Malaysian Journal of Medicine and Health Sciences (eISSN 2636-9346)

ORIGINAL ARTICLE

Weather Variability on Mosquito-borne Disease Distribution in Terengganu, Malaysia: A Retrospective Study

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ABSTRACT

Introduction: The trend of several mosquito-borne diseases in Malaysia has shown an increasing pattern over the past few years despite close monitoring and continuous control initiatives by the public health authority. This study aimed to provide an assessment of the weather variability of mosquito-borne disease in Terengganu state from 2009 to 2018. **Methods:** Terengganu has been selected because it is geographically unique and experiences two monsoon seasons per year, which is known to influence the occurrence of mosquito-borne diseases. A ten-year data on mosquito-borne diseases and weather variables were used. Correlation analyses were used to determine the degree of the relationship between mosquito-borne disease and weather variables. **Results:** Overall, the results showed multiple variations in the relationship between weather variables with mosquito-borne disease cases. The results indicated a weak negative correlation between cases of rainfall and relative humidity throughout the study period. **Conclusion:** As a conclusion, having enough information on various patterns of weather variables is needed to provide an early warning system to stop the mosquito-borne disease outbreak through the management effective disease control programs.

Keywords: Agent, Environment, Host, Mosquito-borne disease, Weather variables.

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INTRODUCTION

Mosquito-borne diseases are complex and dynamic. Their emergence and re-emergence (eg: chikungunya, dengue fever, Japanese Encephalitis (JE), malaria, West Nile, yellow fever, lymphatic filariasis and Zika) across continents have brought a large number of mortality and morbidity in various subtropical and tropical regions. To this day, mosquitoes have been documented as the vector responsible for transmitting numerous diseases. From almost 3,500 species of mosquitoes throughout the world, around 200 species can transmit diseases to humans (1).

Mosquito populations tend to increase when environmental variables such as temperature, humidity, vegetation, and land-use patterns change (2,3). Since mosquito-borne diseases are weather sensitive, a lot of consideration have been given to its implications on the risk of diseases in the future. From a biological perspective, weather variables are one of the more important factors affecting incidences of mosquito-borne diseases, since they affect the mosquito's growth, development, as well as the survival rate of pathogens such as viruses and parasites within the mosquitoes.

The knowledge on the relationship between these factors is a necessity for public health authorities to assert some measures of surveillance and control over the vectors, and to implement effective early warning systems (4-6). Therefore, adequate knowledge about the interaction between vector population with human settings is needed (2). Nowadays, the dynamic spatial and temporal patterns of mosquito-borne diseases are easily observable due to the abundance of mosquitoes and their ability to sustain themselves while relying on several environmental factors.

Since the threat of mosquito-borne disease cases have been increasing slowly for decades, the Ministry of Health Malaysia has introduced several control programmes such as disease surveillance, vector surveillance and control, clinical management on diagnosis, and emergency responses at both state and national levels to manage and reduce the burden of these diseases (7). During outbreaks, activities under the vector control programme focused on reducing the number of mosquito populations. This effort is neither sustainable nor easily managed, often due to a large number of habitations within a region as well as the fact that the mosquitoes targeted may be at different stages of larval development (2). Despite the Malaysian government's recent efforts to combat mosquito-borne disease cases, which are still on the rise, this study aimed to determine the relationship between weather variables and mosquito-borne disease surveillance data to develop an effective and accurate preventive and control management.

METHODS AND MATERIALS

Study site and study population

This study was conducted in the eastern coast state of Peninsular Malaysia called Terengganu. It is located between the longitude 103.1324° E and the latitude 5.3117° N. This state is divided into seven main administrative districts namely Kemaman, Dungun, Marang, Kuala Terengganu, Hulu Terengganu, Setiu and Besut. The most concentrated area in terms of population is the Kuala Terengganu district. It is located along the South China Sea coast and acts as the city's administrative centre. The total geographical area is 13,035 km and the total population in this state is 1.125 million. About 97.25% of the population resides in rural areas whilst the remaining minority can be found in urban and sub-urban areas. The major ethnic group is Malay and most of them are farmers. This study focused on the whole area of Terengganu state. Terengganu was selected due to an increase in cases reported on mosquito-borne diseases as well as due to its unique geography whereby it experiences two monsoon seasons per year. Fig. 1 shows the location of the Terengganu on the map of Malaysia.

