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High temperature and risk of hospitalizations, and effect modifying potential of socio-economic conditions: A multi-province study in the tropical Mekong Delta Region

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ABSTRACT

The Mekong Delta Region (MDR) in Vietnam is highly vulnerable to extreme weather related to climate change. However there have been hardly any studies on temperature-hospitalization relationships. The objectives of this study were to examine temperature-hospitalization relationship and to evaluate the effects of socio-economic factors on the risk of hospitalizations due to high temperature in the MDR.

The Generalized Linear and Distributed Lag Models were used to examine hospitalizations for extreme temperature for each of the 13 provinces in the MDR. A random-effects meta-analysis was used to estimate the pooled risk for all causes, and for infectious, cardiovascular, and respiratory diseases sorted by sex and age groups. Random-effects meta-regression was used to evaluate the effect of socio-economic factors on the temperature-hospitalization association.

For 1 °C increase in average temperature, the risk of hospital admissions increased by 1.3% (95% CI, 0.9–1.8) for all causes, 2.2% (95% CI, 1.4–3.1) for infectious diseases, and 1.1% (95% CI, 0.5–1.7) for respiratory diseases. However the result was inconsistent for cardiovascular diseases. Meta-regression showed population density, poverty rate, and illiteracy rate increased the risk of hospitalization due to high temperature, while higher household income, houses using safe water, and houses using hygienic toilets reduced this risk.

In the MDR, high temperatures have a significant impact on hospitalizations for infectious and respiratory diseases. Our findings have important implications for better understanding the future impacts of climate change on residents of the MDR. Adaptation programs that consider the risk and protective factors should be developed to protect residents from extreme temperature conditions.

1. Introduction

There is increasing scientific evidence that rising anthropogenic greenhouse gas emissions have led to global warming, which results in more frequent and intense extreme weather events such as high temperatures (IPCC, 2013; Mcmichael et al., 2006). In many location, a significant increase in the number of hospitalizations is associated with high temperatures (Faunt et al., 1995; Juopperi et al., 2002; Michelozzi et al., 2009), and previous studies have suggested that high temperatures are associated with elevated risks of both communicable (Phung et al., 2015e; Phung et al., 2015c; Phung et al., 2014) and non-communicable diseases (Ebi et al., 2004; Schwartz et al., 2004; Bayentin et al., 2010; Oshige et al., 2006; Turner et al., 2012a; Phung et al., 2015a). Nevertheless, the evidence for the effects of high temperatures on hospital admissions is less conclusive, even though the effect on mortality has been reported worldwide (Huang et al., 2012; Yang et al., 2015; Guo et al., 2014; Gasparrini et al., 2015). For example, studies have indicated that high temperatures are associated with elevated hospital admissions due to cardio-respiratory diseases in several US cities (Konken et al., 2003; Lin et al., 2009; Shwartz et al., 2004). However, some European studies have found no significant effects of high temperatures on admissions due to cardiovascular causes (Kovats et al., 2004; Linares and Diaz, 2008; Michelozzi et al., 2009), and the effects of temperatures on admissions vary inconsistently with sex and age (Phung et al., 2015a). Moreover, most previous studies have been conducted in developed countries that have a temperate climate. There is a lack of research on temperature-hospitalization relationships in developing countries with subtropical and tropical climates (Basu, 2009; Kovats et al., 2004; Michelozzi et al., 2009;Phung et al., 2015a).

The Mekong Delta Region (MDR), a tropical region of 13 provinces in Vietnam, is considered one of the areas in South-East Asia most

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vulnerable to extreme hydro-meteorological events associated with climate change (Yusuf and Francisco, 2009). A previous investigation (Can Tho Donre, 2009) indicated that the mean temperature in the central MDR increased by 0.5 °C between 1978 and 2008, and the mean temperature is predicted to increase by up to 4 °C by the year 2100, and the number of days that have an average temperature higher than 35 °C will increase (Chaudhry and Ruysschaert, 2008). In addition, residents' capacity for adaptation may be limited by physical and social problems such as ground surface deformation, environmental pollution, rapid urbanization, unsustainable development, low socio-economic status, limited resources to respond to climate change and difficulties in coordination between local agencies (CTCCCO, 2013). The preventive surveillance reports and hospital records show that the rates of both communicable (e.g. dengue fever) and non-communicable diseases (e.g. cardio-respiratory diseases) have recently increased in the MDR. However, no comprehensive study of the relationship between temperature and health effects has been conducted for the MDR as a whole.

