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# Impact of ambient temperature on clinical visits for cardio-respiratory diseases in rural villages in northwest China

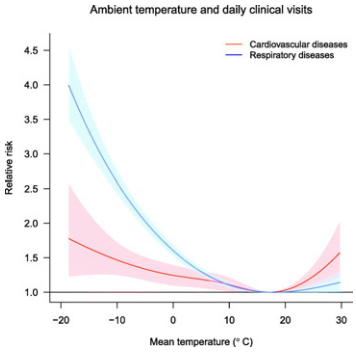
Qi Zhao [a,1], Yi Zhao [b,1], Shanshan Li [c], Yajuan Zhang [b], Qingan Wang [b], Huiling Zhang [b], Hui Qiao [b], Wuping Li [b], Rachel Huxley [d], Gail Williams [a], Yuhong Zhang [b,*], Yuming Guo [c,*]

[a] Division of Epidemiology and Biostatistics, School of Public Health, University of Queensland, Brisbane, 4006, Queensland, Australia
[b] School of Public Health and Management, Ningxia Medical University, Yinchuan, 750001, Ningxia Hui Autonomous Region, China
[c] Department of Epidemiology and Preventive Medicine, School of Public Health and Preventive Medicine, Monash University, Melbourne, 3004, Victoria, Australia
[d] School of Public Health, Curtin University, Kent Street, Perth, 6102, Western Australia, Australia

## HIGHLIGHTS

- Temperature and cardio-respiratory clinical visits was studied in rural China.
- An U-/reverse J-shaped association was found for the two illness, respectively.
- Extreme cold was stronger and immediate on respiratory disease.
- Moderate cold resulted in most of the temperature-related clinical visits.

## GRAPHICAL ABSTRACT

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## ABSTRACT

*Background:* The association between temperature and cardio-respiratory disease in urban areas has been widely reported but there is limited information from populations living in rural areas that may be disproportionately affected by climate change.
*Objectives:* To quantify the associations between daily temperature and clinical visits due to cardiovascular and/or respiratory disease in rural villages in the Ningxia Hui Autonomous Region, China over 2012–2015.
*Methods:* Daily data on clinical visits and weather conditions were collated from 203 villages. A quasi-Poisson regression with distributed lag non-linear model was used to examine the associations between daily temperature and clinical visits up to 28 days, after controlling for potential confounders.
*Results:* Over three years, 158,733 and 1,272,212 clinical visits were recorded for cardiovascular and respiratory diseases, respectively. Both low and high temperatures were associated with an increased risk of clinical visits for cardiovascular-related conditions, whereas only low temperatures were associated with increased clinical visits related to respiratory illness. The cold effect on cardiovascular visits appeared at the lag 6th day and persisted until the 22nd day, resulting in a cumulative relative risk (RR) 1.55 (95% CI: 1.26–1.92), compared with the minimum-clinical visit temperature. The cold effect on respiratory visits appeared immediately and lasted over the lag 0–28 days, with a cumulative RR 2.96 (2.74–3.21). Suboptimal temperature accounted for approximately 13% and 26% of clinic visits due to cardiovascular and respiratory disorders, respectively, with the majority of cases attributable to moderate – rather than extreme – cold temperature.

* Corresponding authors.
*E-mail addresses:* zhabour@163.com (Y. Zhang), yuming.guo@monash.edu (Y. Guo).
[1] These two authors contributed equally to the paper.

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*Conclusions:* In rural settings, sub-optimal temperatures explained nearly one quarter of all clinical visits due to cardiovascular and respiratory diseases. Although extreme cold temperature had a stronger, more immediate, prolonged effect on respiratory disease than for cardiovascular disease, moderately cold temperatures accounted for most of the overall burden of clinical visits.



## 1. Introduction

Worldwide, the last 30 years has been the warmest period since 1880, accompanied by more extreme hot temperature events while cold extremes remain (Guha-Sapir et al., 2017; Morak et al., 2013; NOAA National Centers for Environmental information, 2017). There is sound evidence indicating that both extreme cold and hot temperatures induce substantial physiological stress on the human body and both temperature extremes are associated with a range of health outcomes resulting in increased morbidity and mortality (Gasparrini et al., 2015; Zhang et al., 2017). Globally, cardiovascular and respiratory diseases, which have been demonstrated to be strongly associated with both cold and hot temperatures (Basu, 2009; Mäkinen et al., 2009; Michelozzi et al., 2009), are among the leading causes of mortality resulting in >26 million deaths each year, with >75% of cases occurring in low- or middle-income countries (World health Organization, 2017).

