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The effect of heat waves on mortality and effect modifiers in four communities of Guangdong Province, China

Weilin Zeng [a,1], Xiangqian Lao [b,1], Shannon Rutherford [c], Yanjun Xu [d], Xiaojun Xu [d], Hualiang Lin [a], Tao Liu [a], Yuan Luo [a], Jianpeng Xiao [a], Mengjue Hu [a], Cordia Chu [c], Wenjun Ma [a,*]

[a] Guangdong Provincial Institute of Public Health, Guangdong Provincial Center for Disease Control and Prevention, Guangzhou, China
[b] School of Public Health and Primary Care, Faculty of Medicine, The Chinese University of Hong Kong, China
[c] Center for Environment and Population Health, School of Environment, Griffith University, Australia
[d] Institute of Chronic Non-communicable Disease Control and Prevention, Guangdong Provincial Center for Disease Control and Prevention, Guangzhou, China

HIGHLIGHTS

- Mortality effects of extreme heat were mainly explained by high temperature.
- Extreme heat effects were higher for the rural areas than urban areas.
- Extreme heat effects were higher for respiratory mortality, for the elderly and for females.

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ABSTRACT

Background: Heat waves have been reported to be associated with increased mortality; however, fewer studies have examined the effect modification by heat wave characteristics, individual characteristics and community characteristics.
Methods: This study investigated the effect of extreme heat on mortality in 2 urban and 2 rural communities in Guangdong Province, China during 2006–2010. The effect of extreme heat was divided into two parts: main effect due to high temperature and added effect due to prolonged heat for several consecutive days. A distributed lag non-linear model was used to calculate the relative risk with consideration of lag days and potential confounding factors. Separate models were further fit by individual characteristics (cause of death, age and gender) and heat wave characteristics (intensity, duration and timing), and potential effect modification of community characteristics was examined using a meta-regression, such as educational levels, percentage of the elderly, Gross Regional Domestic Product (GDP).
Results: The overall main effects (ER = 8.2%, 95% CI: 3.4%, 13.2%) were greater than the added effects (ER = 0.0%, 95% CI: −3.8%, 4.0%) on the current day. The main effect peaked at lag0–2, and was higher for the two rural areas compared to the two cities, for respiratory compared to cardiovascular mortality, for those ≥75 years old and for females. The modifying effects of heat wave characteristics and community characteristics on mortality were not statistically significant.
Conclusion: This study suggests the effects of extreme heat were mainly driven by high temperature, which can be modified by some individual characteristics.

1. Introduction

There have been many studies examining the mortality risk from heat waves (Basagana et al., 2011; Gosling et al., 2007; Huynen et al., 2001; Knowlton et al., 2009; Whitman et al., 1997). Studies on associations of temperature with mortality could be divided into analyses of discrete events and time-series analyses of large arrays of consecutive daily data (Hajat et al., 2002; Wu et al., 2013). Recently, a few studies have brought these approaches together by assuming that the effect of heat may be described as the sum of two contributions: a "main effect" because of the independent effect of daily high temperature, and an "added effect" due to duration of sustained heat for several consecutive days (Gasparrini and Armstrong, 2011; Huang et al., 2012). For example, a study of 108 U.S. cities found that most of the excess death risk

* Corresponding author at: Guangdong Provincial Institute of Public Health, Guangdong Provincial Center for Disease Control and Prevention, No. 160 Qunxian Road, Panyu District, Guangzhou, China. Tel.: +86 20 31051602; fax: +86 20 31051652.
E-mail address: mwj68@vip.tom.com (W. Ma).
[1] Weilin Zeng and Xiangqian Lao contributed equally to this work.

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with heat waves came from main effect rather than the added effect (Gasparrini and Armstrong, 2011).

Additionally, there may be some potential factors that can modify the effect of extreme heat on mortality, such as heat wave characteristics (Anderson and Bell, 2011; Barnett et al., 2012), individual characteristics and community characteristics (Basagana et al., 2011; Ma et al., 2012; O'Neill et al., 2003). Some previous studies showed higher mortality risk from heat waves with higher intensity, longer duration, or earlier occurrence in the summer (Anderson and Bell, 2011; Barnett et al., 2012; D'Ippoliti et al., 2010; Rocklov et al., 2012). Besides, studies showed that preexisting health status and demographic characteristics (e.g., age, gender and cause of death) could also modify the mortality effects of heat (Medina-Ramón et al., 2006). However, most of these studies were conducted in developed countries, and the findings remained inconsistent.

