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Impact of diurnal temperature range on mortality in a high plateau area in southwest China: A time series analysis

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HIGHLIGHTS

- The effect of DTR on daily mortality was estimated in a high plateau city with a large DTR in China.
- A time-series analysis with 7 years of daily mortality data was used to assess the effect of DTR.
- The effect of DTR on mortality was non-linear, with J- or U-shaped curves.
- Relative risk assessments showed strong monotonic increases starting at DTR 16 °C.
- Males and people <75 years old were more susceptible to extreme high DTR than females and older people.

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ABSTRACT

Background: Diurnal temperature range (DTR) is an important meteorological indicator that reflects weather stability and is associated with global climate change and urbanization. Previous studies have explored the effect of DTR on human health in coastal cities with small daily temperature variations, but we have little evidence for high plateau regions where large DTRs usually occur. Using daily mortality data (2007–2013), we conducted a time-series analysis to assess the effect of DTR on daily mortality in Yuxi, a high plateau city in southwest China.
Methods: Poisson regression with distributed lag non-linear model was used to estimate DTR effects on daily mortality, controlling for daily mean temperature, relative humidity, sunshine duration, wind speed, atmospheric pressure, day of the week, and seasonal and long-term trends.
Results: The cumulative effects of DTR were J-shaped curves for non-accidental, cardiorespiratory and cardiovascular mortality, with a U-shaped curve for respiratory mortality. Risk assessments showed strong monotonic increases in mortality starting at a DTR of approximately 16 °C. The relative risk of non-accidental morality with extreme high DTR at lag 0 and 0–21 days was 1.03 (95% confidence interval: 0.95–1.11) and 1.33 (0.94–1.89), respectively. The risk of mortality with extreme high DTR was greater for males and age <75 years than females and age ≥75 years.
Conclusions: The effect of DTR on mortality was non-linear, with high DTR associated with increased mortality. A DTR of 16 °C may be a cut-off point for mortality prognosis and has implications for developing intervention strategies to address high DTR exposure.

1. Introduction

Climate change and temperature variation are associated with increased frequency, intensity and duration of adverse weather events (e.g., heat waves, cold spells, El Niños and storms) and have drawn the attention of researchers, especially concerning the adverse impacts on human health (Curriero et al., 2002; Iniguez et al., 2010; Yang et al., 2013). The association of daily ambient temperatures and

Abbreviations: CI, confidence interval; df, degrees of freedom; DLNM, distributed lag non-linear model; DTR,, diurnal temperature range; ICD-10, the Tenth Revision of the International Classification of Diseases; Q-AIC, quasi-Akaike information criteria; RR, relative risk.

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mortality has been extensively demonstrated in various geographic regions, populations and climatic zones worldwide (Basu and Samet, 2002; Curriero et al., 2002; Iniguez et al., 2010; Medina-Ramon et al., 2006; Yu et al., 2011). Typically, the effects of daily ambient temperatures on mortality have been shown to be non-linear, following V-, U-, W-, J-, or inverse J-shaped curves that usually indicate increases in mortality at temperatures below the cold threshold or above the hot threshold (Curriero et al., 2002; Iniguez et al., 2010; Medina-Ramon and Schwartz, 2007; Wu et al., 2013; Yu et al., 2011).

Previous studies usually adopted daily mean, minimum, maximum or apparent temperature as ambient temperature indicators to explore the effects of temperature on mortality (Basu and Samet, 2002; Saez et al., 1995; Wu et al., 2013). In recent years, diurnal temperature range (DTR) has been suggested as a predictor of mortality and found an independent risk factor for human health by an increasing number of epidemiological studies (Kan et al., 2007; Song et al., 2008; Yang et al., 2013). Calculated as the daily maximum temperature minus the daily minimum temperature within 1 day, DTR is an important meteorological indicator associated with global climate change and urbanization that reflects the stability of weather (Cheng et al., 2014; Xu et al., 2014; Zhou et al., 2014).

Most previous studies have shown that mortality risk depends on exposure to the current day's DTR and on the exposure experienced during several previous days ("lag" or delayed effects) (Braga et al., 2001; Guo et al., 2011; Vutcovici et al., 2014). Among time-series studies, the generalized additive model has been commonly used to quantify the effect of DTR on mortality and calculate the lag effects, because daily mortality counts typically follow the Poisson distribution and the effect of DTR on health is potentially nonlinear (Song et al., 2008). Recently, a new methodological framework, the distributed lag non-linear model (DLNM), has been used for simultaneously representing the non-linear and distributed lag effects between a predictor and an outcome in time series data (Gasparrini, 2014; Gasparrini et al., 2010). Developed on the basis of a "cross-basis" function, DLNM is a flexible model in understanding and investigating the relationship between DTR and mortality (Gasparrini et al., 2010; Goldberg et al., 2011).

