The Effect of High Temperatures on Risk of Hospitalization in Northern Vietnam

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Abstract

The evidence on the temperature and morbidity relationship is limited, especially from tropical regions including Vietnam. This study's objective was to examine the high temperature-hospitalisation relationship in northern Vietnam. To assess ambient temperature hospitalizations associations in seven provinces of northern Vietnam Generalized Linear and Distributed Lag Models were used. Overall risk for all causes, and infectious, cardiovascular, and respiratory admissions in study provinces was estimated using a random-effects meta-analysis. The pooled estimates showed a significant effect of high temperature on same day (Lag 0) hospitalizations. A 1°C increase in temperature was significantly associated with 1.1% (95% Confidence Interval- CI, 0.9–1.4%) increase in risk for all-cause, 2.4% (95% CI, 1.9–2.9%) increase in risk for infectious, 1.3% (95% CI, 0.9–1.6%) increase in risk for respiratory, and 0.5% (95% CI, 0.1–0.9%) increase in risk for cardiovascular disease admissions. However, the province specific temperature-hospitalisation effect was variable and mostly inconsistent for cardiovascular diseases. Our research in northern Vietnam adds to the evidence of high temperatures associated with hospitalisations in a sub-tropical climate. Our findings have important implications for promoting appropriate adaptation strategies to reduce climate change associated health impacts in similar settings.

Introduction

Changes in temperature are one of the direct pathways by which climate change affects human health (Watts et al. 2015). Manifestations of climate change such as both increases in mean temperature and intensification of extreme temperatures (Smith et al. 2014) pose significant mortality and morbidity risks (Watts et al. 2015; Bunker et al. 2016). Ample research indicate that high temperature is associated with increased risk of deaths and illnesses (Chen et al. 2018; Song et al. 2017; Bunker et al. 2016; Guo et al. 2014; Ye et al. 2012; Basu et al. 2009) that include both chronic conditions such as cardiovascular, respiratory and cerebrovascular diseases (Song et al. 2017, Basu et al. 2009, Turner et al. 2012) and infectious diseases (Phung et al. 2015a, b, c; Hashizume et al. 2008). While the evidence regarding the association between temperature and deaths is consistent (Chen et al. 2018; Bunker et al. 2016; Guo et al. 2014; Basu et al. 2009), the evidence regarding the association between temperature, and morbidity and hospital visits is mixed (Song et al. 2017; Bunker et al. 2016; Ye et al. 2012; Turner et al. 2012). For example the recent meta-analysis by Bunker et al. (2016) and a review of systematic review on temperature and health effects by Song et al. (2017) while indicating a significant increase in mortality risks from cardiovascular and cerebrovascular diseases with increase in temperature found no such morbidity risk was observed with temperature rise for those disease groups. However, in several US cities both heat waves and summer temperatures have been found to be associated with increased hospital visits for cardiovascular and respiratory diseases (Zanobetti and Schwartz, 2008; Koken et al. 2003; Lin et al. 2009). In contrast several European studies did not demonstrate any such relationship (Kovats et al. 2004; Linares and Diaz, 2008; Michelozzi et al. 2009). Turner et al. (2012) in their meta-analysis found a significant association between high temperature and respiratory morbidity but no such association for cardiovascular morbidity. Additionally, limited evidence is available on temperature and health relationship from developing countries with tropical or sub-tropical climates (Bunker et al. 2016; Phung et al. 2016).

Vietnam, located in South-East Asia, has diverse climate across its lands, and is highly vulnerable to climate change (World Bank, 2011). Vietnam's southern parts experience a tropical climate, and northern parts in the humid subtropics observe greater seasonal variation (ISPNORE, 2009). Climate change projection scenarios for Vietnam indicate an annual average temperature rise between 1.6°C and 3.7°C by the end of 21st century (Schmidt-Thomé et al. 2014). Previous research, largely in the southern Mekong Delta areas, have indicated that elevated temperatures are associated with an increased risk of water- and vector-borne diseases, cardiovascular and respiratory diseases, and risk of hospital admissions among young children (Phung et al. 2015a,b,c). However, few studies have reported temperature-morbidity and mortality relationships in the subtropical northern Vietnam. Studies in Hanoi (Xuan et al. 2014) and Thai Nguyen provinces (Giang et al. 2014) indicate significant increase in mortality and hospital admissions due to cardiovascular diseases with cold temperatures, especially in the elderly. However these studies were limited to single disease, single city and the elderly, thus do not adequately represent the relationship between temperature and adverse health effects in the general population across the different climate regions in Vietnam.

