The association between high temperature and hospitalizations for cardiovascular diseases under climate change scenarios in Ho Chi Minh City

Phung Duc Nhat*1, Duong Thi Minh Tam*2, Dang Van Chinh2, Vo Le Phu3,4, Tran Ngoc Dang5, Mai Tien Thanh5

1 University of Medicine Pham Ngoc Thach, 2 Quang Trung street, District 10, Ho Chi Minh City, Vietnam
2 Institute of Public Health, 159 Hung Phu street, District 8, Ho Chi Minh City, Vietnam
3 Faculty of Environment and Natural Resources, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet street, District 10, Ho Chi Minh City, Vietnam
4 Vietnam National University Ho Chi Minh City, Linh Trung ward, Thu Duc District, Ho Chi Minh City, Vietnam
5 University of Medicine Ho Chi Minh City, 217 Hong Bang street, District 5, Ho Chi Minh City, Vietnam

Corresponding authors: nhatphd@pnt.edu.vn duongtam81@gmail.com

Abstract. Global warming is anticipated to induce an increase in the frequency and intensity of hot days and heatwaves, which ultimately have effects on public health. The study aimed to identify the impacts of high temperature and developing climate forecasting projections focused on cardiovascular causes in Ho Chi Minh city (HCMC). The projections were built up based on updated climate scenarios in HCMC. Poisson regression model combined with a distributed lag non-linear model (DLNM) was applied. The forecasting model for cardiovascular causes was performed by using the Global Climate Model (GCM) and Yasushi Honda model. Result showed that the average daily temperature induces an increase in the risk of hospitalisation, in which temperature below 25.7°C reduced number of patients due to cardiovascular disease, meanwhile temperature above 25.7°C has increased hospitalisations. Heat waves over 31°C had the strongest impact on the > 60 years old elderly people after 5 days lag and decreased its impact consecutively to age groups of 41 to 60, 16 to 40, and less than 15 years old. The incremental prediction for the hospitalised cardiovascular disease cases based on the RCP4.5 scenario was 79,713 cases and based on the RCP8.5 scenario was 81,362 cases, respectively.
1. INTRODUCTION
Climate change is one of the most challenges in the 21st century. The Intergovernmental Panel on Climate change (IPCC) found that global average temperature on earth increased 0.85°C in period 1880-2012 [1]. Many studies observed an increase in number of hospitalisation in cases and deaths of cardiac diseases due to extreme weather events. A study in California in 2006 revealed that on a heat wave the number of hospitalisation caused by heart diseases and other climate-related diseases increased significantly [2]. A retrospective study in Taiwan on temperature, cardiovascular diseases death during the period 1991-2006 was carried out to measure effect of temperature change on heart diseases’ death. Results showed that the proportion of death increase 0.226% when temperature fluctuation increases by 1%. The death cases of cardiac diseases increased from 1.2% to 4.1% when other environmental factors were included into the predict model. Meanwhile, Ebi K. (2017) found out that only about one-third of studies on climate change were conducted in developing countries [3]. This study aims to build up a model to predict the impact of climate change on community health by updated scenarios on global warming and increase of sea level to supply the policy makers with evidence to integrate into socio-economic development plan of Ho Chi Minh City (HCMC) to eliminate and to increase climate change resilience of community health of Ho Chi Minh City.

2. MATERIALS AND METHOD
2.1. Data collection
We obtained daily admission data for the period from 1 January 1997 to 31 October 2018 from the hospital records of health centres and hospitals in 24 districts of HCMC through The Health Department. Data on hospital admissions included daily counts for arterial hypertension, myocarditis. Data extracted from the admission records included those on primary and discharge diagnoses (ICD-10 codes), date of admission, date of discharge, age, sex, and the district of residence of individual patients. To avoid exposure misclassification, patients from locations other than HCMC were excluded.

