Impact of weather factors on hospital admission of hand, foot and mouth disease under climate change scenarios in Ho Chi Minh City.

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Abstract. Hand, foot, and mouth disease (HFMD) is one of the most common communicable diseases in Vietnam. The present study aims to examine the association between weather factors and HFMD in association with hospitalisation. Daily and weekly weather and HFMD data from 2013 to 2018 in Ho Chi Minh City were deployed. Poisson regression model combined with a distributed lag non-linear model (DLNM) was applied to examine the relationship between weather factors and HFMD. The forecasting model for HFMD was performed by using the Global Climate Model (GCM) and Yasushi Honda model. The result showed that the average daily temperature induces an increase in the risk of HFDM hospitalisation was 26°C-30°C. The average daily humidity also caused increasing the risk of hospitalisation of HFMD was 75% - 85%. However, the average daily humidity <60% reduced the risk of getting HFMD. The study provides quantitative evidence that the incidence of HFMD cases was associated with meteorological variables including average daily temperature and daily humidity in Ho Chi Minh City. This findings implies that there is a need for building a public health policy for eliminating and mitigating climate change impact on community health in a resilient approach.

1. Introduction
Climate change is one of the biggest challenges in the 21st century in which a wide range of socio-economic sectors has been affected ubiquitously. The Intergovernmental Panel on Climate Change (IPCC) found out that the average global surface temperature on earth increased 0.85°C during period 1880-2012 [1]. Hand, foot, and mouth disease (HFMD) is a common infectious disease spread from human to human, easy to become an outbreak caused by an intestinal virus. The most common pathogens...
are Coxsackie virus A16 and Enterovirus 71 (EV71). In recent decades, Asian countries endured frequent and expanded outbreaks of HFMD with a high rate of mortality mostly occurred in children. However, there is no effective and specific treatment approach nor vaccine to this disease [2]. In Vietnam, there are few studies on the relation of climate change and HFMD. According to Ebi and Hess (2017), only one-third of studies on the impact of climate change on health were conducted in developing countries [3]. This study aims to build a model to predict the impact of climate change on community health based on updated scenarios of climate change and to provide the City authority with evidence to integrate into economic and social development plan of the City. Further, this study findings implies the need for building a public health policy for eliminating and mitigating the impact of climate change on community health in HCM City in a resilient way.

2. Materials and methods

2.1. Data collection

Daily counts of HFMD cases in 24 districts of Ho Chi Minh City from 1 January 2013 till 31 December 2018 were obtained from Center for Diseases Control of Ho Chi Minh City (HCDC). Since 2008, HFMD has been categorized into an infectious disease, local hospitals and clinics were required to report HFMD cases to HCDC communicable disease surveillance system within 24 hours. All HFMD cases were first diagnosed symptomatically. Then, the clinical diagnoses of HFMD were strictly examined and verified through laboratory evidence. Extracted data included age, sex, date of admission, date of discharge, residential district, and the International Classification Diseases 10th revision (ICD10) code. To avoid exposure misclassification, patients from locations other than HCMC were excluded. Therefore, data of HFMD cases were reliable and fully reflected changes in HFMD cases in HCMC. Overall, the reporting was representative and accuracy of HFMD in Ho Chi Minh City.

There are no meteorological monitoring stations within each districts in Ho Chi Minh City, data from the station in adjacent cities 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 2013 to 31 December 2018 were collected in the same period with hospitalization data. The necessary information included temperature (minimum, maximum, and average), temperature range, humidity, wind speed, and rainfalls. These daily data were then converted to the mean of weekly average temperature (°C), wind speed (m/s), relative humidity (%), and cumulative rainfall (mm) for analysis.

2.2. Data analysis

Firstly, meteorological data and HFMD 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 HFMD counts adjusted with other meteorological variables. The model was specified as follows:

\[
E(Y_i) = \exp(\alpha + f(T_i|\beta_1) + (\text{specific covariates}) + (\text{smooth function of time)})
\]

\[F(T_i/\beta_1): \text{The function of temperature}\]

\[\text{Specific covariates: Confounding variable}\]

\[\text{Smooth function of time: The function of the time variable, to adjust for the long-term trend and seasonality.}\]

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 temperatures [4]. DLNM can help determine the non-linear and lag effects of the relationship between weather factors 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 explain better and be chosen.
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 weather factors including max, min, average temperature of HCMC in 2025, 2030, 2050 on 3 scenarios of climate change RCP4.5 (medium), RCP6.0 (high 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 et al. (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. Descriptive analysis

A retrospective statistical data on admission cases of HFMD disease in Ho Chi Minh City from 2013 to 2018 is depicted in Table 1 below.

