Effects of ambient temperature on bacillary dysentery: A multi-city analysis in Anhui Province, China

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HIGHLIGHTS

• High weekly mean temperature increased risks of bacillary dysentery (BD) in Anhui.
• Urbanization level modified associations between high temperature and BD incidence.
• For children <5, effect of high temperature on BD increased in high urbanized cities.

GRAPHICAL ABSTRACT

Abstract

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ABSTRACT

Background: Rising ambient temperature is expected to increase incidence of bacillary dysentery (BD), but few studies have compared the temperature-BD effects of different age groups and cities in China, especially in a multi-city setting.

Objectives: We used city-specific data including BD cases and meteorological variables to determine the relationship between BD incidence and temperature at provincial level.

Methods: Weekly BD disease surveillance data and meteorological variables were collected in all 16 prefecture-level cities in Anhui Province of China. Firstly, city-specific weekly mean temperature-BD incidence associations were estimated with Distributed Lag Nonlinear Model (DLNM). Secondly, city-specific estimates were pooled at province-level through multivariate meta-analysis. Also, we conducted subgroup analyses for ages (children <5 years old and population of other ages) and urbanization of cities (high and low level), respectively.

Results: In Anhui, BD morbidity risk increased with increasing weekly mean temperature. Relative risks (RR) at the 90th percentile (27.5 °C) versus the 50th percentile (17 °C) of weekly mean temperature were 1.42 (95% confidence interval (CI): 1.16, 1.75) and 2.02 (95% CI: 1.76, 2.32) for children <5 and population of other ages, respectively. The relative risk of high temperature on other ages group was higher than that of children under
1. Introduction

Bacillary dysentery (BD) is an intestinal infectious disease caused by the bacterial pathogen *Shigella* spp., and its clinical symptoms mainly include fever, bloody diarrhea, abdominal cramps and tenesmus (Kelly-Hope et al., 2008; Lee et al., 2017). It is spread by fecal contamination of food or water or by person-to-person contact (Kelly-Hope et al., 2008; Lee et al., 2017). It is estimated that there are more than 80 million cases of bloody diarrhea and 700,000 related deaths worldwide each year, of which about 95% occur in developing countries (Lee et al., 2017).

Since 2004, the Chinese center for disease control and prevention has reported infectious diarrhea disease including BD as a Class B infectious disease through China Information System for Disease Control and Prevention (CISDCP). Although the Chinese government has been committed to preventing and controlling BD, the incidence of BD in China is also gradually decreasing, but the disease burden remains high (Zhang et al., 2016). Update to study period of 2015, annual incidence rate of BD was approximately 16.1 per 100,000 in Anhui Province and 10.1 per 100,000 in China. The BD burden of children under 14 years of age had exceeded that of other age groups (Li et al., 2016). In Chinese studies, BD cases occurred most often in the summer and autumn, roughly from May to September (Yan et al., 2017; Zhang et al., 2016), and observed north-south differences in peak duration (Zhang et al., 2016), which seems to be driven by both human and environmental factors, including socio-economic, health conditions and climate change. Specifically, in the process of disease transmission and spatial and temporal distribution, climatic factors possibly played an important role (Kelly-Hope et al., 2008).

Climate change will be an important factor affecting the health of people in vulnerable areas (Kolstad and Johansson, 2011). Temperature is considered to be the primary factor affecting the incidence of infectious diarrhea. Some studies examined the relationship between temperature and BD in single cities. Such as in Jinan, a 1 °C increase in monthly maximum temperature might relate to an 11.40% increase in BD (Zhang et al., 2008). In Changsha, a 1 °C rise in mean temperature, mean maximum temperature, and mean minimum temperature might lead to 14.8%, 12.9%, and 15.5% increases in the incidence of BD disease, respectively (Gao et al., 2014). And in Beijing linear relationship was observed between temperature and BD for temperature >12.5 °C (Li et al., 2015). The relative risk in Hefei associated with a 1 °C increase in temperature was 1.04 (95% CI 1.00–1.07) (Cheng et al., 2017). Evidence suggests that the incidence of BD in some Chinese cities increases as temperatures rise, but different local climatic conditions, different data scales and analysis methods lead to different conclusions (Yan et al., 2017).