There are no meteorological monitoring stations within each districts in Ho Chi Minh City, data from the station in adjacent areas closest to the city center were used. Therefore, we obtained representative weather data from 7 monitoring stations managed by Southern Regional Hydro meteorological Center to cover for the whole city. Daily weather data from 1 January 1997 to 31 December 2018 were collected in the same period with hospitalization data. The necessary information included temperature (minimum, maximum, and average), temperature range. These daily data were then converted to the mean of weekly average temperature (°C) for analysis.
2.2. Data analysis

Firstly, meteorological data and cardiovascular hospitalisation cases were linked by date and analyzed using a time-series design. A distributed lag non-linear model (DLNM) was constructed to represent a modeling framework to flexibly describe associations showing potentially non-linear and delayed effects in time-series data. In present study, DLNM combined with a quasi-Poisson distribution was performed to quantify the relationship between daily temperature and cardiovascular hospitalisation counts adjusted with other meteorological variables. The model was specified as follows:

\[ E(Y_i) = \exp\{\alpha + f(T_i|\beta_1) + \text{(specific covariates)} + \text{(smooth function of time)}\} \]  
\[ F(T_i/\beta_1): \text{The function of temperature} \]  
\[ \text{Specific covariates}: \text{Confounding variable} \]  
\[ \text{Smooth function of time}: \text{The function of the time variable, to adjust for the long-term trend and seasonality.} \]

In addition, to account for the potential non-linear relation between temperatures and health outcomes, we applied a distributed lag non-linear model (DLNM) using a cross-basis function of multiple lag-day temperature [4]. DLNM can help determine the non-linear and lag effects of the relationship between temperature and health, simultaneously. The optimal model and parameters were selected and validated using post estimation residuals and the Akaike’s information criterion (AIC) in which the model with the least AIC was chosen due to its better explanation.

To forecasting hospital admissions incremental and rising temperatures, our study assumes factors: population, health services, and treatment remain unchanged, and forecasts to 2025, 2030, 2050 by performing analysis in 2 stages:

The first step used Global Climate Model (GCM) PRECIS developed by Hadley Meteorological Centre, the UK to forecast temperature including max, min, average temperature of HCMC in 2025, 2030, 2050 on 3 scenarios of climate change RCP4.5 (medium) and RCP8.5 (high). This study applied the GFDL-CM3 and CNRM-CM5 of the PRECIS model and downscaled at 25 km spatial resolution to forecast the climate of HCMC. In previous studies, the PRECIS model had better results than other models in predicting Vietnam’s climate.

In the second step, we applied method developed by Yasushi Honda (2014) in a previous study to calculate incremental number of admitted cases to hospitals due to hot temperature events with forecasted weather data in the years 2020, 2025, 2030, and 2050 [5].
3. RESULTS AND DISCUSSION

3.1. Cardiovascular diseases in HCMC by day and week during 1997 - 2018

Table 1. Cardiovascular diseases in HCMC by day during 1997-2018

| Data                          | Mean  | SD   | Min  | 25%  | 50%  | 75%  | Max  |
|-------------------------------|-------|------|------|------|------|------|------|
| Weather                       |       |      |      |      |      |      |      |
| Max. temperature (°C)         | 33.7  | 1.9  | 25.0 | 32.5 | 34.0 | 35.0 | 38.5 |
| Mean temperature (°C)         | 28.4  | 1.5  | 23.1 | 27.5 | 28.5 | 29.4 | 32.6 |
| Min. temperature (°C)         | 25.3  | 1.7  | 18.0 | 24.3 | 25.5 | 26.4 | 30.0 |
| Cardiovascular hospitalisation cases |      |      |      |      |      |      |      |
| Arterial hypertention         | 76.4  | 24.0 | 19   | 58   | 74   | 93   | 170  |
| Acute coronary syndrome       | 4.6   | 2.4  | 0    | 3    | 4    | 6    | 15   |
| Myocarditis                   | 0.1   | 0.3  | 0    | 0    | 0    | 0    | 2    |
| Cardiovascular cases by age,  | 81.1  | 24.8 | 22   | 62   | 79   | 98   | 179  |
| Gender                        |       |      |      |      |      |      |      |
| Male                          | 26.8  | 9.6  | 0    | 20   | 26   | 33   | 74   |
| Female                        | 49.0  | 15.2 | 10   | 37   | 48   | 60   | 100  |
| 0 – 15 years old              | 0.4   | 0.8  | 0    | 0    | 0    | 1    | 8    |
| 16 – 40                       | 3.6   | 3.5  | 0    | 2    | 3    | 4    | 26   |
| 41 – 60                       | 22.7  | 7.7  | 5    | 17   | 22   | 28   | 51   |
| > 60                          | 54.4  | 17.6 | 13   | 41   | 53   | 66   | 120  |

Average mean temperature was 28.4°C, min and max temperature consecutively were 23.1°C and 32.6°C, respectively. In cardiovascular diseases group, admission was highest in arterial hypertension (76.4%), in which the number of female cases was higher than male, and by age group the highest group was older than 60 years old group.