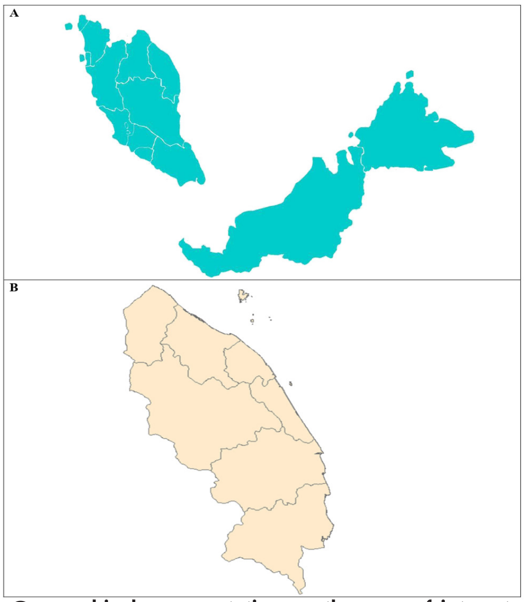

Fig. 1: Geographical representation on the area of interest of this study A: Terengganu state in Malaysia B: Terengganu map based on district administrative boundaries

Study design

This study applied an integrated epidemiological study design to assess the effect of weather variability pattern on mosquito-borne disease distribution. A retrospective cross-sectional study was conducted from 2009 to 2018 to analyse several information about mosquito-borne disease occurrence in Terengganu. Secondary data from public domains that contained anonymous on human subjects were also collected from Vector Borne Disease Division and Malaysia Department of Meteorological. The permission to access all the data was obtained through a formal application. The surveillance data on different types of mosquito-borne diseases were collected through passive surveillance systems for ten years, while the weather data were obtained from meteorological and seismological services of high quality to fulfil the socio-economic and security needs. The collection of multiple types of data sets can provide a baseline that will be useful in developing a prediction model in the future of mosquito-borne disease outbreak. The information was collected and reviewed over time to allow stakeholders, public health epidemiologist, and health workers to understand the spread and prevalence of mosquito-borne diseases within their respective fields.

Data Sources, Integration and Management

This study relied on two main data sources; (i) the mosquito-borne disease surveillance data (dengue, malaria, lymphatic filariasis, Japanese Encephalitis (JE), and chikungunya) which were obtained from the Vector Borne Disease Control Division of the Terengganu State Health Department as secondary data, and (ii) weather variables data (temperature, relative humidity and rainfall) with variation in terms of location and time were obtained from Malaysia Department of Meteorological under the Ministry of Science, Technology and Innovation. The original mosquito-borne disease surveillance data was an aggregate on the occurrence of mosquito-borne disease cases based on weekly data of the year 2009 to 2018. The cases database was presented for all 7 main districts in Terengganu state. This present study only used mosquito-borne disease datasets that consisted of cases confirmed through serological test. The weather data were a monthly dataset with four attributes (month, mean temperature, rainfall and relative humidity), captured from the local station in Kuala Terengganu, Terengganu (Latitude: 5° 23′ N, Longitude: 103° 6′ E, Elevation: 5.2 m) from the year 2009 to 2018 in Microsoft Excel format. Only one station data was used, which was the closest weather station to all districts due to the availability of the data and the weather destination would not differ considerably across the space (8). The Statistic Package for Social Science (SPSS, version 26) was used to analyze all of the data.

