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Standardized Morbidity Ratio and Its Application to Chikungunya Disease Mapping in Malaysia

Standardized Morbidity Ratio dan Aplikasinya Terhadap Pemetaan Penyakit Chikungunya di Malaysia

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Abstract

Disease mapping has recently become an important method in the fields of public health research and disease epidemiology. Disease mapping is a spatial representation of epidemiology data. Chikungunya disease is an endemic mosquito-borne illness in many tropical and sub-tropical countries, including Malaysia. The disease is quite similar with the dengue disease. However, the Chikungunya virus is not fatal. Precautionary steps must be taken to avoid spreading the Chikungunya virus, which has increasing number of cases every year. Therefore, the aim of this paper is to discuss the suitable methods to estimate its relative risk. The methods involved using the number of Chikungunya cases itself and the Standardized Morbidity Ratio (SMR). SMR method is the most common method used in disease mapping studies. The results include disease risk maps for all states in Malaysia showing the distribution of high and low risk areas of Chikungunya disease.

Keyword Chikungunya disease, disease mapping, relative risk estimation, SMR method

Abstrak

Pemetaan penyakit kini telah menjadi satu kaedah penting dalam penyelidikan berkaitan kesihatan awam dan epidemiologi penyakit. Pemetaan penyakit merupakan persembahan ruang bagi data epidemiologi. Chikungunya merupakan sejenis penyakit bawaan nyamuk dan endemik di kebanyakkan negara tropika dan sub-tropika termasuk Malaysia. Penyakit ini hampir sama dengan penyakit denggi. Walau bagaimanapun, virus Chikungunya tidak akan menyebabkan kematian. Langkah berjaga-jaga perlu diambil bagi mengelakkan penyebaran virus Chikungunya ini yang mempunyai kes setiap tahun. Oleh itu, tujuan kajian ini ialah untuk membincangkan kaedah yang sesuai digunakan bagi menganggar risiko relatif. Kaedah ini melibatkan penganggaran bilangan kes Chikungunya menggunakan kaedah SMR. SMR ialah kaedah yang biasa digunakan dalam kajian pemetaan penyakit. Hasil kajian merangkumi peta risiko penyakit bagi kesemua negeri-negeri di Malaysia yang memaparkan taburan kawasan dengan risiko tinggi dan rendah bagi penyakit Chikungunya.

Kata kunci penyakit Chikungunya, pemetaan penyakit, penganggaran risiko relatif, kaedah SMR

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INTRODUCTION

Disease maps are visual representations of intricate geographic data, providing a quick overview of the collected information and mainly used for explanatory purposes. Disease maps can also be presented to survey the high and low risk areas. Hence, it helps policy and resource allocation in those areas. Generally, it involves the usage and the interpretation of shaded or coloured maps displaying the incidence of specific diseases in the area of interest. Maps showing relative risks of a disease in a geographical region are important for identifying areas that deserve closer scrutiny or greater attention. Many researchers including epidemiologists, biostatisticians, medical demographics and academics are interested in disease mapping as it can be used to represent and analyse the geographical distributions of disease incidence or prevalence data in maps. Recently, disease mapping has become an important tool and technique in studying disease epidemiology and health services research.

A study conducted by Barrett (2000), has revealed that a German physician named Finke produced a world map of diseases in 1792, which might be the first world disease map. Barrett concluded that the original had either been lost or destroyed because it was a manuscript map that was not reproduced. As reported by Barrett (1993), this was based on the results of his investigations, that there was no subsequent reference to Finke's map. Barrett (2000) stated that contemporary researchers believed that either the Berghaus map produced in 1848 or the Schnurrer map produced in 1827 was the earliest world disease map. Disease mapping may be useful, especially for government agencies to allocate resources or identify hazards related to a disease (Meza, 2003). The risk predicted by the map relies on the accuracy of the model to develop the map.

This research is concerned with the geographical distributions of infectious diseases, which can have many miscellaneous usages. Lawson (2001) categorized such research into three main areas of application, which are disease mapping, disease clustering and ecological analysis. In disease mapping, the purpose of the analysis is to estimate the true relative risk of a disease of interest across a geographical study area. The main aim is to reduce the noise in a disease map. In contrast, the purpose of disease clustering analysis is to examine potential environmental hazards based on whether a disease map reveals localised clusters of cases. It is also used to determine the location of any such cluster, which is important for public health surveillance. Thirdly, ecological analysis focuses on the analysis of geographical distributions of disease in relation to explanatory variables, where various supplementary issues relating to disease mapping can be identified.