| Variables       | Mean | SD  | Min | Median | Max  |
|-----------------|------|-----|-----|--------|------|
| HFMD cases      | 46.98| 67  | 2.00| 13     | 618.00 |
| Temperature (°C)| 28.42| 1.28| 24.1| 28.5   | 32.1  |
| T. range (°C)   | 8.38 | 1.007| 4.8 | 8.3    | 13    |
| Humidity (%)    | 73.1 | 5.97| 58  | 73.1   | 86    |
| Wind velocity (m/s)| 2.76 | 0.70| 1.6 | 2.7    | 5.2   |
| Rainfall (mm)   | 36.50| 49.03| 0   | 15.7   | 279.8 |

Weekly mean value of temperature in HCMC was 28.42 °C during 2013 – 2018, in which the lowest and highest temperature were 24.1 °C and 32.1 °C, respectively. Temperature range weekly was 8.38 °C, with the lowest and highest values of 4.8 °C and 13.5 °C. Relative weekly humidity was 73.1%, with the lowest and highest values of 58.0% and 86%. Weekly wind velocity was 2.76 m/s, with the lowest and highest values of 1.6 m/s and 5.2 m/s, respectively. The weekly average rainfall was 36.5 mm.
In recent years, the situation of HFMD infection remains severe in Ho Chi Minh City. Figure 1 shows that annual admission cases were highest in 2014 (8,175 cases). Afterwards, the trend declined since 2015-2018. The two years of 2013 and 2014 were HFMD outbreak events with high number of cases, then there were a declined trend (2014-2017) and after that the cases raised in 2018. Recent data from the World Health Organisation (WHO) showed that HFMD cases increased on a seasonal trend. Until April, 2014 accumulative cases of HFMD in China, Macau, and Singapore increased 1.1-1.5 times compared to the same time period [2]. Increased trend of HFMD cases could be observed in other countries. Some studies also revealed that this increased trend was observed in many Asian countries, including Linsuwannon in Thailand [6], Qingdao, China [7], Edmond Ma in Hongkong, China [8].

**Figure 1.** Weekly number of admitted HFMD cases 2013 - 2018

Weekly number of HFMD case over time

Weekly mean temperature over time

Weekly humidity over time
Since 2011, HFMD is officially reported in Vietnam by Circular 48/2010/TT-BYT, issued on December 31st, 2010 by Ministry of Health. After that HFDM cases increased 6 to 7 times yearly compared to previous year and registered as one of the top ten mortality diseases in Vietnam. A study by Huynh Nguyen Phuong on “relation between communicable diseases and climate change in Can Tho city 2014 – 2018” proved that admission of HFMD increased year by year with 510 cases in 2014 and 1,270 cases in 2018 [9]. In Southern region of Viet Nam, an investigation of HFMD showed an abrupt increase of HFMD cases (an epidemic outbreak) in 2011 by 6 – 24 times compared to period 2008 - 2010 [10]. Further, an analysed data from sentinel surveillance system of Northern region of Viet Nam during the period of June 2016 - December 2018 also revealed this increased trend [11].
3.2. Relation between daily HFMD cases and weather factors

Many studies have proved that meteorological factors contribute to the epidemic of HFMD, including temperature, relative humidity, rainfall, wind speed. This study’s results showed that an increase in admission risk of HFMD by daily average temperature in the range of 26°C-30.1°C. The findings of this study were generally consistent with findings from different regions of the world [12, 13]. A study by Chen (2014) in Canton city, Guangtong province, China indicated a positive correlation between HFMD cases with a rise in temperature with a lag of 3-7 days [14]. On temperature range, admission risk increased in the range of 4.5°C to 7.5°C, however, temperature range of less than 4°C would decrease admission cases significantly. It was possible that temperature could affect the survival and transmission of the HFMD virus in the environment, as well as the behavior and activities of the hosts, thereby influencing the dynamics of the infection transmission [15]. HFMD is transmitted through direct...
contact with nose discharge, saliva, and fluid from the blisters. Additionally, it can spread through food and water which have been contaminated with fecal droplets or liquid from the mouth or nose of infected persons. Weather variables may affect the transmission of HFMD in both directly and indirectly way. The rate of replication of viruses and the survival of viruses in the environment may directly be affected by the surrounding temperature. Climate changes may affect the human behavior and hence influence the dynamics of HFMD.