As climate change continues, climate-related burden of diarrhea may increase (Levy et al., 2016), and it is of great significance to quantify the relationship between meteorological factors and infectious diarrhea in China, and yet there are very few large-scale examples of these. Few studies have investigated the associations between high temperature and BD in China, especially in a multi-city setting. We used these city-specific data including BD cases and meteorological variables to determine the relationship between BD incidence and high temperature at provincial level, and examine high temperature associated with high-risk ages and cities.

2. Methods

2.1. Study location

Anhui Province is located in eastern China, including 16 prefecture-level cities (Fig. 1), with moderate economic development and a high proportion of rural population (61.3%) (Gao et al., 2016). The study area locates in a sub-humid warm temperate continental monsoon climate zone, with a hot and rainy weather in summer seasons (Gao et al., 2016). We collected all 16 cities shown in Fig. 1 as the basis of our analyses.

2.2. Classification of cities by urbanization

The quartile classification of 16 cities according to urbanization rate was shown in Fig. 1. The urbanization rate of a city refers to the percentage of the population living in urban areas in the total population. According to the 2016 Anhui Province statistical yearbook (Statistics Bureau of Anhui Province and NBS Survey Office in Anhui, 2016), the 25th percentile (P25) of the urbanization rate was 45.1%, and the 75th percentile (P75) of the urbanization rate was 60.7%.

2.3. Disease data

BD is a class B national infectious disease in China. According to diagnostic criteria for BD (WS287–2008) in China (Ministry of Health of the People’s Republic of China, 2008), a clinically diagnosed BD case was defined as a patient with the following clinical features: fever, chills, abdominal pain, tenesmus, bloody or mucus stool or stool containing >15/high power field (HPF) leukocytes or purulent cells, and microscopically discernible red blood cells and phagocytic cells. A confirmed BD case was defined as a patient through clinical diagnosis combined with the pathogenetic examination of isolation of *Shigella* spp. from a stool specimen (Chang et al., 2016). All clinical and hospital doctors must report all clinically diagnosed and confirmed BD cases to the local centers for disease control and prevention (CDC) within 24 h through the internet-based Chinese disease control and prevention information system. In this study, BD cases included clinically diagnosed cases, and confirmed cases through clinical diagnosis combined with the pathogenic examination.

Daily BD records from 1 January 2010 to 31 December 2015 were collected by Anhui provincial CDC. Case information included gender, age, residential address, and date of onset. All extracted BD cases with complete and accurate geographical location were classified and summarized according to their respective cities.

2.4. Meteorological data

City-specific daily mean temperature (°C), maximum temperature (°C), minimum temperature (°C), average relative humidity (%), and accumulated rainfall (mm) were obtained from the China Meteorological Data Sharing Service System (http://data.cma.cn/). The information of matching weather stations was shown in Fig. 1 and other literatures (Gao et al., 2016). We used meteorological data from another city with close distance and latitude to fill in missing meteorological data from Tongling and Chizhou weather stations (only from January 2010...
to April 2012, Tongling by Wuhu, Chizhou by Anqing). Daily meteorological data were averaged over a week to obtain weekly meteorological data.

2.5. Data analysis

We used two-stage analytic approach. Firstly, city-specific weekly mean temperature-BD incidence associations were estimated with Distributed Lag Nonlinear Model (DLNM). Secondly, city-specific estimates were pooled at province-level through multivariate meta-analysis (Gasparrini et al., 2015).

A generalized linear model combined with a DLNM with a quasi-Poisson distribution to account for over-dispersion was applied separately in each city in order to obtain estimates of city-specific temperature-BD associations. DLNM could describe complex nonlinear and lagged dependencies of temperature-BD through a cross-basis function, which defined the conventional exposure-response relationship and the additional lag-response relationship, respectively (Gasparrini, 2014). We selected a cross-basis composed of one \( ns \) (natural cubic B-spline, \( df = 3 \)) for the exposure-response with two knots placed at the 33th and 67th percentiles of city-specific temperature distributions, and another \( ns \) (\( df = 3 \)) for the lag-response with an intercept and one internal knot placed at 2 for lag of 0–4 weeks to capture the delayed effects of extreme temperature. For exposure–response relationship, \( ns \) with 3 \( df \) was fixed based the assumption that both high and low temperature may have impact on BD incidence. The lag period (0–4 weeks) was expected to capture the effects of meteorological variables on intestinal infectious diseases with an average lag period of 3–4 weeks even 1 month (Singh et al., 2001; Zhang et al., 2008). Based Quasi Akaike information criterion (QAIC), relative humidity and rainfall were controlled for by using \( ns \) (\( df = 2 \) and 2), respectively. To control for seasonal pattern and long-term trend, we used the \( ns \) of week time (\( df = 5 \)). To control the auto-correlation, we included the first-order lagged residual item into models.

