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The Minimum-Maximum Weather Temperature Difference Effect on Dengue Incidence in Sleman Regency of Yogyakarta, Indonesia

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Abstract

Dengue is a viral disease, transmitted by *Aedes aegypti*, and is still a big problem in tropical areas, including Indonesia, where the temperatures are relatively warm and suitable for vector mosquito life. In the dry season, the day and night temperature differences are quite sharp and, at that time, the number of dengue cases is low. In this study, the difference between day and night temperature is referred to as daily temperature fluctuation and represented by the maximum and minimum temperature difference in each month. The research was conducted in Sleman Regency, Yogyakarta Province, Indonesia, as an endemic area, and the data were collected from 4 endemic areas in Sleman; Gamping, Godean, Sleman, and Depok districts. The data collected were quantitative with serial data retrospective. Secondary data of monthly dengue incidence in the years 2008 - 2013 were obtained from the Regency Health Office and used as a dependent variable. Monthly minimum and maximum temperatures in the same periods were obtained from the Agency of Meteorology, Climatology, and Geophysics. The differences between the minimum and maximum temperatures were calculated, to be used as independent variable data, and represented the different day and night temperatures of the month. Data were analyzed by using linear regressions to determine the influence of fluctuating temperature on the incidence of dengue. Results show that fluctuating temperature affected dengue incidence in the districts of Godean (p = 0.000; $R^2 = 0.207$) and Gamping (p = 0.006; $R^2 = 0.125$), but did not affect it in Sleman (p = 0.164) or Depok (p = 0.075). The data suggests that fluctuating temperature affected dengue incidence with powers of 20.7 % in Godean and 12.5 % in Gamping.

Keywords: Aedes aegypti, daily temperature fluctuation, dengue incidence

Introduction

Dengue is a viral disease that is transmitted by *Aedes* bites. This disease remains a big problem for public health in tropical areas, including Indonesia. The incidence of dengue is strongly related to the existence of *Aedes* mosquitos, especially *Aedes aegypti*, as the primary vector. Temperature is one of the climatic factors that influence dengue transmission through the reproductive cycle [1], the biting frequency [2], and the incubation period of the virus in a mosquito's body (extrinsic incubation period/EIP) [3]. Mourya [4] showed that the optimum temperature for fast mosquito reproduction cycle is 26 - 30 °C. The faster the reproduction cycle, the higher the mosquito density, so the number of

transmission will also increase [1]. In addition, temperature also affects the frequency of mosquito bites, because female mosquitoes suck blood for reproductive purposes [5]. The frequency of blood feeding will increase when the reproductive cycle progresses faster [5]. According to Goindin et al. [6], the interval between the first blood feeding period and the next period (the gonotrophic cycle) ranges from 1.15 - 3.38 days, depending on the temperature. Regarding the effect of temperature on EIP in mosquito bodies, research by [7] indicates that EIP is fastest when the ambient temperature reaches 30 °C. However, other research indicates that EIP is also influenced by daily temperature fluctuation, although the results are still in the laboratory research phase. Sharp daily temperature fluctuations will accelerate EIP [8]. Faster EIPs will cause transmission to be more effective, since the number of viruses in the vector mosquito body will quickly increase to reach a sufficient amount of transmissions. The effect of daily temperature fluctuations on EIP in the laboratory has not been shown to affect the occurrence of dengue in the field. Existing field studies show that there are inconsistent results for the relationship between temperature and dengue incidence in field studies in Indonesia. Research in Jakarta [9], Semarang City [10], Surabaya City [11], and Batam City [12] showed a relationship between temperature averages and dengue incidence, but those in Sleman Regency of Yogyakarta [13], Padang City of West Sumatera [14], and in Sumenep of East Java [11] did not.

Geographically, Indonesia lies between 6 North latitude - 11 South latitude and 95 East Longitude - 141 East Longitude; the low latitude causes Indonesia to have a tropical climate, characterized by a high average temperature (> 18 °C) and a small daily amplitude. There are 2 seasons in Indonesia, which are controlled by the seasonal movement of the Inter-Tropical Convergence Zone (ITCZ). The wet season occurs in November - March, which peaks in January - February, and dry season peaks in July - September [15]. Generally, dengue incidence increases in the wet season as the result of increasing rainfall, humidity, and warmer temperatures [15]. Trapped rainwater will increase the number of breeding places, while high humidity and warmer temperatures will increase survival and accelerate the reproductive cycle of mosquitos, improving the vectorial capacity of *Ae. aegypti*. In contrast, the cooler temperatures during the dry season reduces the survival of mosquitos, resulting in reduced vectorial capacity [3]. In contrast, large daily fluctuations in temperature could accelerate EIP in the laboratory [7], so as to increase the possibility of transmission. This perhaps sustains the phenomenon of dengue in the environment.

