The impacts of climatic conditions on dengue fever and general emergency hospital admissions in tropical Indonesia

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Abstract. Changes in climate parameters such as air temperature, rainfall, and humidity may dramatically impact the occurrence of infectious diseases. Dengue fever is a prevalent disease that has been extensively reported in relation to climate change, particularly in tropical countries such as Indonesia. In addition, the consequences of climate change may affect the physiological responses of our bodies, which could lead to a rise in hospital admissions even in tropical countries. Wet Bulb Globe Temperature (WBGT) is an index to estimate the effect of air temperature, humidity, and solar radiation on human bodies. First, this study aims to investigate the influence of climatic conditions, including air temperature (AT), relative humidity (RH), and rainfall (RF), on the occurrence of dengue fever in Jakarta, Bandung, and Malang city, through a cross-correlation analysis. Second, it also explains the relationships between WBGT and general emergency hospital admissions in Indonesia and Japan. The results showed that climate conditions such as rainfall and humidity had a strong correlation with the incidence of dengue in Indonesia, with a relatively short lag of around 2-5 months in the form of negative values, while positive values were observed with a lag of 9-10 months with some exceptions in Jakarta. Extreme WBGT changes do not affect general emergency hospital admissions in both Hiroshima and Indonesian cities, although the WBGT changes clearly affected the emergency hospital admissions caused by the heat stroke in Hiroshima.

1 Introduction

Tropical countries experience climate change impacts, including extreme weather events such as shifts in rainfall patterns and increase in temperature. According to Indonesia Public Health 2017, dengue fever in Indonesia increased during 2008-2016, and Jakarta has been one of the highest dengue-endemic regions in Indonesia. In addition, the consequences of climate change may affect the physiological responses of our bodies, which could lead to a rise in hospital admissions even in tropical countries [1]. Wet Bulb Globe Temperature (WBGT) is an index to estimate the effect of air temperature, RH, and solar radiation on human bodies. The WBGT limits need to be determined based on the possibility of being hospitalized due to extreme weather conditions. Heat stroke is one of the heat-related illnesses due to extremely hot temperatures. Many previous studies found a strong correlation between summertime temperature and the incidence of heat stroke, and to date, most studies focus on the effects of the highest temperature [2]. In Western Japan, the temperature can reach 35 °C or above during the summer, but the average temperature for major observation in Japan during summer is 31.5 °C [3], whereas Indonesia also experiences the same level or even hotter. However, the incidence of heat stroke in Indonesia is infrequent. This research aims to examine the influence of climatic conditions, including air temperature (AT), relative humidity (RH), and rainfall (RF), on the incidence rate of dengue fever in Jakarta, Bandung, and Malang city.

Additionally, this study also investigates the relationship between WBGT and general emergency hospital admission in Indonesia and hospital admissions caused by heat stroke in Japan.

2 Methods

2.1 Dengue fever: cross-correlation

Cross-correlation was used to analyze the associations between climate factors and the incidence rates of dengue fever in Jakarta, Bandung, and Malang (Table 1). In addition, cross-correlation can find the time lag when the highest correlation is obtained. Cross-correlation contains both positive correlation and negative correlation. Positive correlation refers to the tendency of two variables to move in the same direction, while the relationship of negative correlation is always the opposite. The data used are monthly incidence rates from 2010 to 2020, which were obtained from the health department in each city in the form of secondary data. The incidence rates (IR) indicate the number of incidences per 10,000 people in each city, considering the exact population of that year. The incidence rate is an important concept in epidemiology research, and it is the most appropriate measure of the frequency of morbidity development in a population over time[4]. Weather conditions are represented by monthly average data from 2010 to 2020.
from the Meteorological, Climatological, and Geophysical Agency.