The aims of this study are to examine the association between ambient temperature and risk of hospitalization for infectious, respiratory and cardiovascular diseases and to evaluate/quantify the modifying effects of socio-economic factors on the temperature-hospitalization relationships across the provinces in the Mekong Delta Region in Vietnam.

2. Material and methods

2.1. Research location

The Mekong Delta Region (MDR) has an area of 39,000 km^2 (ARCBC, 2014) (Supplement 1). The MDR comprises 13 provinces and has a total population of 17.33 million people (GSO, 2012). It has a tropical climate with two main seasons: the dry season (December–April) and the wet season (May–November). The main industries in the MDR are agriculture and fishing, which are considered to be the most productive in Vietnam. As a low-lying coastal region, the MDR is remarkably vulnerable to changes in hydro-meteorological factors such as rising temperatures, sea level rises and floods (Phung et al., 2015d). In recent times, increases in both infectious diseases and non-communicable diseases have been a concern of health authorities in the MDR.

2.2. Data collection

Data on hospital admissions 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, Helminthiases, B65-83, sequelae of infectious and parasitic diseases, B90-94). Data was obtained from the hospital records of 13 provincial/city hospitals for the January 2002–December 2014 period (Supplement 1). Data extracted from the hospital records comprised primary and discharge diagnoses, dates of admission and discharge, age, sex, and address of the individual patients. Patients who were transferred for admissions and non-residential addresses were excluded from the analysis. The time-span of daily hospitalization data varied from 4 to 10 years, depending on the time that a computerised database had been operational in each provincial hospital. All provincial hospitals have used the same software developed for hospital record management, so the data source quality is similar across the Mekong Delta region. There is no missing data for daily records but 5 provinces (Ben Tre, Ca Mau, Tien Giang, Tra Vinh, and Vinh Long) have missing data for gender.

Daily meteorological data were obtained from the provincial hydro-meteorological stations (Supplement 1) from January 2002 to December 2014. The data comprise: daily minimum, maximum, and average temperatures (°C) and relative humidity (%), and daily cumulative rainfall (mm). The available socio-economic indicators used for temperature-impact sensitivity (population density, % rural population, % illiterate of population aged 15+, % poverty housing, in-migration rate) and those used for adaptive capacity (household income, % houses using safe water, and % houses with hygiene toilets) for each province were obtained from the Vietnam General Statistics Office (GSO, 2012), Vietnam National Census (VN GSO, 2008), and Vietnam Health Statistics Yearbook (HSY, 2012).

2.3. Data analysis

Three steps were involved in the data analysis. Firstly, we examined the province-specific temperature-hospitalization relationship for each province. Secondly, we used a random-effect meta-analysis to estimate the pooled effect sizes of temperature on all-cause, infectious, cardiovascular, and respiratory admissions. Thirdly, we used meta-regression to examine the modifying effect of socio-economic factors on the temperature-hospitalization relationship. Stratification analyses were also performed for sex and age groups (0–60, 60–75, and 75+).

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 is:

$$Y_t \sim Poisson\,(\mu_t)\ \mathrm{Ln}(\mu_t) = \alpha + \sum_{t=0}^{6}\beta_i T_{t,l} + \beta_j H + \beta_k R + s(time, 7 * year) + \gamma \mathrm{DOW} + offset(LNPOP) \quad (1)$$

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; and LNPOP is the natural log scaled population, which was modelled using an offset.

We used the linear distributed lag model of temperature for lags up to 6 days to examine the delayed effect of temperature on hospitalizations for a week. Constraints on the effect estimates for similar lags were imposed to reduce the collinearity effect. 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 potential confounding effects of humidity, rainfall, and day of the week were also adjusted by inputting these variables into the models.

Because the temperature-hospitalization effect size may vary with different population sizes, resulting in considerable heterogeneity of findings, 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), sex (male and female), and age groups (0–60, 60–75, and 75+). Heterogeneity between studies was quantified by the coefficient of inconsistency (*I-squared*) which describes the percentage of total variation across provinces that is due to heterogeneity (Higgins et al., 2003).

The relationship between the temperature-hospitalization association (RR) and socio-economic indicators is assumed to be linear, so we used a random-effect linear meta-regression technique to examine the influence of socio-economic factors on the temperature-hospitalization relationship. The model includes Ln(RR) as the dependent variable and socio-economic factors as the independent variables. Due to the high variability of shape, area and population distribution of the provinces, the use of raw relative risk may not fully represent the relative magnitude of underlying risk. To address this problem, we applied the Empirical Bayesian (EB) technique (Clayton et al., 2003) to adjust the neighbouring spatial effects in examining the influence of socio-economic factors on the temperature-hospitalization association.