RESULTS

Weather Pattern of Temperature, Rain Fall and Relative Humidity in Terengganu

To understand how the pattern of weather variables contributed towards mosquito-borne disease occurrences in Terengganu, a scatter plot graph that represented data for the overall ten years were created. On a monthly basis, the patterns of average rainfall, temperature, and relative humidity over the time period were calculated to understand the distribution for each variable. Fig. 2 shows the scatter plot graph of monthly weather variables from 2009 to 2018. This graph was divided into 3 sections with different colour codes namely A, B, and C representing temperature (orange), rainfall (blue) and relative humidity (green) respectively. To pinpoint any difference in patterns, the profiles of the weather variables were compared and subsequently analysed.

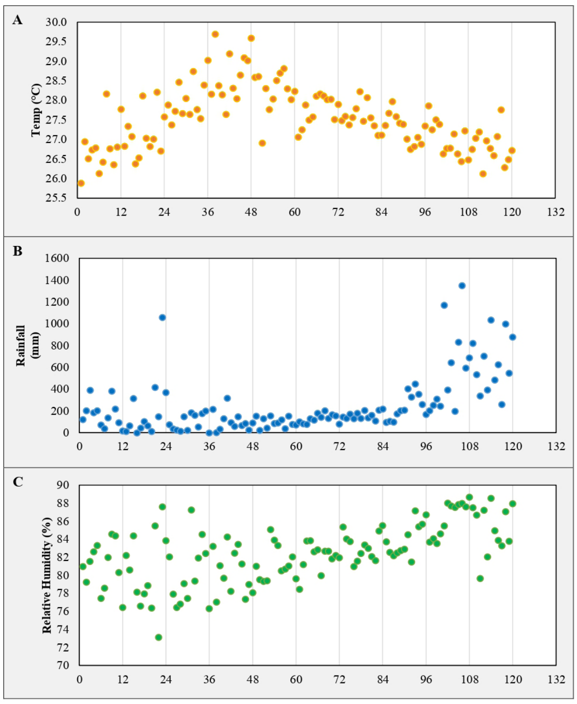

Fig. 2 Scatter plot graph of monthly weather variables for a continual period from 2009 to 2018. The scatter plot graph was divided into 3 sections namely A, B, and C representing temperature (orange), rainfall (blue) and relative humidity (green) respectively.

The results were shown on the scatter plot graph indicated an obvious difference in temperature patterns throughout the year. It can be seen that the distribution was a quite similar year to year even though there was a difference in pattern for certain years. The graph showed that the temperature levels most likely peaked around the range between 29°C to 30°C. The pattern of rainfall remained quite similar during the early parts of the study period but began to show a significant difference in the trend towards the end of the study period. Higher rainfall intensity occurred mostly towards the end of the year with levels around the range of 1000-1500 mm. In contrast, the average pattern of relative humidity showed a relative distribution that remained similar throughout the year with levels within the range of 70% to 90% being recorded.

Relationship between Distribution of Mosquito-Borne Disease and Weather Variables

Respondents were aged between 21 to 60 years old. Majority of respondents were female (71.1%), married (55.4%), had number of dependent less than two (81%), Malays (66.1%), had normal BMI (52.1%) and were smokers (95.9%). Most of the respondents graduated with diploma (55.4%) and their household income was less than RM5000 for 54.4% of the respondents. See Table I.

Prevalence of Musculoskeletal Symptoms

The monitoring data for mosquito-borne illnesses were used to estimate the strength and direction of the association between mosquito-borne disease cases and meteorological factors. *Pearson's* correlation and cross coefficient (*r*) test was used to evaluate the association between mosquito-borne illness cases and meteorological factors, and the study was carried out over a 10-year period from 2009 to 2018. This study gave insight into the impact of weather variables on how mosquito-borne diseases occur. The weather variables in question are average temperature (°C), average rainfall (mm) and average relative humidity (%). Only three types of mosquito-borne diseases were included in the analysis and they are dengue fever, malaria and lymphatic filariasis. These diseases were chosen because they were the only three to show any significant changes in response to weather variability.