<table>
<thead>
<tr>
<th>No</th>
<th>Variable</th>
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<th>Unit</th>
</tr>
</thead>
<tbody>
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<td>Communicable diseases</td>
<td>per 10,000 people</td>
</tr>
<tr>
<td>2</td>
<td>X1</td>
<td>Air temperatures (AT)</td>
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</tr>
<tr>
<td>3</td>
<td>X2</td>
<td>Rainfall (RF)</td>
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</tr>
<tr>
<td>4</td>
<td>X3</td>
<td>Relative humidity (RH)</td>
<td>%</td>
</tr>
</tbody>
</table>

2.2 Regressions analysis: general emergency hospital admissions and heat stroke

General emergency hospital admissions in Indonesia were obtained from the Health Office in each region, while heat stroke data in Hiroshima Prefecture and Higashi Hiroshima City was obtained from Fire and Disaster Management Agency, Ministry of Internal Affairs and Communication. Both data sets were analyzed with the monthly maximum WBGT in 2015-2020. There have been numerous proposed equations for estimating WBGT. WBGT used in this study is employed by ISO 7243, computed by combining the measurements of two derived parameters: natural wet-bulb temperature (tnw) and black globe temperature (tg). WBGT changes in each city will be divided into three categories: monthly changes, three-month changes, and six-month changes. Regression analysis will be utilized in this study to determine WBGT changes in the incidence rate of both general emergency hospital admissions in Indonesia and the incidence rate of heat stroke in Japan. The variables used at this stage are listed in the table below.

<table>
<thead>
<tr>
<th>No</th>
<th>Variable</th>
<th>Remarks</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Y</td>
<td>The incidence rate (IR) of heat stroke/hospital admissions</td>
<td>per 10,000 people</td>
</tr>
<tr>
<td>2</td>
<td>X1</td>
<td>WBGT monthly changes</td>
<td>°C</td>
</tr>
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<td>3</td>
<td>X2</td>
<td>WBGT three-month changes</td>
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</tr>
<tr>
<td>4</td>
<td>X3</td>
<td>WBGT six-month changes</td>
<td>°C</td>
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</table>

3 Result and Discussion

3.1 Cross-correlation for dengue fever

Figure 1 shows dengue fever incidence rates in three cities, respectively. Indonesia experiences a hot-humid climate throughout the year, consisting of the dry season (May to September) and the rainy season (November to March). Among the three cities, the average temperature in Bandung is not as high as the other cities because of its high altitude (700-800 m above sea level).

As shown in Fig. 1, overall, the incidence rates of dengue fever are relatively low in Bandung, ranging from 0.24-3.3/10,000 people, compared to those in the other cities. Constant annual changes can be observed in all three cities, although the magnitudes vary among the cities. This implies that there are seasonal changes in dengue fever. The incidence rates increase particularly from March to May, which is the transitional period from the rainy to dry season.

On top of that, there are several peaks (epidemics) in some years, but the timing is different depending on the cities. In Jakarta, for example, the incidence rate was particularly high, approximately 30/10,000 people, in March 2010 and April 2016 (37/10,000 people). In Malang, such peaks were seen in May 2015 (14/10,000 people) and February 2019 (13/10,000 people). The results imply that the incidence rates of dengue fever are influenced not only by long-term climatic conditions but also by seasonal changes. Other local factors affect the incidence rates, possibly causing an intermittent epidemic within the city [5].

The cross-correlation results are presented in Figs. 2-4. In the figures, positive r-values indicate that the incidence rate increases with the increase in the weather parameter and vice versa. As shown in the case of dengue fever (Fig. 4.), the trend lines draw similar wave curves regardless of the cities and weather parameters, starting from positive r-values to negative values and then turning to positive values again, except for the air temperature of Jakarta. The peak r-values can be seen around a lag of 2-5 months (negative values) and 9-11 months (positive values), with some exceptions. This similar pattern is probably attributed to the seasons (i.e. dry season and rainy season). As previously discussed, it was found that dengue cases increased notably during March and May, which is the transitional season entering the dry season. Time lags between weather parameters and dengue incidence in this study can be caused by several possibilities involving various factors, for example, the breeding period of dengue vectors. During the rainy season, many puddles, the place where mosquitoes breed, are formed. Thus, the rainy season facilitates the breeding of mosquitoes. Mosquito breeding happens not only outdoors but also inside the house, such as in puddles in water reservoirs, backyards, pottery, etc. Partially due to poor ventilation, indoor humidity can be as high as 80-100% RH, particularly during the rainy season in Indonesia. This would help trigger the breeding of mosquitoes as well. It is supported by research conducted by William that RH affects mosquito lifespan, breeding speed, flight distance, and biting habits [6]. It was also reported that high humidity with optimal AT would increase vector reproduction, while low humidity decreases mosquitoes' survival effectiveness [6].

