EFFECTS OF CLIMATE VARIATIONS ON HAND-FOOT-MOUTH DISEASE IN HO CHI MINH CITY

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ABSTRACT

Abnormal emergence of epidemics has been believed to be one of the most significant effects of climate change on human health, especially in the tropical zone. Hand-foot-mouth disease (HFMD) which possibly related to climatic changes has emerged in Vietnam since 2003. Ho Chi Minh City (HCMC) is particularly a Southern city with the highest cases and mortality numbers of HFMD in the whole country. Therefore, we conducted a retrospective observational study to analyse the association between climate variations and HFMD in HCMC. HFMD and meteorological data from 2010 to 2014 were collected from The Preventive Medicine Centre of HCMC and Sub-Institute of Hydrometeorology and Environment of South Vietnam. The research used time-series analysis and Poisson regression model to analyse the effects of climate fluctuations on HFMD, adjusting for seasonal and trend effects, lag effects and degrees of freedom. The research findings showed that climate variables (average temperature, average humidity, minimum humidity, precipitation, and the Southern Oscillation Index (SOI) daily data) had a significant influence on HFMD. Noticeably, the effects of climate variations on HFMD were considerable in children aged 1-3 and 3-5 years. The maximum lag effects were 3 weeks for temperature and humidity, 4 weeks for precipitation, and 6 weeks for SOI. Specifically, the relative risk of HFMD increased by 7.2 % for every 1°C increase in temperature, 6.75 % for every 1% increase in humidity, 6.32 % for every 5 mm increase in precipitation, 4.42 % for every 5 units increase in SOI. The study provided a quantitative evidence that the increase of HFMD was significantly affected by the increase of climate variations. Therefore, the study provided the foundation for developing theory that is used in models and, ultimately, for making forecasts about future impacts of HFMD associated with climatic changes.

Keywords: climate variations, hand-foot-mouth disease, time-series analysis, climate change.

1. INTRODUCTION

HFMD is a common childhood infection and a self-limiting illness [1], but many cases of severe illness and death were recorded [2]. Outbreaks of HFMD have been reported in some
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Areas of the world since 1970s but there has not been much attention [3, 4]. Over the last decade, many outbreaks of HFMD have been reported in countries of the Western Pacific Region like Taiwan, Japan, Malaysia, Singapore and Vietnam, and China [1]. HFMD has emerged in Vietnam since 2003, from 12 patients with encephalitis, who sought treatment at the hospital [5]. Nearly 80% of the HFMD cases have been annually reported in the southern region in Vietnam [6]. Particularly, cases and mortality rate of HFMD were reported the highest in HCMC in 2011 [7]. The relationship between climate variables and infectious diseases has been mentioned in the literature for a long time. The distribution and outbreak of infectious diseases were possibly affected by the extreme climate variables. HFMD is also an infectious disease which strongly influenced by climatic changes [8]. The seasonal distribution of HFMD is a clear evidence for the association between climate variables and HFMD [8, 9]. Some studies Japan or in China showed the number of HFMD cases increased significantly with increasing average temperature and relative humidity [8, 10, 11]. On the other hand, the effects of El Niño/Southern Oscillation (ENSO) on HFMD were analysed through SOI by a study in Shenzhen, China [12]. There have not been research studies mentioned the effects of ENSO on HFMD, and also infectious diseases. In Vietnam, the research studies on HFMD have mainly focused on the fields of clinical treatment and descriptive epidemiology [5, 7, 13]. Meanwhile, the impacts of climate fluctuations on HFMD is not well understood. Therefore, we conducted a retrospective observational study from 2010 to 2014 to assess the effects of climate variations on HFMD in HCMC. The research would be the first study providing quantitative evidence of effects of climate variations on HFMD in Vietnam.