3.2. Distribution of hospitalisation by group of cardiovascular diseases by year (arterial hypertension, acute coronary syndrome, myocarditis).

![Figure 1. Hospitalisation of cardiovascular diseases by year in HCMC period 1997 – 2018](image-url)
The result showed that hospital admission of cardiovascular diseases had an increase trend by year. During period of 1997 to 2018, a total of 319,450 cases of arterial hypertensions admitted to hospitals was reported in HCMC. With cardiovascular diseases group, during 2006 – 2018 hospitalisation of arterial hypertensions increased by year. Meanwhile, acute coronary syndrome fluctuated slightly during 1997 to 2018. In Viet Nam, cardiovascular diseases caused 31% total of deaths annually. On a national survey on risk factor of non-communicable diseases (NCDs) in 2015, percentage of hypertensions in adults from 18-69 years of age was 18.9%, however only 13.6% of them were reported to be managed in a health settings [6]. The proportion of communicable diseases was in a decrease trend, but NCDs proportion was in an increase trend. In 2000, worldwide there were 972 million arterial hypertensions, in which 639 million people were in developing countries. It is projected that there will be 1.56 billion of cases with arterial hypertensions in 2025 (equivalent to 29.2% of total world population) [7].

During the study period, a total of 358,995 cases of cardiovascular diseases was hospitalised in HCMC. The result showed that hospitalisation cases increased by year. There was only 113 cases in 1997, and was 35,211 cases in 2018. Further, hospitalisations also increased in both male and female, in which number of female outweigh over that of male.
Figure 3. Cardiovascular diseases hospitalisation yearly by age group in HCMC during 1997–2018

Hospitalisation caused by cardiovascular diseases was highest in group over 41 year of age, in which the highest one was over 60 years old group. Controversy, there were very rare cases under 15 years old, less than 100 cases each year. Over 60 years old was always the group with highest hospitalised cases. The risk of cardiac event increased by age. Epidemiological studies found out age as one of the most predictable factor for heart disease. In group older than 65 years old, they comprised more than half of heart stroke and four-fifth deaths by stroke. Increase of these types of diseases was in relation with lifestyle, behavior, and habits. This findings is similar to that found in the USA in which coronary disease was the top reason of deaths in the US with 82% of total death was in over 65 year old group in 2005 [8]. Further, the cases of coronary were estimated to be about 80 millions of American, and half of them were from 60 years old [9].
3.3. Relation between number of cardiovascular diseases and temperature

Monthly average temperature in HCMC period 1997 – 2018 was highest during March to May (28.6°C – 28.9°C); lowest in January (26.6°C) and December (26.5°C). Monthly average temperature range was highest in January and February (10.2°C – 10.6°C), then decreased from March to September. The result shows that when temperature increased, the number of arterial hypertension hospitalisation also increased.

**Figure 4.** Time series cardiovascular diseases and temperature by month during 1997 – 2018
3.4. Relationship between number of cardiovascular diseases and daily temperature

Figure 5. Short term relation between temperature and hospitalisation of cardiovascular cases in HCMC during 2013-2018

Days with temperature under 25.7°C decreased the number of hospitalisation by cardiovascular diseases and temperature above 25.7°C increased cardiovascular cases. However, when identifying the effect of temperature ≥ 31°C in relation with daily hospitalisation caused by cardiovascular diseases, we could see an increase trend after 0 to 2 days, and a decrease trend after 3 days but the number increases again from 4 to 19 days later.

Previous studies have documented that people with chronic diseases, especially cardiovascular diseases, are more susceptible to high temperature. The mechanism of heat effect on cardiovascular includes changes in thermoregulation response, blood viscosity, surface blood circulation, and endothelial cell damage [10]. As the temperature increases, the capacity for dry heat exchange is reduced because of a reduction in the temperature gradient between the skin surface and the ambient air. As a result, losing water and salt from sweating during exposure to high temperatures. This finding implies that patients with cardiovascular disease should be taken care of during both hot and cold periods [11].
Figure 6. Influence of heat waves on cardiovascular hospitalisation by age groups
(Age groups from 41-60 years old and > 60 years old)

Optimal temperature for the age group of < 15 was 30.3°C, 16 – 40 years of age was 29.5°C and > 40 years of age was 25.7°C, respectively. There was a significant statistical difference between 40 - 60 years old group and > 60 years old group on optimal temperature. Heat wave ≥ 31°C had a strong relation in older people group with relative risk (RR) on 5 days-lag of age group above 60 years higher than group 41 – 60 years old and group less than 15 years old.