The most common method used in disease mapping is a classical model based on the standardized morbidity ratio (SMR). The analysis of risk estimation based on SMR needs to be done first before developing a suitable disease mapping model. This analysis is used to assess the status of an area with respect to the disease incidence. The initial aim of this research was to discuss about SMR, which can be used to estimate relative risk (RR) in disease mapping. In this paper, an overview of the Chikungunya disease and its situation in Malaysia are provided, followed by a review on previous research conducted using SMR and their drawbacks. SMR method was then applied using the Chikungunya incidence data and the result will reveal accurate representations of the disease occurrence in Malaysia.

This research is particularly concerned with tract data covering all states and territories in Malaysia, collectively referred to as states for convenience.

Chikungunya Disease and Its Situation in Malaysia

Chikungunya is a viral disease spread by the bite of infected *Aedes* mosquitoes. Human infections caused by Chikungunya virus were reported for the first time in East Africa about five decades ago in 1952 to 1953 during a fever epidemic that developed along the border between Tanzania and Mozambique (Cavrini et al., 2009). The word 'Chikungunya' comes from the Kimakonde language, which means 'curved over', referring to a patient's body shape as bending to bear pain. The geographic range most affected by Chikungunya virus is from Africa to Asia. In Malaysia, an outbreak of Chikungunya virus occurred in Klang, between December 1998 and February 1999 (Lam et al., 2001). The majority of the cases occurred in adults and the clinical presentation was similar to classical Chikungunya infections. The movement of migrant workers from countries where Chikungunya was an endemic introduced the virus into Malaysia.

The symptoms of infection are fever and severe pain in the joints, particularly the small joints. Other signs include muscle pain, headache, nausea, fatigue and rash. Chikungunya virus infection can cause a debilitating illness, but the joint pain usually ends within few days or weeks. However, the symptoms can return because Chikungunya and dengue hemorrhagic are from the same family. Furthermore, the symptoms are very similar, which can also weaken the immune system, causing the body to be susceptible to other diseases. Typically, Chikungunya fever lasts few days to few weeks, but some patients have prolonged fatigue lasting several weeks. The incubation period, which means the time from infection to the illness can be in the range of two to twelve days. But it usually occurs about three to seven days. Commonly, Chikungunya virus is not fatal for patients. Chikungunya is detected through blood test. As the clinical emergences of Chikungunya and dengue hemorrhagic fever are similar, laboratory confirmation is important, especially in the areas of occurrence of dengue disease. As with dengue, there is no drug or vaccine to prevent Chikungunya.

The data used in this research were provided by the Ministry of Health Malaysia. Figure 1 presents the total number of Chikungunya cases reported for each state in Malaysia from epidemiology week 1 to epidemiology week 52 in the year of 2010. Fifteen states were involved in this study, which were Perlis, Kedah, Pulau Pinang, Perak, Selangor, Kuala Lumpur and Putrajaya, Negeri Sembilan, Melaka, Johor, Pahang, Terengganu, Kelantan, Sarawak, Sabah and Labuan. For the purpose of this paper, the data for Kuala Lumpur and Putrajaya were combined. Obviously, we can see that Sarawak had the highest number of cases, which was 550 cases. The second highest was Sabah, which reported 191 cases of Chikungunya. Three states were free from Chikungunya disease, which were Perlis, Kedah and Melaka. From 3 January 2010 to 1 January 2011, the total number of Chikungunya disease involving all states in Malaysia was 804 cases with no reported fatality (Ministry of Health Malaysia, 2010).