To get a better view of results, the data on mosquito-borne disease and weather variables were summarized and displayed in a correlation matrix (Fig. 3). The *Pearson's* correlation and cross correlation coefficient of mosquito-borne diseases (green) and weather variables (orange) were shown for each scatter plot with significant coefficients (*r*) being highlighted in red. It was clearly showed multiple variations in the relationship between weather variables with mosquito-borne disease cases. Overall, no significant value for all weather variables with all mosquito-borne disease cases were shown. From the

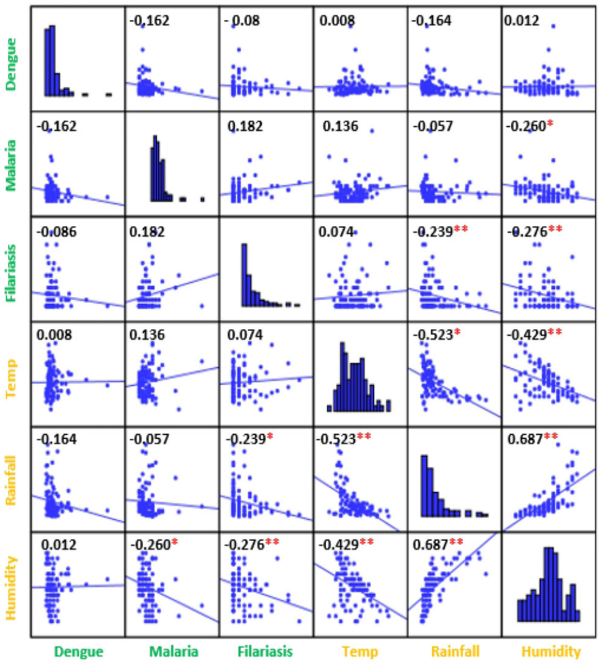

Fig. 3 The correlation plot shows the integration of mosquito-borne disease (green) and the weather variables (orange) in Terengganu from 2009 to 2018. Note: (**) Correlation is significant at 0.01 level (2-tailed) (*) Correlation is significant at 0.05 level (2-tailed) (green).

figure, the statistical analysis showed that dengue fever had no correlation with average temperature, relative humidity, and average rainfall (p>0.05). For malaria, the similar association was establish where there is no correlation with average temperature, relative humidity, and average rainfall (p>0.05). Lymphatic filariasis was significantly correlated to two variables of average rainfall (r=-0.239, p=0.018) and average relative humidity (r=-0.276, p=0.006).

DISCUSSION

The measurement on the average monthly readings of each variable gave a clear indication of differences in seasons. These differences are influenced by the weather itself. The climate of the Artic indirectly affects the monsoon seasons (9). Plus, these weather variables were affected dramatically by global warming as well as other regional and global phenomena such as monsoons (10). Areas affected by monsoons like Terengganu tend to receive the highest amount of rainfall in the summer season and almost double the maximum rainfall in the winter season. This factor significantly affects the trend of decreasing averages as observed in the relative humidity levels. Besides the distributional changes during a monsoon season tend to affect the climate in the sense of producing less precipitation in the summer, with an increase in average temperature (9). These variations may cause a change in the transmission patterns and trends of infectious diseases worldwide, especially for diseases carried by mosquitoes.

Changes in climate is one of the environmental elements believed to influence the trend in distribution and transmission of mosquito-borne diseases. The results of the present study clearly indicated that weather variability such as temperature, rainfall and relative humidity did not directly impact the trend of incidence and transmission trends except at a low level for certain types of diseases. These interrelations between mosquito-borne diseases with those parameters were supported in numerous studies (2-4,11-14). These results indicated insignificant correlation between dengue fever cases and weather variables, especially for rainfall. The study findings suggested that this might be due to the fact that the Aedes mosquito is a domesticated vector with synanthropic habits. For instance, Aedes aegypti can find shelter in human settlements which provide minimal changes in temperature and relative humidity as well as protection from extreme wind and rain. Moreover, inter-correlation between dengue fever and rainfall shows that this factor can be a crucial in influencing the life pattern of mosquitoes in terms of mating, oviposition and host-seeking patterns (16). Furthermore, rainfall affects the quantity of dengue vectors at all stages of a mosquito's life cycle (adult, pupae, larvae and eggs) (17). Moist environments created by precipitation will cause an increase in vector population and longevity. Hence, it can be concluded that higher levels of relative humidity create a favourable environment for the transmission of dengue fever. In contrast, another study found a negative association between dengue cases and rainfall (2). The difference in outcome was due to the continual fluctuations of rainfall, which may have an impact on mosquito survival rates (18).