We combined city-specific estimates through fixed-effects meta-analysis. The estimates of multivariate meta-analysis represented the province-level effects were obtained through an intercept only model. We predicted the average relative risk (RR) with confidence interval (CI) of exposure-response relationship, over average mean temperature and temperature range across cities (Gasparrini et al., 2012). Cochran’s Q-test and \( I^2 \) statistic was applied to evaluate heterogeneity across cities. Cochran’s Q-test could test the significance of heterogeneity. Multivariate meta-regression models, each including a single meta-predictor (urbanization rate and per capita GDP), were used to extend the analysis by Wald test (Gasparrini et al., 2012). To explore the explained percentage of city-specific factors on heterogeneity, we computed the spatial stratified heterogeneity \( q \)-statistic (SSH-q) (Wang et al., 2016). We selected the city-specific RRs at 27.5 °C as dependent variable, and urbanization rate was categorized into three levels (\( \phi P25, P25\text{-}P75, \phi P75 \)). Factor detector results showed \( q \) statistic, and the percentage of heterogeneity explained by urbanization rate equaled 100\% (Wang et al., 2016).

Using meta-regression model, the exposure–response associations were predicted for the values of the 25th percentile (low level) and 75th percentile (high level) of urbanization rates (Gasparrini et al., 2012). We summarized the results by computing the RRs at the 90th percentile (27.5 °C) from these curves, using the 50th percentile (P50) of weekly mean temperature (17 °C) as the reference. We compared those overlapped 95% CIs of the RRs of different ages and urbanization subgroups using the method introduced by Altman and Bland (Altman and Bland, 2003). In this method, \( z \) test was used to test the difference between log transformed relative risks.

We conducted subgroup analyses for populations of different ages (children <5 years of age and population of other ages) and cities of
different urbanization level (high and low), respectively. We performed sensitivity analysis by changing of $\text{df}$ for weather variables and time, and conducted the Partial autocorrelation function (PACF) plots of the residuals of models to check whether existed autocorrelation (Supplementary figures). All analyses were performed using ArcGIS 10.5 (ESRI, USA) and R software (package “dlnm” and “mvmeta”).

### 3. Results

Summary statistics for weekly numbers of BD cases reported and meteorological variables in 16 cities of Anhui during Jan 1st 2010 - Dec 31st 2015 were shown in Table 1. There was a total of 72,649 BD cases during the study period in Anhui, with 19,959 cases of children under 5 years of age. The most prevalent cities were Fuyang (19,678), Suzhou (14,960), and Hefei (11,242). Wuhu (0.4665) had the highest proportion of childhood BD cases, followed by Hefei (0.3299), and Suzhou (0.3183). In Anhui, the BD incidence peaked in 26th–33rd weeks (July–August) according with high ambient temperature, as shown in Fig. 2. From 2013 onward, the number of BD cases reported at the peak in Anhui decreased approximately by half.

The associations between weekly mean temperature and BD incidence estimated from model were illustrated in Table 2 (for all cities) and Fig. 3 (panel A/C). As a whole for all study cities of Anhui, both the 50th percentile (P50) of weekly mean temperature (17 °C) was the reference for two age groups: children <5 and population of other ages. Summarized by RR at the 90th percentile versus the reference of 1.42 (95% CI: 1.16, 1.75) and 2.02 (95% CI: 1.76, 2.32), for children <5 and population of other ages, respectively. The relative risk of high temperature on other age groups was higher than that of people under five years old ($p = 0.006$).

The province-pooled specific lag-response curves at the 90th percentile (P90) of weekly mean temperature percentile (27.5 °C) are represented in Fig. 3 (panel B/D). For two age groups, the lag effects seemed increased after lagged two weeks, and most of the risk was limited to 4 weeks (lag 0–4).