This study examines the effect of temperature on risk of hospitalization for all causes, and cardiovascular, respiratory and infectious illnesses in multiple cities in northern Vietnam.

Methods

Study setting

The selected provinces are representative for the northwest, northeast, and Red River Delta region of Vietnam. The northwest is a mountainous region with a population of 3.5 million people. Its climate is characterized by cold, dry, sunny winters. Summers in the region are hot due to a high frequency of hot and dry days and westerly winds (IPSNOR, 2009). Northeast Vietnam has a population of 13 million accounting for 15% of Vietnam's population. The climate of this region is strongly influenced by the north-eastern monsoon (Mui, 2006). The summers are hot, humid and coincide with the rainy season, but in contrast to the northwest, dry conditions are rare because of less frequent westerly winds. Red River Delta has a population of 17 million, of which a half live in the capital city, Hanoi. Summers are also hot and rainy. The mean annual temperature in the northeast and Red River Delta regions is 23°C. All three regions have distinctive seasons, including: Spring (February-April), Summer (May-September), Autumn (September-November), Winter (November-February).

Data sources

Daily hospital admission data were obtained from 7 provincial hospitals comprising (Bac Giang (BG), Tuyen Quang (TQ), Phu Tho (PT), Dien Bien (DB), Lai Chau (LC), Ha Noi (HN), Quang Ninh (QN) – 1 hospital in each province) located across northern Vietnam (Supplemental Figure 1) for the period between January 2005 and December 2015. Hospital admission data included daily counts for all causes (excluding external causes), cardiovascular diseases (I00-99; excluding: acute rheumatic fever, I00-02, and chronic rheumatic heart diseases, I05-09), and respiratory diseases (J00-99; excluding: lung diseases due to external agents, J60-70), and certain infectious and parasitic diseases (ICD10-Code: A00-B99; excluding: infections with predominantly sexual mode of transmission, A50-64, HIV, B20-24, Helminthiasis, B65-83, sequelae of infectious and parasitic diseases, B90-94). Disease classification was based on primary and discharge diagnosis. We also extracted background information (e.g. age, sex, and address) of individual patients and their dates of admission and discharge from hospital records. The time-span of daily hospitalization data varied from 2 to 11 years as the electronic data management system became operational in the respective provincial hospital. Patients not from those 7 selected provinces and hospital records (<1%) with missing data were excluded from the analysis. Daily meteorological data (ambient temperature, humidity and precipitation) were obtained from the provincial hydro-meteorological stations or from the closest airport weather stations. The precipitation data for province Phu Tho was not available, therefore humidity only was adjusted for in the respective model.

Data Analysis

Data analyses involved three steps. First, we performed descriptive statistics for exposure (temperature) and outcome (hospitalization) variables (i.e. hospitalisation for all causes, infectious diseases, respiratory and cardiovascular diseases). Second, we examined the province-specific temperature-hospitalisation relationship for each province using mean temperature centered at 24°C for each province. Third, we performed a random-effect meta-analysis to estimate the pooled effect sizes of temperature on all-cause, infectious, cardiovascular, and respiratory admissions. Poisson Generalized Linear Model (GLM) and Distributed Lag Model (DLM) were used to examine the province-specific association between temperature and daily average temperature and risk of hospitalization. The province-specific Poisson regression time-series model used was:

$$Y_t \sim \text{Poisson}(\mu_t) \ln(\mu_t)$$

$$= \alpha + \sum_{l=0}^6 \beta_l T_{t,l} + \beta_H H + \beta_R R + s(\text{time}, 7 * \text{year}) + \gamma \text{DOW}$$

where Y_t is the observed daily count of hospital admissions on day t ; α is the intercept; T_t is the daily average temperature on day t and l is the lag days; H is the daily average humidity; R is the daily cumulative rainfall. s is the Flexible spline function with 7 knots per year; DOW is the day of the week.

The linear distributed lag model of temperature for lags up to 6 days (a week) was used to examine the delayed effect of temperature on hospitalizations. A flexible spline function with 7 knots per year was used to control for long-term trends and seasonal patterns in hospitalizations (Bhaskaran et al. 2013). The model was adjusted for humidity, rainfall, and day of the week to control for potential confounding effects.

