Science of the Total Environment 490 (2014) 838–848

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

# Temperature, hospital admissions and emergency room visits in Lhasa, Tibet: A time-series analysis

Li Bai [a], Cirendunzhu [b], Alistair Woodward [c], Dawa [b], Zhaxisangmu [b], Bin Chen [a], Qiyong Liu [a,d,e,*]

[a] State Key Laboratory for Infectious Disease Prevention and Control, National Institute for Communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, 155 Changbai Road, Changping District, Beijing 102206, PR China
[b] Tibet Center for Disease Control and Prevention, 21 Linkuo North Road, Lhasa, Tibet 850000, PR China
[c] School of Population Health, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand
[d] Shandong University Climate Change and Health Center, 44 Wenhua Road, Jinan, Shangdong 250012, PR China
[e] Collaborative Innovation Center for Diagnosis and Treatment of Infectious Diseases, Hangzhou 310003, PR China

## HIGHLIGHTS

- This is the first to examine temperature effects on morbidities in Tibet.
- Heat were more strongly associated with morbidity than were cold.
- Heat were associated with increases of total emergency room visits.
- Temperature effects on hospitalizations were cause- and population-specific.

## ARTICLE INFO

*Article history:*
Received 16 January 2014
Received in revised form 30 April 2014
Accepted 6 May 2014
Available online xxxx

Editor: Lidia Morawska

*Keywords:*
Emergency room visits
Hospital admissions
Morbidity
Temperature
Tibet
Vulnerability

## ABSTRACT

*Background:* Tibet of China, with an average altitude of over 4000 m, has experienced noticeable changes in its climate over the last 50 years. The association between temperature and morbidity (most commonly represented by hospital admissions) has been documented mainly in developed countries. Little is known about patterns in China; nor have the health effects of temperature variations been closely studied in highland areas, worldwide.
*Objective:* We investigated the temperature–morbidity association in Lhasa, the capital city of Tibet, using sex- and age-specific hospitalizations, excluding those due to external causes.
*Methods:* A distributed lag non-linear model (DLNM) was applied to assess the nonlinear and delayed effects of temperature on morbidity (including total emergency room visits, total and cause-specific hospital admissions, sex- and age-specific non-external admissions).
*Results:* High temperatures are associated with increases in morbidity, to a greater extent than low temperatures. Lag effects of high and low temperatures were cause-specific. The relative risks (RR) of high temperature for total emergency room visits and non-external hospitalizations were 1.162 (95% CI: 1.002–1.349) and 1.161 (95% CI: 1.007–1.339) respectively, for lag 0–14 days. The strongest cumulative effect of heat for lag 0–27 days was on admissions for infectious diseases (RR: 2.067, 95% CI: 1.026–4.027). Acute heat effects at lag 0 were related with increases of renal (RR: 1.478, 95% CI: 1.005–2.174) and respiratory diseases (RR: 1.119, 95% CI: 1.010–1.240), whereas immediate cold effects increased admission for digestive diseases (RR: 1.132, 95% CI: 1.002–1.282). Those ≥65 years of age and males were more vulnerable to high temperatures.
*Conclusion:* We provide a first look at the temperature–morbidity relationship in Tibet. Exposure to both hot and cold temperatures resulted in increased admissions to hospital, but the immediate causes varied. We suggest that initiatives should be taken to reduce the adverse effects of temperature extremes in Tibet.



* Corresponding author at: State Key Laboratory for Infectious Disease Prevention and Control, National Institute for Communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, 155 Changbai Road, Changping District, Beijing 102206, PR China.
*E-mail addresses:* baili_ChinaCDC@163.com (L. Bai), cirendunzhuok@126.com (Cirendunzhu), a.woodward@auckland.ac.nz (A. Woodward), xzcdcdawa@sina.com (Dawa), 270577463@qq.com (Zhaxisangmu), drchenbin@126.com (B. Chen), liuqiyong@icdc.cn (Q. Liu).

http://dx.doi.org/10.1016/j.scitotenv.2014.05.024

## 1. Introduction

Variations in temperature affect human health in many ways (IPCC, 2014). The effects of both high and low temperatures on short-term increases in daily mortality and morbidity have been reported worldwide, particularly in developed countries, including the US (Barnett, 2007; Basu and Ostro, 2008; Braga et al., 2002), Canada (Pengelly et al., 2007), Europe (Aström et al., 2013; Vandentorren et al., 2006), and Australia (Vaneckova and Bambrick, 2013; Vaneckova et al., 2008). Temperature-sensitive health outcomes include chronic conditions such as cardiovascular diseases, respiratory diseases and renal diseases, as well as infectious diseases (vector-borne and water-borne) (IPCC, 2014).