Previous studies in China have mainly focused on the associations between temperature and all-cause or cause-specific mortality with little consideration of the potential effect on morbidity (Guo et al., 2012b). For example, although cardio-respiratory diseases account for approximately 30% of annual hospital admissions and health-care costs (National Health and Family Planning Commission of the PRC, 2016), there is limited information regarding the possible impact of suboptimal temperature on these outcomes (Guo et al., 2012a; Wang et al., 2013). Importantly, few studies in China have directly compared the association between temperature with cardiovascular and respiratory diseases within the same study population, which is necessary to fully understand how temperature variation impacts on these health outcomes at the population level (Liu et al., 2011).

In China, evidence regarding the health burden associated with suboptimal temperatures has been derived chiefly from large cities (Li et al., 2014; Tian et al., 2012), with limited information from rural areas where the incidence of cardiovascular and respiratory disease is the highest (National Health and Family Planning Commission of the PRC, 2016). The Ningxia Hui Autonomous Region, one of the most undeveloped regions in China, comprises the Loess Plateau, Mongolian Plateau and Tibet Plateau, and is an area with wide variation ranges of monthly temperature (25.2–31.2 °C) and diurnal temperature (12–15 °C) (Bureau of Statistics of Ningxia Hui Autonomous Region, 2016; China Weather Network, 2010). The average temperature in this region has increased by 1.5 °C since the 1960s, accompanied by abnormal temperature events, such as dry-hot winds and cold spells, occurring frequently all year round (China Weather Network, 2010). Such events may increase the incidence of cardiovascular and respiratory disease in the population. Moreover, any effects could be exacerbated by the regions' poor infrastructure and limited health resources, especially for residents in the poorest counties of Haiyuan and Yanchi (National Bureau of statistics of the People's Republic of China, 2015b).

The aim of this study was to quantify the associations between daily temperature and clinical visits for cardiovascular and respiratory diseases in rural villages in the Ningxia Hui Autonomous Region of China during 2012–2015. Evidence generated by this study could be used to guide policy makers with respect to the allocation of health resources and the development and implementation of adaptive strategies in regions at greatest risk of extreme temperature perturbations.

## 2. Material and methods

### 2.1. Data collection

Between 1 January 2012 and 31 December 2015 daily data on clinical visits associated with cardiovascular and respiratory illness were collected from medical centres located in villages of the Haiyuan and Yanchi counties, Ningxia Hui Autonomous Region. Local patients were diagnosed and recorded by village physicians. Considering the possible misclassification in the primary medical centres in China, especially in the rural areas, we did not analyse the association between temperature and subtypes of cardiovascular and respiratory diseases. By 2015, there were 165 villages under 17 towns or townships in Haiyuan county, and 102 villages under 8 towns or townships in Yanchi county (National Bureau of statistics of the People's Republic of China, 2015a). Our data collection indicated that in some villages there were substantial missing records in certain dates. In this study villages with <180 days records in a specific year were treated as of poor quality and excluded from further analysis. Considering core living areas of towns or townships usually far from other villages, data from these areas were included in this study which were defined as separate villages. In total, data were available from 134 and 69 villages from the two counties, respectively (Fig. 1). Village-specific population data were collected from the 2010 Census published by the National Bureau of statistics of the People's Republic of China (http://www.stats.gov.cn).

Daily data on meteorological conditions during the study period were collected from 839 city- or county-based meteorological stations across China, including daily mean temperature, relative humidity, wind speed, and sunshine hours, through China Meteorological Data Sharing Service. Village-specific meteorological variables were obtained using different approaches. Specifically, daily mean ambient temperature and relative humidity in the centroid of each village were interpolated from the data of the 839 stations using ordinary kriging model as described by Guo et al. (2013). Daily data on wind speed and sunshine hours in each village were replaced by the records from nearest meteorological stations.

### 2.2. Data analysis

A quasi-Poisson regression with distributed lag non-linear model (DLNM) was applied, using time series designed data from each village, to examine the associations between mean daily temperature and clinical visits for cardiovascular and respiratory diseases, respectively. The generalised additive mix model was used to perform quasi-Poisson regression to control for the random effect of each village. In addition, the models controlled for the following parameters: long-term trend, seasonality, day of the week, public holidays, and village-specific population sizes. The full model is described as follows:

$$Y_{it} \sim Poisson\ (\mu_{it})$$

$$Log\ \ (\mu_{it}) = \alpha + \beta Tem_{it} + \gamma Strata_{it} + \delta DOW_{it,} + \varepsilon Holiday_{it} + \text{offset}\ (LOGPOP_i) + \pi Z_i$$

where $Y_{it}$ represents the daily counts of cardiovascular or respiratory visits at village $i$ on day $t$; $\alpha$ is the intercept; $Tem_{it}$ is the cross-basis matrix for modeling the temperature effect over lag 0–28 days (Bhaskaran et al., 2010; Guo et al., 2011); $Strata_{it}$ is a categorical variable of year and calendar month to control for the long-term trend and seasonality; $DOW_{it}$ is a categorical variable to control for the effect