The effect of DTR on mortality has been explored in China (Kan et al., 2007; Song et al., 2008; Zhou et al., 2014), Korea (Lim et al., 2013; Lim et al., 2012), Finland (Holopainen et al., 2013) and Canada (Vutcovici et al., 2014). However, most of the cities under study were high-income and located in low-altitude regions or coastal areas with low DTR. The impact of DTR on daily mortality in a high plateau area, with low atmospheric pressure, thin air and large DTR, has not been reported. In this study, we aimed to estimate the effect of DTR on mortality in Yuxi, a high-altitude city with a large DTR, in Yunnan Province, southwest of China.

2. Materials and methods

2.1. Study area and population

Yuxi city is on the western edge of the Yunnan–Guizhou Plateau, with complex geographic features including plateaus, mountains, valleys and basins. The area has a distinct subtropical plateau monsoon climate, with four spring-like seasons year round, giving the city a stable daily mean temperature but large temperature difference between day and night, morning or evening and daytime, indoor and outdoor, and sunny and shade locations. The area is 15,285 km^2 with a population of 2.30 million (1.18 million males) in 2010, as reported in the sixth national population census.

2.2. Mortality and meteorological data

Individual mortality data were collected from the Center for Disease Control and Prevention in the Hongta District and Tonghai County of Yuxi, which were included in the National Disease Surveillance Points. In 2010, these two districts contained 0.80 million residents, representing 34.55% of the population of Yuxi. Most of the people who live in these two districts are permanent residents, with low mobility.

A total of 28,201 registered deaths (15,581 males) occurred from January 1, 2007 to December 31, 2013, and included information on age, sex, date of birth, date of death, underlying cause of death, permanent address, educational attainment and occupation. The underlying causes of death in these two districts are usually assigned by medical personnel, and examination procedures are routinely performed to ensure accurate data. The daily mortality categories were classified according to the Tenth Revision of the International Classification of Diseases (ICD-10). Non-accidental mortality (ICD-10: A00-R99), cardiorespiratory mortality (ICD-10: I00–I99 and J00–J99), cardiovascular mortality (ICD-10: I00–I99) and respiratory mortality (ICD-10: J00–J99) were examined separately. Daily frequency of non-accidental deaths was summarized by gender and age (<75 and ≥75 years old).

Daily meteorological data including daily minimum temperature, maximum temperature, mean temperature, mean wind speed, sunshine duration, atmospheric pressure and mean relative humidity were obtained from the China Meteorological Data Sharing System for the same period. DTR was calculated as the difference between maximal and minimal temperatures within 1 day (Xu et al., 2014). During the study period, there were no missing values in the daily meteorological data except for daily sunshine duration (0.08% missing). All missing values were replaced by the median for the corresponding variables.

2.3. Statistical analysis

A quasi-Poisson generalized linear regression model combined with DLNM was used to estimate the effect of DTR on daily mortality, while controlling for daily mean temperature, relative humidity, sunshine duration, wind speed, atmospheric pressure, day of the week and the long-term trends of daily mortality, as suggested by previous studies (Gasparrini et al., 2010; Yang et al., 2012). The statistical model used in the analysis was as follows:

$$E(Y_t) = Exp\{\ \alpha + \beta\ DTR_{t,l} + \lambda\ Temp_{t,l} + NS(Time_t, 7\times 7)\ + NS(RH_t, 3) + NS(Sunshine_t, 3) + NS(WS_t, 3) + NS(AP_t, 3) + \gamma\ DOW_t\ \}$$

where t is the day of the observation ($t = 1,2,3\ldots2557$), Y_t is the observed daily death counts and $E(Y_t)$ is the expected number of deaths on day t. $Exp\{\ \}$ is the natural exponential function; α is the intercept; $DTR_{t,l}$ is a matrix obtained by the DLNM to model non-linear and distributed lag effects of DTR over a lag of 0 (the current day) to l days, and β is the vector of coefficients for $DTR_{t,l}$; $Temp_{t,l}$ is a matrix obtained by applying the DLNM to mean temperature with the vector of coefficients of λ; and $NS(\ )$ is the natural cubic spline. A nature cubic spline for time with 7 degrees of freedom (df) per year was used to describe the long-term trends and seasonality (Gasparrini et al., 2010). We also used natural cubic splines with 3 df at equally spaced quantiles for relative humidity (*RH*), sunshine duration (*Sunshine*), wind speed (*WS*) and atmospheric pressure (*AP*) as per previous studies (Gasparrini et al., 2010; Guo et al., 2011; Yang et al., 2013). The moving average of lag 0–2 days for relative humidity, sunshine duration, wind speed and atmospheric pressure was used. DOW_t is the day of the week effect (a categorical variable) on day t, and γ is the vector of coefficients.

We used a "natural cubic spline-natural cubic spline" DLNM, examining both the non-linear and lag effects of DTR on mortality with natural cubic splines. We placed spline knots at equally spaced values in the range of DTR, with the knots in the lag space placed equally on a logarithmic scale to mirror greater expected smoothness with increasing lag. The median value of DTR (10.2 °C) was used as the reference for calculating the relative risks (RRs) and 95% confidence intervals (CIs) across the study period (Guo et al., 2011; Yang et al., 2012). The RRs