The inconsistency of the research results on the mean temperature affecting dengue in the field, and the possibility of daily temperature fluctuations perhaps affecting EIP in the laboratory, prompted this current research on whether daily temperature fluctuations affect the incidence of dengue in the field. This research aimed to reveal the influence of daily temperature fluctuations on dengue incidence. The results are expected to provide a climatic factors that affects dengue incidence, so as to improve the forecasting model of dengue as part of the development of an early warning system (EWS).

Material and methods

Geography and climate of study area

Sleman Regency is located in the northern part of Yogyakarta, Indonesia (110° 33' 00" and 110° 13' 00" E, 7° 34' 51" and 7° 47' 30" latitude) (**Figure 1**). It consists of 17 districts and 86 sub-districts and had a population of 1.126.888 inhabitants in 2011 [15].

Gamping and Godean are at altitudes of < 100 m asl, with Sleman and Depok at 100 - 499 m asl [17]. Sleman Regency has a wet tropical climate, with a rainy season between November - April and a dry season between May - October. The peak of the rainy season is in January - February. Data of the year 2008 - 2013 showed that the highest rainfall occurred in January 2013 (728 mm), and the lowest in August - September in almost every year (0 mm); the highest average temperature was in October 2014 (27.5 °C), and the lowest in January 2010 (23.8 °C), and the highest humidity was in June 2013 (90 %) and the lowest in August 2011 (67 %).



Figure 1 Research sites in 4 districts (blue color): District of Gamping, Godean, Depok, and Sleman, Sleman Regency, Yogyakarta Province, Indonesia (created by Tri Wulandari Kesetyaningsih).

Regional characteristics

Gamping and Depok district are urban areas of Sleman Regency and the agglomerated area of Yogyakarta, the municipality serving as a center of education, industry, commerce, and services [17]. Gamping district was an endemic area with a relatively high dengue hemorrhagic fever (DHF) trend during the 5 years from 2008 - 2013. Depok was a high dengue endemic area, which had a relatively declining trend over the 5 years (2008 - 2013).

Godean and Sleman districts are suburban, located quite far from the municipality of Yogyakarta, and have been developed into a center for activities for the surrounding area community, thus becoming growth centers [15]. Dengue cases increased over the 5 years from 2008 - 2013 in Godean, so this region was included in the category of moderately endemic areas that had an increasing trend of cases.

Dengue data

What is meant by dengue, clinically, is DF (dengue fever), dengue hemorrhagic fever (DHF), and dengue shock syndrome (DSS) [18]. There was a lack of data concerning dengue fever (DF), and only DHF and DSS data were available in the Regency Health Office of Sleman. Therefore, the term 'dengue' in this research means DHF and DSS. Dengue hemorrhagic fever and DSS are defined as legal notices of dengue fever and dengue shock syndrome, which are confirmed referring to WHO [19] by local health authorities.

Data collection of dengue incidence was conducted after we obtained a permission letter from Regency Government (Permission Letter No. 070/Bappeda/775/2015). It was conducted during the period of June - August 2015. Monthly dengue notification of study areas (districts of Gamping, Godean, Depok,

and Sleman) obtained from Regency Health Office of Sleman, Yogyakarta, for the period of January 2008 - December 2013, was used as a dependent variable. The data were validated by checking the data available at the Community Health Centers of each district. If there were differences in data, then the data used in the study was a combination of data available in the Regency Health Office with data available in the Community Health Centers.

Climatic data

Climatic data were collected after we obtained a permission letter from the Agency of Meteorology, Climatology, and Geophysics (BMKG) of Yogyakarta province (permission letter no. KT.401/490/YGI/III/2015). We obtained monthly minimum and maximum temperature data from the Agency of BMKG of Yogyakarta province in the same period with dengue incidence data (January 2008 - December 2013). Data of difference between the minimum and maximum temperatures of each month were obtained by calculating the difference between the minimum and maximum temperatures per month. The difference between the minimum and maximum temperatures per month. The difference between the month as an independent variable. It showed that temperature fluctuations increased in the dry season (May - October) relatively.