The Cochran Q test provided evidence for heterogeneity for two age groups (Table 3). And through univariate meta-regression analysis and Wald test, we found urbanization rate was a significant meta variable for both two age groups ($p = 0.000$). $F$ statistics dropped from 34.5% to 18.7% for children under 5, and from 37.9% to 22.3% for population of other ages. Results of spatial stratified heterogeneity $q$-statistic showed that urbanization rate explained 11.4% ($p = 0.515$), 13.3% ($p = 0.442$) of heterogeneity for under five and other ages, respectively.

Fig. 4 showed the exposure-response and lag-response relationships of subgroup analyses by age and urbanized level of cities (values see in Table 2). For children under five, Fig. 4 (panel A) illustrated that high temperatures, on average, had a greater impact in high urbanized cities, with a significant raise in risk: the RR at 27.5 °C versus 17 °C increased from 1.01 (95% CI: 0.70, 1.46) for low urbanized cities to 1.56 (95% CI: 1.20, 1.92) for high urbanized cities ($p = 0.044$). For other ages group in Fig. 4 (panel C), the RR changed from 1.67 (95% CI: 1.32, 2.13) for low urbanized cities to 2.16 (95% CI: 1.84, 2.53) for high urbanized cities ($p = 0.082$).

### 4. Discussion

This study examined the impacts of high temperature on BD disease in a multi-city setting within the province of Anhui of China using the DLNM model, and confirmed that the positive associations between weekly BD incidence and high temperature in Anhui Province had varied over cities and ages. Most cases occurred in 26th–33rd week (July and August), which is consistent with the increasing BD cases associated with rising temperature. Our findings suggest that public health programs should focus on preventing BD related to high temperature, especially among high urbanized cities in Anhui of China.

In this study the effects of high temperature on BD incidence were estimated using DLNM model. We applied the DLNM model to reveal changes in the risk of BD incidence with ambient temperature, including the cumulative effects of different temperatures over the coming four weeks (Lag 0–4 weeks) in Fig. 3 (panel A/C), and the effect of high temperature conditions (27.5 °C) on subsequent BD incidence at different lag weeks (Lag = 0,1,2,3,4, respectively) in Fig. 3 (panel B/D). Some studies also had assessed the associations of high ambient temperature and different kinds of diarrhea, such as non-cholera diarrhea (Hashizume et al., 2007), infectious gastroenteritis, and bacillary dysentery (Zhang et al., 2007). Studies in some Chinese cities had found that increased temperature would lead to more cases of BD, such as in Jinan (Zhang et al., 2008), Changsha (Gao et al., 2014), Beijing (Li et al., 2015) and Hefei (Cheng et al., 2017).

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### Table 1

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>Min</th>
<th>P25</th>
<th>Median</th>
<th>P75</th>
<th>Max</th>
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<tr>
<td>Bacillary dysentery (Total)</td>
<td>14.3</td>
<td>0.0</td>
<td>2.0</td>
<td>6.0</td>
<td>15.0</td>
<td>259.0</td>
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<tr>
<td>Children &lt;5</td>
<td>3.9</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
<td>4.0</td>
<td>80.0</td>
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<tr>
<td>Other ages</td>
<td>10.4</td>
<td>0.0</td>
<td>2.0</td>
<td>4.0</td>
<td>11.0</td>
<td>210.0</td>
</tr>
<tr>
<td>Mean temperature (°C)</td>
<td>15.9</td>
<td>−4.2</td>
<td>7.2</td>
<td>17.3</td>
<td>23.9</td>
<td>34.4</td>
</tr>
<tr>
<td>Min temperature (°C)</td>
<td>12.1</td>
<td>−9.2</td>
<td>3.5</td>
<td>12.9</td>
<td>20.6</td>
<td>30.1</td>
</tr>
<tr>
<td>Max temperature (°C)</td>
<td>20.9</td>
<td>0.7</td>
<td>12.9</td>
<td>22.8</td>
<td>28.4</td>
<td>41.0</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>71.8</td>
<td>25.5</td>
<td>64.7</td>
<td>73.3</td>
<td>80.3</td>
<td>97.4</td>
</tr>
<tr>
<td>Rainfall (mm)</td>
<td>3.2</td>
<td>0.0</td>
<td>0.1</td>
<td>1.3</td>
<td>4.1</td>
<td>54.9</td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Population</th>
<th>Cities</th>
<th>Weekly mean temperature (P90/27.5 °C vs. P50/17 °C)</th>
</tr>
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<tr>
<td>Children &lt;5</td>
<td>Total</td>
<td>1.42</td>
</tr>
<tr>
<td></td>
<td>High urbanized</td>
<td>1.56</td>
</tr>
<tr>
<td></td>
<td>Low urbanized</td>
<td>1.01</td>
</tr>
<tr>
<td>Other ages</td>
<td>Total</td>
<td>2.02</td>
</tr>
<tr>
<td></td>
<td>High urbanized</td>
<td>2.16</td>
</tr>
<tr>
<td></td>
<td>Low urbanized</td>
<td>1.67</td>
</tr>
</tbody>
</table>

