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The effects of high temperature on cardiovascular admissions in the most populous tropical city in Vietnam

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ABSTRACT

This study examined the short-term effects of temperature on cardiovascular hospital admissions (CHA) in the largest tropical city in Southern Vietnam. We applied Poisson time-series regression models with Distributed Lag Non-Linear Model (DLNM) to examine the temperature-CHA association while adjusting for seasonal and long-term trends, day of the week, holidays, and humidity. The threshold temperature and added effects of heat waves were also evaluated. The exposure-response curve of temperature-CHA reveals a J-shape relationship with a threshold temperature of 29.6 °C. The delayed effects temperature-CHA lasted for a week (0–5 days). The overall risk of CHA increased 12.9% (RR, 1.129; 95%CI, 0.972–1.311) during heatwave events, which were defined as temperature ≥ the 99th percentile for ≥2 consecutive days. The modification roles of gender and age were inconsistent and non-significant in this study. An additional prevention program that reduces the risk of cardiovascular disease in relation to high temperatures should be developed.

1. Introduction

Climate change is a major public health threat due to the effect of extreme weather events on health (Luber and Mcgeehin, 2008; Huang et al., 2011). A significant increase in number of hospitalizations occurs in relation to exposure to high ambient temperature (Faunt et al., 1995; Juopperi et al., 2002; Michelozzi et al., 2009), and previous studies have shown that one of the predominant causes of hospital admissions associated with high temperature is cardiovascular diseases (CVD) (Ebi et al., 2004; Schwartz et al., 2004; Bayentin et al., 2010; Oshige et al., 2006; Turner et al., 2012). Even though the best known risk factors for the cause of CVD are related to lifestyle habits such as smoking, alcohol consumption, insufficient physical activity, high blood pressure and cholesterol, and obesity (WHO, 2007), environmental factors such as temperature and air pollution also make a significant contribution to CVD onsets (Gerber et al., 2002). Nevertheless, the evidence on the effects of high temperature to the CVD admissions is less consistent, even though the effect on mortality has been consistently demonstrated in urban locations worldwide (Huang et al., 2012b; Baccini et al., 2008; Basu, 2009; Mcmichael et al., 2008; Yang et al., 2015; Gasparrini et al., 2015; Son et al., 2014; Lubczynska et al., 2015; Guo et al., 2014). For instance, studies have shown that high temperatures are associated with increased hospital visits and admissions for cardio-respiratory diseases both during heatwaves and at other times of the summer in several US cities (Konken et al., 2003; Lin et al., 2009; Shwartz et al., 2004). In contrast, some European studies have found no significant association between high temperatures and admissions for cardiovascular causes (Kovats et al., 2004a; Linares and Diaz, 2008; Michelozzi et al., 2009). Another study in California has also shown no significant association between high temperatures and cardiovascular admissions (Green et al., 2010). Most previous studies have been conducted in developed countries with

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temperate climate. There is a lack of studies, however, of the temperature-cardiovascular relationship in developing countries with subtropical or tropical climates (Basu, 2009; Kovats et al., 2004b; Michelozzi et al., 2009).

Vietnam is a developing low-income country which is highly vulnerable to climate change, particularly in the Southern Mekong Delta region (Yusuf and Francisco, 2009). There is evidence of a steady increase in temperature of 0.05–0.2 °C per decade over the last 5 decades, and the temperature has been predicted to increase by amounts from 1.1 to 1.9 °C in low emission scenarios and 2.1–3.6 °C in high emission scenarios (Asian Development Bank, 2009). Concurrently, Vietnam has been undergoing an epidemiological transition, in which the overall mortality and morbidity patterns have shifted from communicable to non-communicable diseases (Ha and Chisholm, 2011). A recent study has indicated that one-third of total deaths due to non-communicable diseases were attributed to cardiovascular diseases (CVD), mainly strokes and ischaemic heart diseases (IHD), and the CVDs are ranked first among the causes of mortality in Vietnam. These diseases have also been found to make up the largest share (approximately 20%) of the total burden of disability-adjusted life years (DAILYs) lost (Ha and Chisholm, 2011). Nevertheless, to date, there has been a lack of evidence on the short-term relationship between extreme temperature events and cardiovascular diseases in Vietnam.

This study aimed to examine the short-term effects of ambient temperature on daily hospital admissions due to cardiovascular diseases in the largest and most populous city in Southern Vietnam.