Data analysis

Monthly incidence of dengue data was obtained as a dependent variable, and the data of monthly minimum-maximum difference temperatures were obtained as an independent variable. The data were analyzed by using linear regression to reveal the influence of temperature fluctuation on dengue incidence. We used SPSS version 15.0 to analyze the data.

Results

The influence of temperature on the incidence of dengue has been revealed. The temperature affected the breeding of mosquitos and the incubation period of the virus in mosquito bodies, so would affect the vectorial capacity of *Aedes* mosquito. This correlation forms the basis of a temperature variable as a predictor of dengue incidence in a predictive model.

Figure 2 illustrates the distribution of monthly dengue events from 2008 - 2013 paired with minimum-maximum differences of temperatures over the same period in 4 research sites. **Figure 2** shows that the incidence of dengue had different trends among the 4 research sites. Godean district (A) tended to increase from moderate, Gamping district (B) had a stable tendency which is always high, Depok district (C) had a decreasing tendency, and Sleman district (D) had a moderate stable tendency.

When the distribution of dengue is paired with minimum-maximum temperature differences, it appears that, when the temperature difference minimum-maximum is low, the incidence of dengue increases. However, the correlation between these 2 variables needs to be proven statistically. In this study, correlation analysis uses linear regression.

By using linear regression, this study proves that the minimum-maximum temperature difference affected the dengue incidence in Gamping district (p = 0.006 and $R^2 = 0.124$) and Godean district (p = 0.000; $R^2 = 0.163$), but did not affect dengue incidence in Depok district (p = 0.075; $R^2 = 0.053$) and Sleman district (p = 0.164; $R^2 = 0.028$) (**Table 1**). Figure 3 shows that the relationship between the minimum-maximum temperature difference and the incidence of dengue is negative, which means the higher the minimum-maximum temperature difference, the lower the dengue incidence.

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Figure 2 Monthly dengue cases and the difference between minimum and maximum temperature year 2008 - 2013 in sub-districts of Godean (A), Gamping (B), Depok (C), and Sleman (D).

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Figure 3 Scatter plot correlation between min-max difference of air temperature and dengue cases in (A) Gamping (R = -0.353; R² = 0.124), (B) Depok (R = -0.023; R² = 0.053), (C) Godean (R = -0.404; R² = 0.163), and (D) Sleman (R = -0.166; R² = 0.028).

 Table 1 Result of regression test between minimum-maximum temperature differences and dengue incidence in study area.

District	Mean minimum-maximum difference of temperature (°C)	Mean dengue cases	P value	R	R ²
Gamping	13.944	7.264	0.006 ^s	-0.353	0.124
Depok	13.944	6.181	0.075^{ts}	-0.231	0.053
Godean	13.944	4.736	0.000^{s}	-0.404	0.163
Sleman	13.944	1.903	0.164 ^{ts}	-0.166	0.028

Discussion

The relationship between temperature and the presence of *Aedes* has been investigated in an experimental laboratory, with the result that the optimal temperature may accelerate the development of mosquitoes [20,21], increase the survival of mosquitoes [20,22] and accelerate the extrinsic incubation period of the virus in the mosquito body [23] all of which could increase the vectorial capacity of Aedes [24]. We note the fact that, in the dry season, there is a large temperature difference between day and night and a low incidence of dengue, leading to the expectation that there may be a correlation between the 2 variables.

The interaction between temperature, humidity, and rainfall can be explained as follows: any reduction in the relative humidity of 5 % will lower the air temperature by 1 °C. According to Umoh *et al.* [25] there was a positive and high correlation between rainfall and relative humidity (correlation coefficient 0.9021). Thus, it can be said that the high rainfall will increase the humidity, thereby increasing or maintaining the temperature of the environment, so as to create a suitable environment for *Aedes.* Conversely, the dry season, when there is not much water in the soil, causes low humidity, so that nothing maintains the stability of temperature, causing the day-night temperature difference to be greater than in the rainy season.

