013; Yang et al., 2012). In order to fully capture the effects of temperature on mortality, we included a two-dimensional natural cubic spline function to fit effects of temperature and its lag effect, which was produced by dlnm in the model. This function is flexible enough to examine the non-linear exposure-response relationship and delayed effect