Population aging has been viewed as an important factor that could substantially exacerbate the health burden of future rising temperatures globally. Older adults are particularly sensitive to climate change[12]. Numerous studies have provided similar evidence that the elderly population is among the most vulnerable groups [13, 14]. The vulnerability of the elderly is associated with physiological and social factors, such as living alone, pre-existing chronic diseases, reduced physiological function. The vulnerability of the elderly to heat exposure is mainly due to a combination of impaired thermoregulatory capacity to heat, and a high prevalence of comorbidities involving the cardiovascular,
respiratory, endocrine, and renal systems [10]. Aging induces a decrease in thermoregulatory abilities, together with the increased prevalence of chronic diseases, which are likely to contribute to vulnerability to temperature effects in elderly people [15].

b) Effect of temperature and heat wave on gender

Both male and female were affected by the same temperature threshold of 25.7°C, however this threshold affected statistically significance only in female group. In consideration of gender factor, we could see that in the first 5 days of heat wave period, male was affected more than female but after 5 days female was affected more than male.

**Figure 7.** Effect of heat wave on cardiovascular cases by gender
Figure 8. Relation between temperature range and hospitalisation of cardiovascular diseases in HCMC during 2013-2018

Optimal temperature range for hospitalisation of cardiovascular diseases was 10.7°C. When temperature range ≤ 10.7°C there were no increase in hospitalisation but when temperature range higher than the threshold of > 10.7°C there would be an increase in hospitalisation. Consider of threshold ≥ 13°C, number of hospitalisation cases increased dramatically on 9 days lag and decreased after 10 days.

3.5. Anticipation of number of hospitalisation cases caused by cardiovascular diseases in the coming decades

Table 2. Number of hospitalisation by cardiovascular diseases due to high temperature during 2010 – 2049 by different climate change scenarios (RCP)

| No. | Decade       | RCP4.5  | RCP8.5  |
|-----|--------------|---------|---------|
|     | Number of    | Percentage of | Number of    | Percentage of |
|     | hospitalisation cases | hospitalisation (%) | hospitalisation cases | hospitalisation (%) |
| 1   | 2010-2019 (present) | 13,169  | 4.4     | 13,760  | 4.6     |
| 2   | 2020-29      | 24,005  | 8.1     | 20,979  | 7.1     |
| 3   | 2030-39      | 29,646  | 10.0    | 29,579  | 10.0    |
| 4   | 2040-49      | 26,062  | 8.8     | 30,804  | 10.4    |
| Total (2020 – 2049) | 79,713  | 9.0     | 81,362  | 9.2     |

The number of hospitalisation cases caused by the increase of temperature during 2020 – 2049 based on scenario RCP4.5 was 79,713, which was less than the number of hospitalisation cases based on scenario RCP8.5, 81,362 cases. These hospitalisation cases were appropriate with the prediction model of this study when temperature increased 1°C then after a lag from 1 to 4 weeks hospitalisation of cardiovascular diseases increased 8%.
4. Conclusion:
Global climate change induced an increase in the frequency and intensity of hot days and heatwaves, which ultimately have effects on human health. Exposure to high temperature can lead to an increase in hospital admissions for cardiovascular causes. The results of this study showed that the total hospitalisation of cardiovascular cases was in an increase trend in HCMC. Female cases outnumbered male cases. The highest cases were found in people over 40 years old. The mean average temperature weekly was 28.4°C, minimum 23.1°C and maximum 32.6°C, highest during March to May (28.6°C – 28.9°C); lowest in January (26.6°C) and December (26.5°C). When considering the relation between hospitalisation of cardiovascular cases and daily weather factors, the temperature of less than 25.7°C decreased number of hospitalisation cases, meanwhile the temperature of higher than 25.7°C resulted in increased hospitalisation cases. Heat wave ≥ 31°C had a higher impact on higher age groups, with relative risk (RR) on a 5 day- lag of age group above 60 years old which is higher than group 41 – 60 years old and group less than 15 years old.

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