



# Heat and mortality for ischemic and hemorrhagic stroke in 12 cities of Jiangsu Province, China



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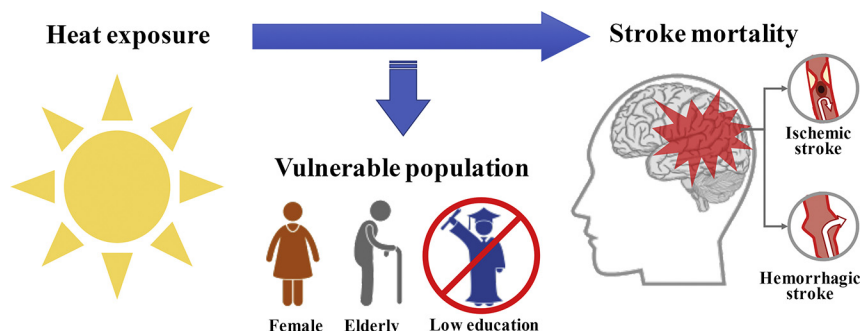
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## HIGHLIGHTS

- Whether heat effect on stroke mortality differs by stroke subtypes remains unclear.
- Significant heat effects on subtypes of stroke mortality were found in Jiangsu.
- Heat effect on mortality was higher in ischemic stroke than in hemorrhagic stroke.
- Female, elderly, and people with lower education level are vulnerable populations.

## GRAPHICAL ABSTRACT



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## ABSTRACT

**Background:** Little evidence exists on the relationship between heat and subtypes of stroke mortality, especially in China. Moreover, few studies have reported the effect modification by individual characteristics on heat-related stroke mortality. In this study, we aimed to evaluate the effect of heat exposure on total, ischemic, and hemorrhagic stroke mortality and its individual modifiers in 12 cities in Jiangsu Province, China during 2009 to 2013.

**Methods:** We first used a distributed lag non-linear model with quasi-Poisson regression to examine the city-specific heat-related total, ischemic, and hemorrhagic stroke mortality risks at 99th percentile vs. 75th percentile of daily mean temperature in the whole year for each city, while adjusting for long-term trend, season, relative humidity, and day of the week. Then, we used a random-effects meta-analysis to pool the city-specific risk estimates. We also considered confounding by air pollution and effect modification by gender, age, education level, and death location.

**Results:** Overall, the heat-related mortality risk in 12 Jiangsu cities was 1.54 (95%CI: 1.44 to 1.65) for total stroke, 1.63 (95%CI: 1.48 to 1.80) for ischemic stroke, and 1.36 (95%CI: 1.26 to 1.48) for hemorrhagic stroke, respectively. Estimated total, ischemic, and hemorrhagic stroke mortality risks were higher for women versus men, older people versus younger people, those with low education levels versus high education levels, and deaths that occurred outside of hospital. Air pollutants did not significantly influence the heat-related stroke mortality risk.

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**Conclusions:** Heat exposure significantly increased both ischemic and hemorrhagic stroke mortality risks in Jiangsu Province, China. Females, the elderly, and those with low education levels are particularly vulnerable to this effect.

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## 1. Introduction

Stroke is the world's second leading cause of death after ischemic heart disease in 2010 (Lozano et al., 2013). The absolute number of stroke deaths has been increasing worldwide during the past two decades, with most of this burden occurring in low-income and middle-income countries (Feigin et al., 2014). Disproportionately higher stroke burden was found in China, which accounts for 19.9% of the total mortality (Go et al., 2013). From 1990 to 2013, stroke has increased by 47.7% in China, with a greater increment in ischemic stroke (143.3%) than hemorrhagic stroke (17.9%) (Zhou et al., 2016).

Primary stroke prevention is critical in reducing the high stroke burden. Community-based stroke prevention generally focuses on traditional risk factors, such as hypertension treatment, smoking control, healthy eating habits education (Liu et al., 2011; Liu et al., 2007). The relationship between environmental risk factors and stroke mortality has not been well-understood (Chen et al., 2013). Recent epidemiological studies reported that high temperature (heat) was significantly associated with increased risk of total stroke mortality (Breitner et al., 2014; Chen et al., 2013; Liu et al., 2011; Revich and Shaposhnikov, 2008; Yang et al., 2016). However, few studies have examined the heat effect on subtypes (ischemic and hemorrhagic) of stroke and the limited findings remain inconsistent. High temperature was found to have an adverse effect on ischemic stroke mortality but a beneficial effect on hemorrhagic stroke mortality in four cities of Korea (Lim et al., 2013). On the contrary, a significant negative association between high temperature and ischemic stroke admission risk was reported in Jinan,

China (Wang et al., 2013). A recent meta-analysis suggested heat exposure as a significant protective factor for hemorrhagic stroke risk, but found a nonsignificant association between high temperature and ischemic stroke risk (Lian et al., 2015).

Thus, this study aimed to examine the association of heat exposure with daily total and subtypes of stroke mortality in 12 cities of Jiangsu Province, China, and to detect whether effects differ by individual characteristics (gender, age, education, and location of death).

## 2. Materials and methods

### 2.1. Data collection

This multicity study was conducted in 12 cities in Jiangsu Province, China (Fig. 1), with a total population of 74 million people in 2010. As in previous studies (Bennett et al., 2014; Chen et al., 2015), the study period was restricted to the warm season (May–September) to focus on the heat-related stroke mortality risk.

Daily stroke mortality data from 2009 to 2013 were obtained from the Death Register System from the Jiangsu Provincial Center for Disease Prevention and Control (CDC) for 12 cities, i.e., Changzhou, Huaian, Lianyungang, Nanjing, Nantong, Suzhou, Taizhou, Wuxi, Xuzhou, Yangzhou, and Zhenjiang. In China, death certificates were first completed at the time of death by hospital or community doctors and then reported to CDC via a network reporting system. In death certificates, doctors filled in the causes of death and corresponding International Statistical Classification of Diseases and Related Health Problems



**Fig. 1.** Locations of 12 study cities and 31 weather stations in Jiangsu Province, China.

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