Moreover, some community characteristics might affect the relationship between heat and mortality across communities, such as educational level, socioeconomic status, and the percentage of the elderly (Curriero et al., 2002; O'Neill et al., 2003). People living in urban cities are possibly vulnerable due to the urban heat island effect and greater social isolation (Laaidi et al., 2012; Tan et al., 2009). However, rural residents in developing countries may also be vulnerable because of lower socioeconomic status and limited access to high quality health services and air conditioning. Although some studies have compared the heat wave effect on mortality between urban and rural areas, the results were inconsistent or contradictory (Laaidi et al., 2012; Sheridan and Dolney, 2003; Tan et al., 2009). For example, a European study found that heat-related mortality in urban cities was larger than that in rural areas (Hajat et al., 2007). However, the level of urbanization was not found to be a significant predictor in Ohio, U.S.A. (Sheridan and Dolney, 2003). Exploring this issue in more details through conducting a multi-community study in rural and urban areas of China will help to identify several vulnerable subpopulations and better establish protective health programs for the vulnerable population in the context of climate change.

Several studies have assessed the effect of heat waves on mortality in China (Huang et al., 2010; Levick, 1859; Liu Ling and Zhang, 2010; Pan et al., 1995; Tan et al., 2006). However, most of them mainly focused on a single city, and fewer have examined the possible effect modifiers (Tan et al., 2006). Better understanding on how heat events affected population in subtropical areas is useful for decision makers to better prepare and respond to heat events and more comprehensively to estimate the future burden of heat-related deaths. The current study aimed to assess the effect of heat events on mortality, and explore whether heat wave characteristics, individual characteristics and community characteristics could modify the effect.

2. Materials and methods

2.1. Study sites

Guangdong is one of China's southernmost provinces. It has a typical subtropical climate characterized by hot, humid summers, with an average annual temperature of 22 °C. In the current study, we selected two cities (Guangzhou and Zhuhai) and two rural communities (Nanxiong and Taishan) as study sites (Fig. 1). Guangzhou is the capital city of Guangdong Province with a developed economy, and Zhuhai is a coastal city near Guangzhou. Nanxiong is an undeveloped rural county, located in the northern part of Guangdong Province. Taishan, close to the South China Sea, is a coastal rural county. These four communities were chosen because Guangzhou and Zhuhai were relatively developed areas, with higher population densities and per capita GDP than Nanxiong and Taishan (Table 1) (National Bureau of Statistics of China 2010), which make it possible to compare the heat effect between urban and rural areas. Moreover, the mortality data from four communities are of high quality (Wu et al., 2013; Xie et al., 2013).

2.2. Data collection

For each study site, we obtained daily counts of all-cause mortality excluding external deaths (International Classification of Diseases, Tenth Revision ICD-10: A00-R99), as well as counts by age-of-death group during the period 2006–2010 from Guangdong Provincial Center for Disease Control and Prevention. The Guangzhou data only included 2 districts (Yuexiu and Liwan Districts) due to data availability and quality (Liu et al., 2013; Wu et al., 2013). Daily meteorological data from all

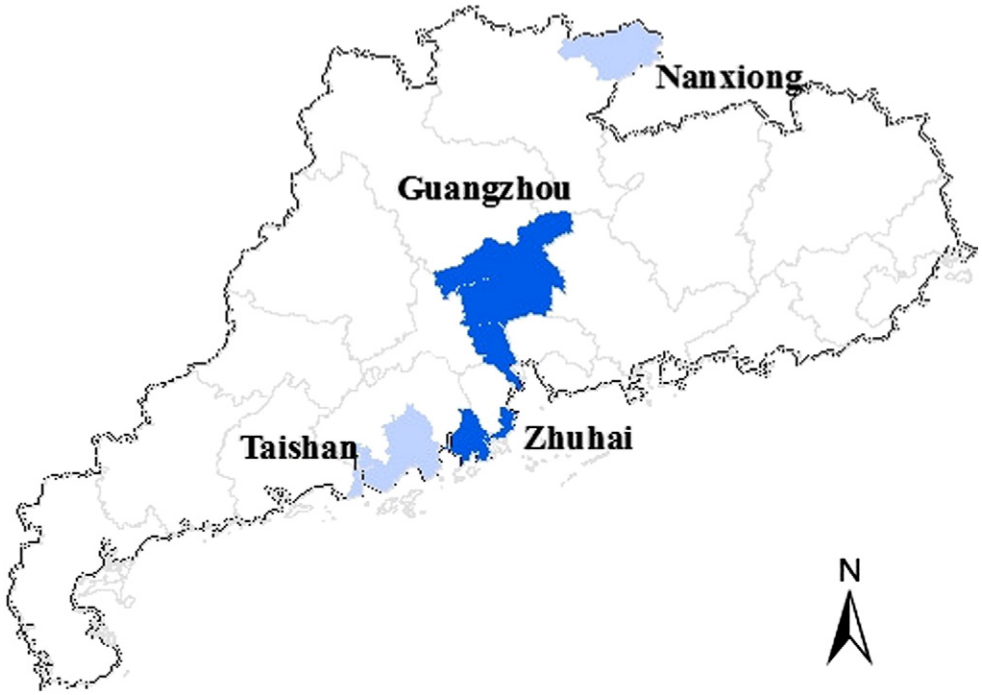

Fig. 1. The location of the study sites in Guangdong Province, China: two urban cities (Guangzhou, Zhuhai) and two rural communities (Taishan and Nanxiong).