A random-effect meta-analysis was applied to calculate within-province and between-province variation and generate pooled effect size (relative risk, RR). The pooled effect sizes, which were calculated for cause-specific hospitalizations, comprising all-cause, infectious diseases (ID), cardiovascular disease (CVD), and respiratory diseases (RD), were computed by lag day (from 0 to 6 days). *I-squared* (coefficient of inconsistency) statistics was used to determine the heterogeneity between studies (Higgins et al. 2003).

All the data analyses were conducted using the “glm”, “db metan” packages of Stata 14.0 (Stata Corporation, College Station, TX, USA).

Results

Descriptive statistics

Table 1 summarizes the descriptive statistics for temperature and hospitalizations for the seven provinces in northern Vietnam during the study period. The average hospital admissions per day ranged from 29 to 235 across the cities, depending on the size of the data-providing hospitals. The average temperature ranged from 21.8 to 24.9°C across the seven provinces. An average maximum temperature (34.0°C) was calculated in 5 provinces except Dien Bien and Lai Chau and an average minimum temperature (6.0°C) was calculated in these two provinces.

Table 1
Descriptive data on temperature and hospitalization across seven provinces in northern Vietnam

Provinces	Study period	Temperature (°C)			Hospitalization (daily average)			
		Mean	Min	Max	All cause	Infection	Cardiovascular	Respiratory
Bac Giang (BG)	2008–15	24.5	9.0	34.0	97	2	7	5
Phu Tho (PT)	2014–15	24.9	10.0	34.0	234	10	15	26
Ha Noi (HN)	2009–13	24.2	9.0	34.0	77	8	5	20
Quang Ninh (QN)	2010–15	24.4	9.0	34.0	89	6	6	14
Tuyen Quang (TQ)	2010–15	24.4	9.0	34.0	84	3	6	12
Dien Bien (DB)	2005–15	22.2	6.0	31.0	51	2	3	9
Lai Chau (LC)	2006–11	21.8	6.0	30.0	29	1	1	7

Temperature-hospitalization Risks

Overall across almost all the provinces, a rise in temperature was consistently associated with an increased risk of hospitalization for all-causes (except PT province), infectious (except LC province), and respiratory diseases (except BG province). The percentage changes in risk of hospitalization with a 1°C increase in mean temperature above 24⁰C are shown in Table 2. A 1°C rise in temperature was associated with increased risk of hospital admissions, a 0.8–1.8% increase for all causes in all but PT province, 1.6–3.5% for infectious diseases in all but LC province, and 1.0-2.1% for respiratory diseases in all but BG province. The temperature and hospital admissions for cardiovascular diseases did not show any significant relationship for any province (Table 2).

Table 2
Province-specific estimate of % change associated with 1°C increase in daily average temperature on daily all- and cause-specific hospitalizations

Provinces ^a	All causes (%)	95% Confidence Interval (CI) ^b	Infectious disease	95% CI	CVD ^c	95% CI	Respiratory	95% CI
BG	1.3	0.7, 1.8 ^d	3.5	2.2, 4.9 ^d	0.6	-0.3, 1.4	0.8	-0.4, 2.0
DB	1.1	0.5, 1.6 ^d	1.8	0.5, 3.1 ^e	0.4	-0.5, 1.4	1.0	0.3, 1.8 ^e
HN	1.1	0.6, 1.7 ^d	2.3	1.3, 3.2 ^d	-0.1	-1.1, 0.1	1.2	0.5, 1.9 ^e
LC	1.8	1.1, 2.5 ^d	1.7	-0.7, 4.2	1.2	-0.1, 3.4	2.1	1.1, 3.1 ^d
PT	0.7	-0.4, 1.8	1.6	0.2, 3.1 ^f	-0.8	-2.3, 0.8	1.9	0.7, 3.0 ^e
QN	1.0	0.3, 1.7 ^e	1.9	1.0, 2.8 ^d	0.9	-0.1, 1.8	1.0	0.2, 1.8 ^f
TQ	0.8	0.2, 1.4 ^e	2.2	0.1, 3.3 ^d	0.5	-0.4, 1.3	1.1	0.4, 1.8 ^e

Table 2 legend

^a BG - Bac Giang, PT- Phu Tho, HN- Ha Noi, QN- Quang Ninh, TQ- Tuyen Quang, DB- Dien Bien, LC- Lai Chau