Similarly, the results also indicated that malaria had no significant correlation with temperature, which was in line with the previous studies (12,14). The disease can be more directly affected by temperature, through its effect on vector biology, parasite development and human activity and behaviour. When temperature rises, precipitation patterns will alter and this in turn will affect the epidemiology of malaria (19). In warmer climates, the abundance of infective Anopheles mosquito increases to higher levels, as can be seen earlier in the simulation as compared to the current climate (20). The biological framework for malaria transmission is very sensitive to weather and climate changes especially in the development of plasmodium parasite in female Anopheles mosquitoes. It has an exponential relationship to ambient temperature throughout its lifecycle as well as its mortality rates and this is observable in the fact that small increases in external temperature will reduce the time required for parasite maturity within the female Anopheles (21).

For lymphatic filariasis, the results indicated a weak negative correlation between cases of rainfall and relative humidity throughout the study period. Although environmental factors such as temperature were not significantly associated with the cases, this factor played an important role in lymphatic filariasis transmissions (22). This is in line with a study by Manhenje et al (13) who reported the highest risk of lymphatic filariasis transmissions increase was related to mean maximum temperature. A favourable temperature as well as low humidity and rainfall is necessary for the survival of most vectors transmitting lymphatic filariasis. The transmission of lymphatic filariasis occurs within the temperature range of 22°C-30°C; a stable temperature range of 20°C-25°C enables the survival of the mosquito and the development of Wuchereria brancrofti in the vectors that transmit the disease (13). At high temperatures around 27°C, the larval development cycle is completed within two weeks. This is considerably faster as compared to the development rates in colder conditions where the cycle will take up to 6 weeks. This factor might increase the average load and transmission potential of the parasites (23). The transmission of lymphatic filariasis will also remain highly active when facilitated by high temperature, with constantly high rates of human-vector contact (24). However, the study conducted in Ghana showed that the rainfall directly influences the number of lymphatic filariasis cases was recorded during the wet season (11). The contrary findings showed that the density of malaria vectors would rise after heavy rains due to the correlation of infective mosquito bites, potentially increasing the incidence and frequency of filarial infections in populations (25).

CONCLUSION

We concluded that the findings in this study revealed a variation in the association of contributing factors from weather variables in the transmissions and distribution pattern of mosquito-borne disease. The data obtained from various agencies are very beneficial to complete the current practices of Integrated Vector Management by providing other contributing environmental factors especially for weather variables which were statistically and significantly proven at particular characteristics of the corresponding area. This interaction could be the largest contributor to disease burden by the changes of the vector existence which can lead Terengganu population to be at risk. The distribution pattern of mosquito-borne disease cases and its interaction with the weather can be used for interactive mosquito-borne disease surveillance modelling and effective prevention and control management not merely in Terengganu state but also adjacent states with the same geographical and environmental factors or in the other areas in Malaysia with a high number of mosquito-borne disease cases. Furthermore, amendments have to be included in the existing policy especially from the Ministry of Health by including the adoption of new technology such as remote sensing development to gain a better comprehension of modulating diseases risk.

ACKNOWLEDGEMENTS

The authors would like to convey their heartfelt appreciation to all organizations participating in this initiative. We would also want to express our gratitude to the Faculty of Health Sciences at Universiti Teknologi MARA (UiTM) for their technical and grantt support (600-RMC/GPK 5/3 (110/2020).

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