2. METHODS

2.1. Data sources

The weekly data of HFMD cases for the study period from August 2010 to December 2014 were obtained from The Preventive Medicine Centre of HCMC. Being a common disease mentioned in Vietnam’s Law on Prevention and Control of Infectious Diseases [14], the weekly data of HFMD cases from three big hospitals in HCMC, including Children’s Hospital 1, Children’s Hospital 2, and the HCMC Hospital for Tropical Diseases were required to report to The Preventive Medicine Centre of HCMC. Therefore, the data of HFMD cases were reliable and fully reflected changes of HFMD in HCMC. According to the data, HFMD cases were children aged 0–5 years.

Daily meteorological data for the study period were obtained from the Sub-Institute of Hydrometeorology and Environment of South Vietnam. The SOI data for the study period were obtained from The Bureau of Meteorology, Australia [15]. The SOI which was calculated using the pressure differences between Tahiti and Darwin gives an indication of the development and intensity of ENSO in the Pacific Ocean. SOI was used as an index representing the climatic changes in HCMC that is located in the impacted areas of the ENSO.

2.2. Data analysis

The meteorological variables and SOI data were calculated for intervals of 7 consecutive days, transformed into a time-series format, which comprised a total period of 230 weeks. The weekly data of HFMD cases were calculated for the weekly prevalence of HFMD per 1,000,000 populations. We used time-series analysis to estimate the abnormality of the weekly prevalence of HFMD per 1,000,000 populations by removing the seasonal and trend effects. We examined the effects of climate variations on HFMD by using the Poisson regression analysis [11].
suitability of the Poisson regression model would be affected by the lag and degrees of freedom of meteorological data. Therefore, we considered two criteria: firstly, the optimal number of degrees of freedom of meteorological data were selected for model based on the principle of minimizing of the sum of the absolute values of partial autocorrelation function (PACF) [8]; secondly, to handle over-dispersion in Poisson regression, the quasi-Poisson dispersion parameter was used in the model.

Furthermore, the lag effects and degrees of freedom (df) of meteorological variables were considered. We examined the effects with different lag time including single-week lag from Lag 1 to Lag 6 to capture immediate and cumulative effects. We also examined the degrees of freedom of meteorological variables with df = 3, 5, 7. The degrees of freedom at 3 (df = 3) was selected because the sum PACF was minimum. The degrees of freedom at 3 was also selected by previous studies in Fukuoka, Japan, and Singapore [11, 16]. Next, we assessed relative risk and standard deviation of relative risk of difference meteorological variables to predict the change of relative risk. The results were reported as percentage changes in the weekly number of HFMD cases per unit increase in meteorological variables, and associated 95% confidence intervals (95% CI). Finally, we also observed the analyses for separate age groups (<1, 1–3, 3–5) using the identical methods. All statistical analyses were examined using R statistical software, version 3.1.2, using the DLNM (distributed lag models non-linear) package, version 3.1.2, using the DLNM (distributed lag models non-linear) package, version 3.1.2 [11].

3. RESULTS AND DISCUSSION

3.1. Descriptive statistical results

HFMD has emerged in Vietnam since 2003 [5] but HFMD outbreaks have occurred often since 2010. A total of 37,871 (100%) HFMD cases in HCMC from August 2010 to December 2014 were included in our analyses, of which 2,708 (7.1%) were in children aged under 1 year, 28,623 (75.6%) in those aged 1–3 years, 5,176 (13.7%) in those aged 3–5 years, and 1,364 (3.6%) in those aged over 5 years. Descriptive statistics for characteristics of the weekly number of HFMD cases by age in HCMC are summarized in Table 1. From the analysis of the weekly reported number of HFMD cases, the weekly prevalence and abnormality of HFMD per 1,000,000 populations were found to differ from year to year, although they typically had two peaks (May-July and Sept-Nov) (Fig.1).