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Fig. 1. Incidence rate of dengue fever in Jakarta, Bandung, Malang

Fig. 2. Cross-correlation between dengue fever and AT in three cities

Fig. 3. Cross-correlation between dengue fever and humidity in three cities

Fig. 4. Cross-correlation between dengue fever and RF in three cities

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3.2 Regressions analysis for heat stroke in Japan and general emergency hospital admissions in Indonesia

In Japan, it has been reported that the incidence rates caused by the heat stroke increase once the outdoor WBGT reaches a certain level [7]. As shown in Fig. 5, this study found the threshold for both heat stroke in Hiroshima prefecture and Higashi-Hiroshima City. The threshold indicated that the emergency hospital admissions caused by heat stroke increased when the monthly maximum WBGT crosses 26°C in Hiroshima prefecture and 24°C in Higashi-Hiroshima during the last six years (2015 - 2021). As expected, there are clear relationships between the two variables.

The heat stroke is not a major issue among ordinally people in Indonesia, although the heat stroke occurs among military personnel or construction workers [8]. Therefore, the hospital admission data caused by heat stroke is not available at the moment. Alternatively, we obtained a general emergency hospital admission data caused by any kinds of emergency diseases and analyzed the associations with the monthly maximum WBGT in Jakarta, Bandung, and Surabaya in addition to Higashi-Hiroshima (Fig. 6). Unlike Fig. 5 (incidence rate of heat stroke), there are no relationships between monthly maximum WBGT and the general emergency hospital admissions not only in Indonesian cities but also in Higashi-Hiroshima.

Figure 7 shows the scatter plots of WBGT and the incidence rate of heat stroke in two Japanese cities (Hiroshima Prefecture and Higashi Hiroshima city) with the three types of WBGT changes: monthly changes, three-month changes, and six-month changes. When the incidence rates are analyzed by three-month changes or six-month changes, the heat stroke incidence can happen. In particular, when the incidence rates are analyzed by six-month changes, the heat stroke incidence increases after the changes exceed 10°C.

However, this study analyzes the general emergency hospital admissions instead of heat stroke incidence rates as shown in Fig. 8, the above-mentioned tendencies cannot be extracted even from Higashi-Hiroshima. Therefore, this study assumed that heat stroke incidence is not commonly aware in Indonesia despite the continuous hot conditions because the seasonal temperature changes are less. In other words, the heat stroke occurrence in Japan is influenced not by the WBGT levels but rather by its sudden changes.

Unfortunately, it is difficult to draw any conclusions from the above-mentioned assumptions in this paper simply because of the unavailability of the data on emergency hospital admission caused by heat stroke in Indonesian cities. A future study is necessary to clarify these assumptions.

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Fig. 7. WBGT changes and heat stroke in Hiroshima prefecture and Higashi Hiroshima city

Fig. 8. WBGT changes and general emergency hospital admissions in Higashi Hiroshima, Jakarta, Bandung, and Surabaya

4 Conclusion

Dengue fever is probably one of the most susceptible diseases to climatic conditions. The results implied that the seasonal changes of air temperature, relative humidity, and rainfalls had strong relationships with dengue fever occurrence with a certain time lag. Other factors, such as social and environmental factors, may affect the incidences, but it is expected that the dengue fever pattern may be altered due to future climate changes. On the other hand, there was no correlation between monthly maximum WBGT changes and general emergency hospital admissions in both Japanese cities and Indonesian cities, although the WBGT changes clearly affected the incidence rates of heat stroke in Japanese cities. A future study is necessary to find the influences of WBGT on the incidence rate of heat stroke in Indonesian cities.

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References


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