^b % change (95% CI) associated with 1°C increase in daily average temperature

^c CVD, Cardiovascular disease

^d p value < 0.001, ^e p value < 0.01, ^f p value < 0.05

The lag effects of temperature on risk of hospitalization due to all causes, infectious diseases, cardiovascular and respiratory diseases were variable across the provinces. Except in PT and QN provinces the temperature-hospitalisation effect for all causes was observed for the same day (Lag 0) with the highest increased risk in LC (1.8%, 95% CI 1.1, 2.5%) and lowest risk in TQ province (0.8%, 95% CI 0.2, 1.3%). For infectious diseases, the temperature-hospitalisation effect was consistently observed for same day (Lag 0) in all but LC province. Similarly increased risk of hospitalization due to high temperature was observed for respiratory causes for same day in all but BG province. However, no significant association was observed for cardiovascular diseases across provinces for different lag days (Supplementary Tables 1–4).

The pooled estimates showed high temperature was significantly associated with same day (Lag 0) increased risk of hospitalizations (Fig. 1), when a 1°C rise in temperature was associated with 1.1% (95% CI, 0.9–1.4%) increase in risk for all-causes admissions, 2.4% (95% CI, 1.9–2.9%) increase in risk for infectious admissions, 0.5% (95% CI, 0.1–0.9%) increase in risk for cardiovascular admissions and 1.3% (95% CI, 0.9–1.6%) increase in risk for respiratory admissions. None of the other lag days showed significant increase in risk of hospitalisation for all causes and infectious, cardiovascular or respiratory diseases.

Sensitivity analyses changing in measure of temperature (maximum, minimum) did not substantially influence the estimates of mean temperature effects on hospitalizations.

Discussion

Our research presents the short-term effects of temperatures on risk of hospitalizations in multiple provinces in northern Vietnam representing tropical climates in a developing country setting. Overall, pooled estimates for all the study provinces in northern Vietnam indicate a significant effect of rise in average temperature above 24°C on same day hospital admissions for all causes,

infectious diseases, respiratory and cardiovascular admissions. However, the province-specific temperature-lag effects on hospital admissions were inconsistent across the provinces and mostly for cardiovascular diseases.

Research on temperature-morbidity relationship has been scarce and most of them are conducted in temperate and developed country settings (Bunker et al. 2016). Consistent with our research, an increased risk of hospital admissions for all causes, respiratory and infectious diseases but no associated risk for cardiovascular diseases was observed from high temperature in the tropical Mekong Delta Region of Vietnam (Phung et al. (2016b)). A 1°C rise in average temperature above 21°C was significantly associated with 1.3% increased risk for all-causes, 2.2% increased for infectious causes and 1.1% increased risk for respiratory causes admissions (Phung et al. 2016b). In contrast a study in a single city of Thailand representing a tropical climate, did not show any significant increase in all-cause admissions from each °C increase in temperature above 29°C but a significant increase in admissions (5.8% increase, 95% CI: 2.3%-9.3%) due to intestinal infectious disease with high temperature (Pudpong and Hajat, 2011). In sub-tropical Hong Kong, 1°C increase in mean daily temperature above 29°C increased overall hospitalizations by 4.5% (Chan et al. 2013). This study also reported significant association between increase in average temperature and hospital admissions due to respiratory and infectious disease (Chan et al. 2013). This inconsistency in research findings and temperature thresholds across different settings reflect differences in population characteristics and activity pattern in different settings, socioeconomic status, and the physical and behavioral adaptation of people living in warmer climates (McMichael et al. 2008; Green et al. 2010; Hondula and Barnett, 2014). Socio-demographic factors did not modify temperature-morbidity relationship in a previous study in MDR (Phung et al. 2016b). However, further research, especially applying a prospective study design, is recommended exploring the factors related to adaptive capacity in tropical climates.

Ample evidence has indicated the strong association between high temperatures and infectious diseases such as gastro-intestinal infections, diarrhoea, and dengue fever (Allard et al. 2011; Harper et al. 2011; Tokarevich et al. 2011; Wang et al. 2012; Lal et al. 2015). This has also been the case in the MDR as demonstrated by a series of studies (Phung et al. 2016a, b; Phung et al., 2015a,b,c). Several mechanisms have been suggested explaining the high temperature and infectious cause of diseases. Temperature influences microorganisms' growth and survival. For example, in warm seawaters diarrheal pathogens like rotavirus and some bacteria proliferate more rapidly (Moe and Shirley, 1982). Similarly, high temperatures lead to rapid growth of bacteria in foods during hot weather resulting in food poisoning (Bentham and Langford, 2001). Temperature is also an important factor influencing mosquito vector behavior and characteristics (e.g. *Aedes* of dengue) that include habitat availability for mosquito egg-laying, development, reproductive behavior and survival of mosquitos, and viral replication within infected mosquitos (Ebi and Nealon, 2016).