3.2. Poisson regression models

The research findings of the Poisson regression analyses showed that the abnormalities of the weekly prevalence of HFMD per 1,000,000 populations were affected by the changes of meteorological variables. The abnormalities for all age groups were positively correlated with 5 climate variables, including average temperature, average relative humidity, minimum relative humidity, precipitation, and SOI (Table 1). The results of statistical test for linearity, normal distribution, and the value of the residual PACF showed that the models were suitable and statistically significant (95% CI). Table 1 also showed that no evidence of correlations of maximum and minimum temperature was detected. After removing these two variables from the regression analysis, we also noticed that maximum relative humidity, solar radiation, and ultraviolet were not significantly correlated with the abnormalities. The results are similar to the previous findings in Japan, Singapore, Hong Kong, Taiwan, and China, which mentioned that increased temperature, precipitation and humidity may have influenced the increase of HFMD incidence [8, 10 – 12, 16 - 21]. Otherwise, the research results in Japan showed the weak
correlation of the effect of precipitation on HFMD incidence \( (p > 0.1) \) [11] while this study indicated that there was a strong correlation between precipitation and the possibility of suffering HFMD (Tab. 1). This discrepancy might be due to the climate conditions (a long rainy season, high annual precipitation) and canal systems in HCMC which are reasonable for distribution of viruses causing HFMD in water and for increases of the abilities of spread and outbreak of disease. Besides, similar to the discovery in the province of Shenzhen, China in 2013 [12], the results also showed the strong correlation between SOI and HFMD abnormalities in HCMC (Tab. 1). Therefore, SOI was considered a climate variable which directly impacted on the possible increase of HFMD in our study.

**Table 1.** Characteristics of the weekly number of HFMD cases and meteorological data in HCMC, 2010-2014.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Of HFMD cases</td>
<td>164.7</td>
<td>658</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>&lt; 1 year</td>
<td>11.77</td>
<td>56</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1-3 years</td>
<td>124.4</td>
<td>532</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>3-5 years</td>
<td>22.5</td>
<td>86</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Average temperature (°C)</td>
<td>27.39</td>
<td>22.51</td>
<td>30.40</td>
<td>0.02 **</td>
</tr>
<tr>
<td>Maximum temperature (°C)</td>
<td>31.63</td>
<td>28.43</td>
<td>34.73</td>
<td>0.30 ***</td>
</tr>
<tr>
<td>Minimum temperature (°C)</td>
<td>24.68</td>
<td>19.6</td>
<td>27.71</td>
<td>0.15 ***</td>
</tr>
<tr>
<td>Average relative humidity (%)</td>
<td>73.43</td>
<td>61.00</td>
<td>84.43</td>
<td>0.015 *</td>
</tr>
<tr>
<td>Maximum relative humidity (%)</td>
<td>85.80</td>
<td>76.86</td>
<td>90.86</td>
<td>0.006 **</td>
</tr>
<tr>
<td>Minimum relative humidity (%)</td>
<td>54.96</td>
<td>37.71</td>
<td>72.29</td>
<td>0.046 *</td>
</tr>
<tr>
<td>Solar radiation (W/m²)</td>
<td>180.6</td>
<td>108.3</td>
<td>266.3</td>
<td>0.036 *</td>
</tr>
<tr>
<td>Ultraviolet (W/m²)</td>
<td>1.66</td>
<td>0.10</td>
<td>4.87</td>
<td>0.026 *</td>
</tr>
<tr>
<td>Precipitation (mm)</td>
<td>11.56</td>
<td>0</td>
<td>84.60</td>
<td>0.018 *</td>
</tr>
<tr>
<td>SOI</td>
<td>11.68</td>
<td>-6.96</td>
<td>48.56</td>
<td>0.0014 **</td>
</tr>
</tbody>
</table>

*, **, *** at the \( P = 0.01, 0.05, 0.1 \) level, respectively.