Large temperature fluctuations at low average temperatures could reduce the reproduction ability of *Aedes* mosquitoes in the laboratory [26] and decrease mosquito survival [3]. This is associated with Canyon *et al.* [27] which found that the frequency of blood-sucking of female mosquitoes pertains to their gonotrophic cycle (reproductive cycle); the faster the reproductive cycle, the higher the frequency of blood sucking female mosquitoes, which in turn will decrease the possibility of transmission of the dengue virus. In contrast, Carrington *et al.* [8] proved that large temperature fluctuations in low temperatures would accelerate the incubation period of the virus in a mosquito's body (extrinsic incubation period/EIP), which could result in increased chances of transmission of the dengue virus. This may be a natural phenomenon, in order to balance the survival of the virus in the environment.

The results show that the magnitude of the minimum-maximum difference temperature affected the incidence of dengue in the 2 areas studied, namely the Gamping and Godean districts (**Table 1**). The greater the difference in minimum-maximum temperature, the smaller the incidence of dengue. Humidity is the other climatic parameter which also affected dengue in Godean (p = 0,01, $R^2 = 0,226$) [13]. This suggests that the influence of climatic factors was still more on the reproductive system [26] and the survival of mosquitoes [3], rather than on the development of virus in mosquito bodies [7], despite the low strength of the effect (**Table 1**).

Other possible influential factors are the host factors and the environmental factors. The host factors that may affect dengue are mobility [28,29], knowledge, behavior, and socio-economic factors [30], whereas environmental factors are the presence of settlements or buildings which have a dirty environment and lots of unused goods around it [31] and with inadequate water supply [32].

Relating to the conditions of Godean as a center of economic activity for the people surrounding the region, it is possible that the incidence of dengue fever is influenced by peoples' mobility and changes in land use, but these should be investigated further.

Good knowledge, followed by positive behavior, in order to prevent dengue through environmental management, is expected to reduce the incidence of dengue. The results of research on the correlation of knowledge and behavior with dengue incidence were varied in different areas. Research conducted by Tedy [33] in Medan, Roose [34], in Pekanbaru and Pristi [35] in Semarang indicated a relationship between knowledge and the incidence of dengue, but this did not correlate with behavioral prevention of dengue [36,37], as well as the density of larvae, in the city of Yogyakarta [38] and in Jamaica [39]; therefore, factors of knowledge, behavior, and socio-economics still need to be investigated as factors influencing the incidence of dengue.

Environmental factors surrounding the residence or place of human activity are very important with regards to the provision of sufficient micro environment for the life of the *Aedes* mosquito. *Ae. aegypti* finds breeding places in clear water, although in little volume, both indoors and outdoors, whereas *Aedes*

albopictus breeds outdoors more, and in clear water, in tree holes or other natural objects [1]. *Ae. aegypti* females have very short flying distances (50 - 100 m), and have a preference for sucking human blood [1]. Based on this fact, the greater likelihood of transmission of dengue occurs in, or close to, residential or other buildings used for human activity. Some studies showed a correlation between the incidence of dengue with settlements [40-42]. The existence of trees around settlements or other buildings for human activity is also important in the transmission of dengue, because the presence of these trees will maintain humidity in the microenvironment [43], making it suitable for the life of the mosquito vector. The optimum humidity for mosquito life is about 70 - 80 % [4].

This research showed that dengue in Depok was not influenced by the minimum-maximum temperature difference. It was also not influenced by other climatic parameters, such as average temperature, humidity, or precipitation in this area [13]. This suggests that the decreasing trends of dengue may be caused by community behavior in this area.

The absence of minimum-maximum temperature difference effect on the incidence of dengue in Sleman district suggests that the incidence of dengue in these places, which have relatively stable moderate dengue levels, might be due to the influence of host factors and the microenvironment around the settlements or other buildings used for human activities. The case-control study undertaken by Kesetyaningsih and Ajeng [44] noted that the incidence of dengue in Sleman district was related with knowledge and behavior, but was not related to socio-economic factors. It might be that the relative stability of dengue cases in Sleman district was driven by host factors, especially knowledge and behavior. There has been no study yet about microenvironmental conditions around the settlements or other buildings used for human activities in Sleman relating to dengue cases.

Conclusions

The maximum-minimum temperature difference affected the incidence of dengue in the districts of Gamping and Godean, which have a high stable trend and an increased trend from a moderate dengue level. The minimum-maximum temperature difference did not affect the incidence of dengue in the Depok and Sleman districts, which have a moderate stable trend and have declined from a high dengue level.

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