The pooled effect of high temperature on cardiovascular admission on the same day in our research corroborates with the results reported elsewhere (Zhai, Zhang & Chai, 2021; Son, Bell & Lee, 2014). However this is in contrast to several other studies (Kovats et al., 2004; Linares and Diaz, 2008; Michelozzi et al. 2009) including in the MDR (Phung et al. 2016b) and a recent systematic review and meta-analysis (Turner et al. 2012), which indicated a negative and non-significant effect of high temperature on cardiovascular admissions. In this research, none of the province specific estimates for temperature effect on cardiovascular admissions were found statistically significant. Previous research among elderly people in Thai Nguyen province of Northern Vietnam also reported a non-significant association between hot temperature and CVD admission (RR 1.17, 95% confidence interval: 0.90–1.52) (Giang et al., 2014). Giang et al. (2014) hypothesized that lowering of blood pressure due to reduced sympathetic tone and dilation of blood vessels from exposure to high temperature could contribute to reduced CVD risk. However, temperature and CVD relationship has been more consistent for mortality with both cold and heat exposure (Moghadamnia et al., 2017) rather than morbidity (Turner et al., 2012). The differential effects of temperature on cardiovascular morbidity and mortality could be due to increased number of temperature-related cardiovascular deaths before seeking care at the hospital (Michelozzi et al. 2009; O'Neill et al. 2003; Michelozzi et al. 2003). Elsewhere reported increase in plasma viscosity and serum cholesterol levels as consequences of high temperature (Ockene et al. 2004). Besides, increase in blood viscosity and cardiac output from high temperatures resulting in dehydration and low blood pressure (Rogot et al. 1992). Further research is, therefore, recommended to examine the pathways of CVD morbidity across different climates considering the local context of population vulnerability.

Our research has several limitations. First, like most hospital-based studies, less severe cases are more likely to be missed in our analysis as hospital data were obtained from the largest public referral hospital at the provincial level, which could underestimate the temperature-morbidity relationship. Second, the relationship between temperature and individual cause-specific diseases was not examined. Such as the case for CVD admissions. Previous studies indicated that the effects of temperature may be different for specific types of CVD diseases (Lin et al. 2009), therefore, knowledge of cause-specific CVD admissions would be pertinent to

quantify the differential effect of high temperatures on CVD morbidity. Third, we could not examine the influence of socio-demographic factors and other adaptive measures (e.g. air conditioning), or amount of time spent outdoors, which are critical factors to measure the actual exposure to high ambient temperatures, and to understand population vulnerability, therefore promote appropriate adaptation strategies.

Conclusions

The results of this multi-province study enhance the evidence that high temperatures increase the risk of overall hospitalizations, and for infectious and respiratory causes in sub-tropical northern Vietnam. As temperature is projected to continue to rise in this region due to climate change our findings have important implications for health service delivery and hence a requirement to consider a range of public health interventions and adaptation strategies (Smith et al. 2014) to raise awareness of people about climate change and health impacts, to prevent this additional burden of disease and its associated increased health costs.

Declarations

Ethics approval and consent to participate

This study is one of a bigger research project in climate change and health in the Mekong Delta Region. The project was approved by the ethical committee of Griffith University (GU Ref No: ENV/23/15/HREC) and Health and Environment Management Agency, the leading agency of the health sector responsible for climate change and health in Vietnam (1290/MT-SKCD).

Consent for publication

Not applicable

Availability of data and materials

The data that support the findings of this study are obtained from Health and Environment Management Agency, Vietnam but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available.

Competing interests

Nothing to declare

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Authors Contributions

M.R.T. conceptualized, curated data, performed data analysis and drafted the manuscript; D.P. assisted with data analysis, writing methods, and drafting the manuscript; S.R. reviewed and edited the manuscript; All the authors (M.R.T., C.C, S.R., C.H. & D.P.) contributed to review and final draft of the manuscript.

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Figures

Figure 1

Pooled estimates of the effect sizes of temperature (1 °C increase) on hospitalisations by lag days.

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