Similarly, daily average humidity of 75% to 85% increased admission risk of HFMD and humidity of less than 60% reduced admission risk. A study in Japan also found out an increase in humidity of 1% would increase the weekly admission cases of HFMD by 4.7% (95%CI: 2.4-7.2) [16]. In addition, study in China in 2014 also revealed a similar result, an increase of 1% in humidity would increase admission cases of HFMD by a range of 0.51% to 1.42% [14]. Previous studies on the pathway of transmission showed that toys and other stuffs sharing contributed to the spreading of HFMD in children, especially in kindergartens. HFMD can also transmitted through pulmonary droplet or by faecal-oral route [17]. Another investigation of 2,912 Chinese districts in 2012 on the relation of humidity and HFMD showed a positive relation in only 54.4% of all districts [18]. First, enteroviruses, the pathogens of HFMD, can survive in the environment for a period of time, increasing the chance to infect vulnerable individuals[19]. Relative humidity may impact the survival time and reproductive capacity of enteroviruses, thereby increasing or decreasing the chance of contact [20]. Previous study has suggested that the sharing of toys and other items among the children might contribute to virus infections, and HFMD could also be transmitted by the fecal–oral route and respiratory droplets [17]. It was possible that, during the humid and rainfall days, the virus could be easily attached to the small particles in the air or the toys and then facilitated the disease transmission [21]. However, this possible mechanism needs to be confirmed in future studies.

Compared with most studies investigating the effects of temperature and humidity on HFMD incidence using monthly or weekly data, our findings may be more accurate. Analyses of the effects of weather factors on HFMD incidence using daily data could be more suitable for HFMD control and prevention. The ability to forecast HFMD on the basis of day-to-day weather variation could permit preventive improvements on public health infrastructure, including access to health care resources, scientific knowledge, active disease surveillance, and targeted more specific control to reduce the risk of the increased transmission.

A few limitations should be considered in this study. First, our study design was ecological in nature which did not allow us to explore individual-based association. Second, our analysis was preliminary and exploratory; we could not exclude the possibility of a spurious finding or unmeasured on founding factors that may be associated with both weather variables and HFMD occurrence. However, since this infection is a common disease in the study area, it is not difficult for the local doctors to make a correct diagnosis, so this concern should not have affected the result to a great extent. Thirdly, this was an ecological study, and the meteorological data were obtained from fixed monitoring stations rather than the real exposure of individuals. Therefore, measurement error is inevitable and may be randomly distributed, consequently underestimating the weather factors-HFMD association.

3.3. Predicted number of increased cases attributable to high temperature in children group of 4-5 years old for future decades.

Table 2. The number of increased cases attributable to high temperature in children group of 4-5 years old

| No. | Decades | RCP4.5 | RCP8.5 |
|-----|---------|--------|--------|
|     |         | Number of cases | Relative cases (%) | Number of cases | Relative cases (%) |
|     |         | RCP4.5 | RCP8.5 |
|     |         |        |        |        |        |
|     |         |        |        |        |        |

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The number of cases admitted to hospitals in children group of 4-5 year old are attributable to high temperature was showed in Table 2. In two different scenarios of RCP, the incremental cases for the period of 2020 – 2049 in scenario RCP4.5 will be 783 cases, less than the cases of scenario RCP8.5, which are 868 cases.

In the children group of 4-5 years old, there were only 2,688 cases (6%) admitted during the period of 2013 – 2018. However, by speculation with the risk function this age group is the main group to be affected by high temperature in future.

With an assumption that all other groups will be affected by high temperature in a similar weather pattern like in children group, there will be 783 cases (5.9%) admitted to hospitals in the period of 2020 – 2049 by RCP4.5 scenario and 868 cases (6.5%) by RCP8.5 scenario. However, resisting strength of HFMD of different ages will be different, therefore, impact of high temperature will be different by different age groups.

Furthermore, in the future period of 2020 – 2049, children group of 4-5 years old will be affected by high temperature and will increase their risk of admission by 5.9% and 6.5% with the RCP4.5 scenario and RCP8.5 scenario, respectively.

4. Conclusion

Climate change has posed a wide range of impacts on socio-economic sectors around the world. HFMD is one of the most common communicable diseases in Viet Nam and is closely related with weather-related events and climate risks. The outbreaks of HFMD in recent years indicated the disease interacts with both weather and seasonal factors. This study indicated that admission risk of HFMD increase in the range of daily average temperature from 26°C to 30.1°C. Meanwhile, daily average humidity range of 75% to 85% caused an increase in the admission risk of HFMD but reduced the admission risk with the range of humidity of less than 60%. Daily rainfall ranging from 5 mm to 55 mm also contributed to an increase in admission risk; on the contrary, daily rainfall equal or higher than 200 mm will reduce admission risk of HFMD. It is assumed that all age groups get the same effect by high temperature as group 4-5 years old, the period 2020 – 2049 will get an accumulative admission frequency of 783 cases (5.9%) and 868 cases (6.5%) by RCP4.5 and RCP8.5 scenarios, respectively. Most importantly, these results imply that there is the need for building up a public health policy in Ho Chi Minh City for mitigating the impacts of climate change on community health in a resilient approach.

Acknowledgements: We would like to thank to Ho Chi Minh City Department of Science and Technology for its funding to this research under the contract No. 43/2018/HĐ-SKHCN. The authors also acknowledged the support of time and facilities from Ho Chi Minh City (HCMUT), VNU-HCM for this study.
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