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Non-linear effects of mean temperature and relative humidity on dengue incidence in Guangzhou, China

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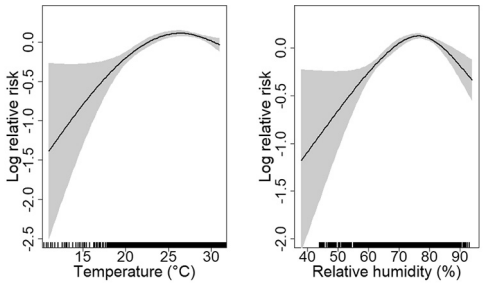
HIGHLIGHTS

- The exposure-response between weather and dengue fever was examined.
- Non-linear effects of temperature and humidity were found.
- The threshold for the effect of temperature was found at 28 °C.
- The threshold for the effect of humidity was found at 76%.
- Positive effects were found for temperature and humidity below the thresholds.

GRAPHICAL ABSTRACT



Temperature and relative humidity are non-linearly associated with dengue fever with thresholds.

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ABSTRACT

Background: Dengue fever is an important infectious disease in Guangzhou, China; previous studies on the effects of weather factors on the incidence of dengue fever did not consider the linearity of the associations.
Methods: This study evaluated the effects of daily mean temperature, relative humidity and rainfall on the incidence of dengue fever. A generalized additive model with splines smoothing function was performed to examine the effects of daily mean, minimum and maximum temperatures, relative humidity and rainfall on incidence of dengue fever during 2006–2014.
Results: Our analysis detected a non-linear effect of mean, minimum and maximum temperatures and relative humidity on dengue fever with the thresholds at 28 °C, 23 °C and 32 °C for daily mean, minimum and maximum temperatures, 76% for relative humidity, respectively. Below the thresholds, there was a significant positive effect, the excess risk in dengue fever for each 1 °C in the mean temperature at lag7–14 days was 10.21%, (95% CI: 6.62% to 13.92%), 7.10% (95% CI: 4.99%, 9.26%) for 1 °C increase in daily minimum temperature in lag 11 days, and 2.27% (95% CI: 0.84%, 3.72%) for 1 °C increase in daily maximum temperature in lag 10 days; and each 1% increase in relative humidity of lag7–14 days was associated with 1.95% (95% CI: 1.21% to 2.69%) in risk of dengue fever.

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Conclusions: Future prevention and control measures and epidemiology studies on dengue fever should consider these weather factors based on their exposure-response relationship.

1. Introduction

Dengue fever is a group of mosquito-borne communicable disease caused by four different dengue virus serotypes (DENV 1–4) (Ali, 2015). Mainly driven by the global climate change and increasing international tourism and trading, dengue fever has expanded to more wide range of the world, and now reported in >100 countries and regions in the world (Brady et al., 2012; Liu et al., 2014).

Since its reemergence in Guangdong Province in 1978, dengue fever has remained a relatively low epidemic level in mainland China until the large outbreak in 2014 (Lin et al., 2016; Xiao et al., 2016), and geographical expansion has been observed in recent years (Sun et al., 2017). Currently, dengue epidemic has been reported in about 27 provinces in mainland China (Sang et al., 2015a; Sun et al., 2017).

Among various potential influencing factors, meteorological factors have been associated with the distribution and transmission of this infection (Gu et al., 2016; Lu et al., 2009; Xu et al., 2016). A great number of studies have supported that ambient temperature, humidity and rainfall are the most relevant weather factors affecting the dengue epidemic (Lu et al., 2009; Xiang et al., 2017). For example, one study in Guangzhou reported that 1 °C increment in daily average temperature was linked with a 6.99% increase in dengue fever incidence with a 3 lag day (Fan et al., 2013). One Poisson model also showed a positive effect of ambient temperature on the incidence of dengue fever in Singapore and Mexico (Colon Gonzalez et al., 2011; Earnest et al., 2012). One issue of those previous studies was that they did not consider the exposure-response relationship. One recent study from Guangzhou examined the temperature-dengue relationship using a piecewise linear spline function, and found that the most appropriate temperature for dengue fever was 21.6–32.9 °C in term of maximum temperature, and 11.2–23.7 °C for minimum temperature at a daily scale (Xiang et al., 2017); another study from the same city, Guangzhou, reported that the highest risk of dengue fever was at a monthly minimum temperature of 18.25 °C (Chuan et al., 2015). The discrepancy of these two studies might be due to time scale and the lag period, as well as the study population. Some studies examined the association with a few lag days (Fan et al., 2013), and other studies did the analysis with a long lag period from a few weeks to months (Chuan et al., 2015; Gu et al., 2016; Lu et al., 2009; Xiang et al., 2017).

Dengue fever infection in human usually need 1–2 weeks for the incubation period (Chan and Johansson, 2012), it is therefore more appropriate to study the effects of meteorological factors on dengue incidence with around 7–14 days' lag. As such, we conducted this analysis to examine the effects of meteorological factors on dengue fever on the basis of the exposure-response curve and appropriate lag period; we selected Guangzhou as the study area, as this city has the most dengue fever cases in mainland China in recent years (Fan et al., 2013).

2. Materials and methods

2.1. Study location

We conducted this study in Guangzhou City. Located in the southern China (Fig. 1), Guangzhou is the core city and serves as the capital city of Guangdong Province. Guangzhou is characterized by a typical subtropical climate and has substantial industrial and population communications with neighboring countries with dengue endemics, and thus is most seriously affected by dengue fever in China, during the period of 2006–2014, about 91.5% (50,350/55,045) and 72% (39,760/55,045) of the recorded dengue cases in China occurred in Guangdong Province and Guangzhou City.

2.2. Data collection

The daily number of dengue fever cases between 2006 and 2014 in Guangzhou was obtained from the China National Notifiable Disease Reporting System. Dengue fever was diagnosed based on clinical symptoms, combined with some exposure history in the epidemic season, for example, mosquito bite, and travelling history in dengue fever epidemic areas, etc. After initial diagnosis, the health department will conduct epidemiological survey, and laboratory testing to confirm the diagnosis.

We retrieved the daily data of meteorological factors from the public weather data sharing platform of China's national meteorological station. The variables for our analysis included daily mean, minimum and maximum temperatures (°C), relative humidity (%), and rainfall (mm) for the period during January 2006 to December 2014.

2.3. Statistical methods

We established the model using the data from June to November during 2006–2014, as almost 99% of the dengue cases occurred in these months in the study area. A generalized additive model was performed to examine the association between the weather factors and dengue fever; we used a quasi-Poisson link to adjust for the over-

Fig. 1. The geographical location of Guangzhou in China.