**Figure 1.** Seasonal distribution of weekly HFMD cases, prevalence, and abnormality in HCMC, 2010-2014.

The effects of climate variations on HFMD essentially corresponded to the biological plausibility [8]. Temperature, humidity and precipitation affected on the habitat of virus [11]. A laboratory study showed the effects of temperature and humidity on virus [22]. Climate conditions in HCMC are very potential for existence and development of enteroviruses. Those
might be the reasons why it was found that enter-viral infections maintained at a constant level throughout the year in HCMC [5]. On the other hand, weather conditions may be associated with changes in human behaviours, which could affect the rise of HFMD [8, 11]. Some studies also showed that human behaviours and physical activities have considerably increased in hot season [23, 24]. People would spend more time for activities outside in hot season, which possibly increased the abilities of interaction and spread of disease [8].

3.3. Lag effects and Age-specific analyses

Our analyses of lag effects indicated that relative risk of weekly HFMD abnormalities for all age groups was affected by all 5 climate variables with different lag settings (Fig. 2). The lag number would be optimal when relative risk was maximum and meteorological variables were minimum [8, 11]. The maximum lag effects were 3 weeks for temperature and humidity, 4 weeks for precipitation, and 6 weeks for SOI (Fig. 2). Our results were similar to previous studies in Japan, Hong Kong, Singapore and China [8, 11, 16, 18]. However, the noticeable difference in our study was the relationship between precipitation, SOI and HFMD which was not consistent with the above studies. The lag effects of SOI factors is specifically longer than the others factors. This may be due to a combination of double lag effects, including (a) the lag effects of the relationship between SOI and temperature, humidity, precipitation, and (b) the lag effects of temperature, humidity, precipitation on HFMD.

The effects of climate variables on the abnormalities of the weekly prevalence of HFMD found in this study mainly occurred in children aged 1-3 and 3-5 years according to our analyses for separate age groups. We did not find the correlation between climate variations and the HFMD abnormalities in the age group under 1. The HFMD abnormalities of 1-3 aged group were affected by all 5 climate variables, and the HFMD abnormalities of 3-5 aged group were affected by all 4 climate variables except average temperature. The results were similar to the study in Fukuoka, Japan [11], but different from the results in Guangzhou, China [8]. We will discuss in more detail how the climate fluctuations affected on the HFMD abnormalities for separate age groups in another article.

3.4. Prediction

Based on the optimal lag number and relative risk results, we investigated whether the relative risk of HFMD was sensitive to the levels of changes of meteorological variables. The results showed that the relative risk would rise followed by the increases of meteorological variables. Specifically, the relative risk would add 7.2 % with increase of temperature (1°C), 6.75 % with increase of humidity (1 %), 6.32 % with increase of precipitation (5 mm), 4.42 % with increase of SOI (5 units). The prediction of the effects was consistent with the findings of a Japan study [11]. Our present findings suggested that weather factors might explain the associations and increases and peaks of HFMD infections.

3.4. Limitation

A few limitations of this study is that the data of HFMD in Vietnam might have not reported completely and systematically although HFMD is a notifiable disease mentioned in Vietnam’s Law on Prevention and Control of Infectious Diseases [14]. Moreover, it is difficult to access to the data source in terms of administrative procedures in Vietnam.
Figure 2. The lag effects of 5 climate variables with different lag settings on relative risk of weekly HFMD abnormalities for all age groups.
4. CONCLUSIONS

The association between climate variations and epidemics has been mentioned in literature, in which climate is one of the main factors affecting the distribution and outbreak of epidemics. Therefore, it is important and essential to treat past temporal patterns of climate fluctuations and HFMD as empirical analogues of future changes. To the best of our knowledge, this research is the first study in Vietnam providing quantitative evidence that the increase of HFMD was significantly affected by the increase of climate variations. The research findings could provide the foundation for developing theory that is used in models, for making forecasts about future impacts of HFMD associated with climatic changes, and, ultimately, in preparation for guiding health resource allocation and intervention strategies.

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REFERENCES

1. WHO – A guide to clinical management and public health response for hand, foot and mouth disease (HFMD), Manila: WHO Regional Office for the Western Pacific, 2011.