2. Methods

2.1. Study area

The study was conducted in Ho Chi Minh City (HCMC) the most populous city in Vietnam. HCMC is located in the South of Vietnam about 1730 km from Hanoi. The total area of the city is 2692.57 km^2, including 19 urban and 5 suburban districts and has a population of 7,162,846 which makes up 8.4% of the population of Vietnam. The population density of HCMC is 2660 people per km^2. In recent years, the population of HCMC has been increasing rapidly due to immigration from other provinces (Huyen, 2012). The climate of is tropical with the annual average temperature ranging from 26 °C to 27 °C. Since 1990 the maximum temperatures have increased in association with the accelerated urbanization of the area, and the increased percent in annual temperature is double that in the surrounding Mekong Delta region. The city experiences 2400–2700 h of sunshine per year. The year has two seasons: the rainy season (May–October) and the dry season (December–April). During the rainy season, the average rainfall is about 1800 mm annually (Asian Development Bank, 2009).

2.2. Data sources

Data on hospital admissions were drawn from the daily count of hospital admissions due to cardiovascular diseases (ICD-10 codes: I00–I99) from February 2004 to December 2013 in the two largest hospitals in HCMC, Gia Dinh People's Hospital and 115 People's Hospital, which have 1200 and 1600 beds respectively. These hospitals are multi-faculty hospitals which receive about 1000–2000 in-patients daily each. The patients come from all districts across HCMC. Data extracted from the hospital admissions were categorized by primary and discharge diagnoses, date of admission, date of discharge, age, sex, and address of the individual patient.

Daily meteorological data were collected from the Southern Regional Hydro-Meteorological Centre for period February 2004 to December 2013. The data were recorded from a hydro-meteorological station located in the central district of HCMC (longitude, 106°39′59.75 East; latitude, 10°47′47.48 North), comprising: daily minimum, maximum, and average temperatures (°C) and minimum, maximum and average relative humidity (%).

2.3. Data analysis

We applied time-series regression methods to examine the association between cardiovascular admissions and temperature using General Additive Model (GAM) and Distributed Lag Non-Linear Model (DLNM) (Gasparrini et al., 2010) with the family of Poisson distributions. We selected the daily mean temperature since this indicator has higher correlation with cardiovascular admissions than minimum or maximum temperature in our dataset (Supplement 2), and the mean temperature also make the Akaike Information Criterion (AIC) value lowest ((29147.61) compared with minimum (AIC, 29156.83) and maximum temperature (AIC, 29178.86). Likewise, the mean temperature was also found to be a better predictor than other temperature indicators across different models in previous studies (Yu et al., 2010, 2011). Several steps were involved in the data analyses as following.

A GAM model (Equation (1)) was used to estimate the association between daily mean temperature and CHA, in which the dependent variable is the daily counts of hospital admissions due to cardiovascular diseases (CVD) and the main exposure variable is the daily mean temperature. In order to capture the non-linear and delayed effects of temperature, we used a DLNM with 4 degrees of freedom natural spline function for temperature, and 4 degrees of freedom natural cubic spline for lag up to 21 days which were proof to be suitable for temperature-daily health outcome study (Guo et al., 2014). The covariates were adjusted to comprise: the flexible spline function of time with 7 degrees of freedom per year for time used to control for the seasonal and long-term trends (Bhaskaran et al., 2013), day of the week (as dummy variables), holidays (as a binary variable, holiday such as weekends and public holidays was coded 1), and the spline function of daily mean relative humidity with 4 degrees of freedom. We assumed a maximum lag of 21 days between exposure and admission, so we included the DLNM of 21 day lags into the GAM model to evaluate the delayed effects of temperature on cardiovascular admissions. These lags were modelled using natural spline function with 4 degrees of freedom.

$$Log(Y_t) = \alpha + s(T_{t-l},\ 4\,df) + s(H_t,\ 4\,df) + s(time,\ 7{*}year) + DOW + HO + \varepsilon_t \quad (1)$$

where t refers to the day of the observation; Y_t is the observed daily cardiovascular admission on day t; T_{t-l} is a matrix created by DLNM for daily mean temperature on day t with l lag days (21 days in this study); H_t is the average humidity on day t; $s(.)$ denotes the spline functions; DOW is the day of the week; HO is holiday; and ε_t is the residual.

In order to determine the threshold of temperature, we first plotted the graph of the overall relationship between temperature and cardiovascular admissions predicted from Equation (1) and then visually checked the possible range of the threshold. Second, we iteratively estimated Akaike information criterion (AIC) values for GAM model using 0.1° increment in mean temperature within the identified range of thresholds from visual inspection using the threshold models (Equations (2)–(4)). The temperature corresponding to the model with the lowest AIC value was chosen as the threshold temperature. The threshold models have been described elsewhere (Chung et al., 2009; Kim et al., 2006; Yu et al., 2010).