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![Fig. 2. Weekly numbers of cases for bacillary dysentery and mean temperature in Anhui of China 2010–2015.](Image)
Shigella spp. are bacteria that causes BD. Shigella is suitable for growth at temperatures ranging from 6–8 °C to 45–47 °C and an optimum temperature of 37 °C (ICMSF, 1996). Higher temperature might increase the survival rate and replication rate of pathogens in the environment. Shigella can be transmitted through the fecal-oral route or through person-to-person contact or by consumption of contaminated food or water. A study of outbreaks of food-borne BD in the United States had shown about 50% of outbreaks were associated with consumption of raw food (Nygren et al., 2013). Also, the survival rate of Shigella is usually increased when the food is kept at a refrigerated temperature (4 °C) (Warren et al., 2006). Under high temperature conditions, people like cold drinks and cold foods will also increase the outbreak of food-borne BD disease.

Our study found that the relationship between the risk of BD incidence and temperature above a certain threshold was almost linear consistently with other study (Liu et al., 2019). Studies in Hefei (the capital city of Anhui Province) revealed that temperature effects elevated linearly above 18.4 °C (temperature threshold in warm season) (Cheng et al., 2017), specially the temperature threshold was 17.0 °C for under-five children BD (Li et al., 2016). Also, in Beijing city, with an approximately linear effect for temperature >12.5 °C (Li et al., 2015), and in Shanghai city between 12 °C and 22 °C, temperature was approximately positively linear correlated with the logarithm of BD counts (Ma et al., 2013). No thresholds were detected in the southern city of China (Zhang et al., 2007). Consistently with other studies, temperature and BD generally show a linear relationship within a certain temperature range. Of course, the majority of BD cases tend to occur at mild high temperatures (Cheng et al., 2017). In Fig. 3 (panel C), the cumulative effects curve of Xuancheng city was different from other cities. In Xuancheng for other ages group (above 5 years old), the proportion of cases that occurred when mean temperature was below 17 °C reached 35% (293/827), which was higher than the average ratio of other cities (24%). This result may reveal that not only high temperatures were associated with the onset of BD, but also low temperatures would have an impact on BD incidence in the specific city.

![Cumulative effect](image1.png)

![Lag-RR plot for mean temp=27.5°C](image2.png)

![Cumulative effect](image3.png)

![Lag-RR plot for mean temp=27.5°C](image4.png)

**Fig. 3.** Meta-pooled and city-specific cumulative and lag effects between weekly mean temperature and BD incidence for Children under 5 (panel A/B) and other ages population (panel C/D).

### Table 3

<table>
<thead>
<tr>
<th>Population</th>
<th>Meta models</th>
<th>Cochran Q test</th>
<th>( \chi^2 ) Wald test</th>
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<tr>
<td></td>
<td></td>
<td>( Q )</td>
<td>( df )</td>
</tr>
<tr>
<td>Children &lt;5</td>
<td>Intercept only</td>
<td>206.1</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td>Urbanization rate</td>
<td>155.0</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td>Per capita GDP</td>
<td>197.9</td>
<td>126</td>
</tr>
<tr>
<td>Other ages</td>
<td>Intercept only</td>
<td>217.4</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td>Urbanization rate</td>
<td>162.2</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td>Per capita GDP</td>
<td>194.2</td>
<td>126</td>
</tr>
</tbody>
</table>
In our study most of the effects of high temperature on BD were limited to 4 weeks (lag 0–4). This result was consistent with other studies on meteorological variables and intestinal infectious diseases, which found an average lag effect of 3–4 weeks or 1 month (Singh et al., 2001; Zhang et al., 2008). The temperature in the previous 1 month was most correlated with the number of monthly BD cases (Gao et al., 2014). A four-week lag was biologically possible because that time includes bacteria that grow in the best environment, spread through contaminated food and water, from the onset of an intestinal infection (Gao et al., 2014; Zhang et al., 2008). Our study also showed that the effects of extreme heat over 2 weeks on the incidence of BD were still present, especially for children under 5 years of age. We thought both re-infected cases and lack of effective treatment and vaccines were responsible for the long-term lag effects. If a child had acute bacterial dysentery, who did not receive standardized antibiotics treatment or still didn’t pay attention to hygiene, it was very easy for children to be re-infected in the short term (Khalili, 2014). This study indicated that the long-term effects of meteorological factors on BD also deserve attention.