Importantly, factors that influence susceptibility to temperature tend to vary from one location to another and we note that little is known about how temperature and other aspects of weather affect human health in highland areas. Tibet of China, lying at an average altitude of more than 4000 m, is called "the third pole of the world". Temperatures on the "roof of the world" have been increasing by 0.32 °C every decade in winters from 1955 to 1996, a much faster rate of change than has been observed in China, or in Asia generally (Liu and Chen, 2000). Accordingly Tibet is regarded as one of the most vulnerable areas to climate change in the world (Du et al., 2011; Yu et al., 2012a). However, in common with many other developing regions, nothing has been documented to date about the potential effects on health of long-term changes in climate, with particular reference to vulnerable subgroups.

The capital city of Tibet, Lhasa, has experienced considerable changes in climate over the past 50 years. Maximum temperatures in Lhasa reached 30.4 °C in 2009 summer. Before this, the highest record is 29.9 °C in 1971. A cross-sectional survey of 619 respondents from urban Lhasa in 2012 summer found that many local residents are aware of the warming that has occurred in recent years (Bai et al., 2013). Over 78% reported that rising temperature is either a "very" or "somewhat" serious threat to their own health, and nearly 40% reported that they had experienced heat-related symptoms. The next step is to relate temperature variations to local measures of health and identify those in the population who are most affected, in order to target interventions and develop Tibetan-specific public health programs.

The objective of this study was to investigate the relationship between temperature and morbidity in Lhasa, using sex- and age-specific hospital admissions excluding those due to external causes.

## 2. Methods

### 2.1. Data Collection

Lhasa, with an elevation of about 3680 m, is located in a flat river valley surrounded by the Himalaya Mountains rising to 5500 m (Picture 1). In 2010 the population of the city numbered 559,400 (287,400 men, 272,000 women). We obtained records of hospital admissions (1 January 2005 to 31 December 2012) and emergency room visits (1 March 2005 to 31 December 2012) from the People's Hospital of Tibet Autonomous Regions, which is located at the center of the city and close to the Potala Palace (Picture 1). This is the biggest public hospital in Tibet, with advanced facilities, more than 500 beds and over 900 staff. It is the only hospital in Tibet with a well-managed electronic medical record system, which can provide daily data from 2005 to the present, and the People's Hospital is also the first choice of most of the local residents whenever they need to see a doctor or have acute health problems.

Hospitalization data included principal diagnosis, admission and discharge dates, total charges, date of birth, sex, ethnicity, and residential street address. Based on the International Classification of Disease, 10th Revision, Clinical Modification (ICD-10) we classified the data into five cause-specific categories: non-external hospital admission (A00-R99); infectious, (A00-B99) cardiovascular (I00-99), respiratory (J00-99), renal (N00-28) and digestive (K20–31, 50–52, 55–63, 92). For emergency room visit data, we obtained only the total daily counts with neither causes nor patients' information. Daily meteorological data for Lhasa were provided by the National Climate Center from 2005 to 2012. The variables included daily maximum, mean and minimum temperature and relative humidity.

### 2.2. Data Analysis

Previous studies have shown that temperature effects on human health are frequently delayed in time. In this study, a distributed lag non-linear model (DLNM) was fitted to examine the relationship between temperature and daily numbers of hospital admissions and emergency room visits. The main advantage of this method is that it is flexible enough to simultaneously describe a non-linear exposure–response association and delayed effects or harvesting (Gasparrini, 2011; Gasparrini et al., 2010). Most recently, DLNM has been applied in studies to quantify the effects of temperature (Guo et al., 2011; Kim et al., 2012; Lin et al., 2013) and air pollution (Goldberg et al., 2013) on mortality.

**Picture 1.** An aerial photograph of Lhasa City, Tibet. (The red triangle represents the location of Potala Palace; the blue one represents the location of the People's Hospital of Tibet Autonomous Regions). (For interpretation of the references to color in this picture legend, the reader is referred to the web version of this article).