Regional differences in socioeconomic status also play an important role in the spread of infectious diseases. As the largest developing country in the world, China is experiencing rapid urbanization. Urban sprawl, characterized by “heat island effect” and high population density, is challenging public health systems. Previous studies have shown that urban areas are warmer than rural areas because of the urban heat

**Fig. 4.** Meta-pooled cumulative and lag effects between weekly mean temperature and BD mobility for Children under 5 (panel A/B) and other ages population (panel C/D) from high and low urbanized cities.
island effect (Cheng et al., 2017). Also, central districts of the city of Wuhan were found to be the high-risk areas of BD incidence (Li et al., 2013). And, population density can modify the relationship between temperature and BD, with an increase of 1000 people per square kilometer associated with the increase of BD being 240% (Xiao et al., 2014). Dense urban populations promote transmission through direct and indirect human contact (Zhang et al., 2016). BD epidemics are most common in crowded areas with inadequate sanitation (Gao et al., 2014). In China, the extent of the impact of climate factors may be highly dependent on sanitation infrastructure in different regions (Kolstad and Johannsson, 2011). So, the development of BD prevention and control in urban villages, which provide humble shelter for migrants and local poor from rural to urban areas, should be intensified (Zhang et al., 2016). This study can lead to increased public awareness and plans for better interventions during the high-temperature season to prevent or reduce the potential outbreak or spread of BD. Further research on specific transmission pathways of BD (water or food transmission) is necessary in highly urbanized cities.

One study projected a temperature rise of 4 °C over land in tropical and subtropical regions by the end of this century, associated mean increased relative risk of diarrhea for developing countries was 8–9% by 2030 compared with period of 1961–1990 (Kolstad and Johannsson, 2011). In the context of climate change, practitioners and policy makers should actively take measures to prevent and control infectious diseases, such as investing in health facilities, strengthening the management of safe drinking water and developing vaccines, which will significantly reduce the burden of diseases related to diarrhea caused by global warming, including BD (Kolstad and Johannsson, 2011). Therefore, under the premise of considering regional climatic conditions and demographic characteristics, public health actions should be actively taken at the present stage to reduce the risk of BD disease caused by climate warming in the future. At the same time, we should strengthen the health education of temperature change and improve people’s awareness of preventing diseases related to climate change.

Our study had two main advantages. Study data in recent years from multiple cities were included in the analysis, and using DLNM model depicted the cumulative risk and lag-response relationships between temperature and BD. In interpreting the results of this study, some limitations should be acknowledged. Our study was an ecological study, and the absence of an individual level association analysis limited the strength of causal inference. Due to the lack of data, this study did not consider the impact of preventive actions such as environmental sanitation and drinking water disinfection in different cities during the epidemic season. Our research results were only from one province in China, which would limit the extrapolation of the conclusions to other regions with different socio-economic and meteorological conditions.

According to current research design and data analysis, the effect of high temperature on BD still existed when the lag period was expanded to four weeks and it is hard to explain. Future study is needed to explore the ideal shape of effect of temperature on BD with decreasing trend until not significant.

5. Conclusions

In summary, we investigated the associations between ambient temperature and BD incidence in multiple cities from Anhui Province of China, and found that rising temperature could result in substantial burden of BD, especially for high urbanized cities. Therefore, public health actions should be actively taken at the present stage to reduce the risk of BD disease caused by climate warming and urbanization in the future.

Competing interests

None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2019.03.443.

References