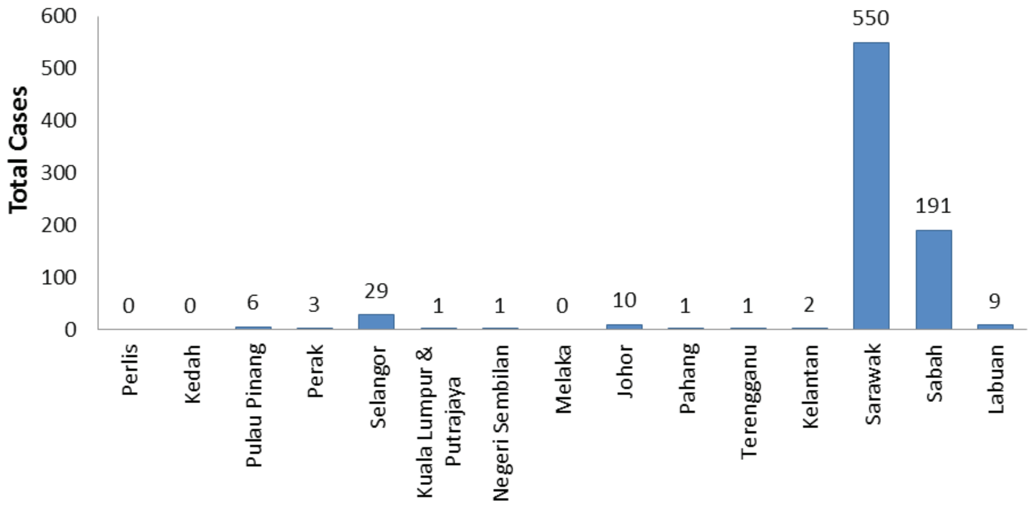

Figure 1 Total number of Chikungunya cases reported for each state in Malaysia for the year 2010

Standardized Morbidity Ratio (SMR)

In broad epidemiological terms, SMR can be described either as the Standardized Mortality Ratio or the Standardized Morbidity Ratio. Mortality refers to death, while morbidity refers to incidence. Generally, the definition of SMR is the ratio of the observed to the expected number of cases. SMR is the most common model used by researchers to estimate the relative risk of a disease in a map. For this study, SMR compared the observed incidence with the expected incidence, which has been used traditionally for the analysis of counts within tracts as mentioned by Lawson (2006). This method is used to estimate a relative risk, which may be interpreted as the probability that a person within a specified region contracts the disease divided by the probability that a person in the population contracts the disease.

For the purpose of this study, the study area to be mapped was divided into M mutually exclusive states (i=1, 2,…, M). Each state had its own observed number of cases (o_i) and expected number of cases (e_i). By using o_i and e_i obtained from the available data, calculation was performed to estimate the relative risk. In its simplest form, SMR is defined as;

$$r_i = \frac{o_i}{e_i}. \tag{1}$$

The expected number of new infective cases (e_i) was calculated as;

$$e_i = N_i \frac{\sum o_i}{\sum N_i} \tag{2}$$

where N_i is the population of state (i) and the summations are for i=1, 2, …, M.

Everybody was assumed to be equally at risk so that the standardization was done based on the total population at risk. Hence, the estimation of relative risk was defined as the probability of a person within the state contracting the disease divided by the probability of a person in the population contracting the disease as shown in Equation 3.

$$r_i = \frac{\left(\frac{o_i}{N_i}\right)}{\left(\frac{\sum o_i}{\sum N_i}\right)} \tag{3}$$

This method was discussed by Samat and Percy (2008) in their study on SMR and its application to dengue disease. In a study carried out by Samat and Percy (2012), the relative risk is defined as the conditional probability that a person within the region contracts the disease divided by the conditional probability that a person in the population contracts the disease. For the relative risk, a value close to 1 shows that there is no real difference between the conditional probability that a person within the specific region contracts the disease compared to the conditional probability that a person in a general population contracts the disease. From this value, we can say that there is no real difference in terms of the likelihood for people to be infected by the virus within a region and within the whole population. If the value of the relative risk is above 1, then it means that the people within the region are more likely to contract the disease compared with the people in the population. In contrast, a relative risk value of less than 1 means that the people within the region are less likely to contract the disease compared to the people in the population.

Depending on the purpose of the study, some factors such as gender, age or life expectancy can be considered as an improved method of standardization. This method has been reported by several authors including Mantel and Stark (1968), Pollard et al. (1981) and Lilienfeld and Stolley (1994). Standardization is a method for overcoming the effect of confounding variables in epidemiological research. Most commonly, it is used to control age. There are two basic methods in standardization known as the direct standardization rates and the indirect standardization rates. Generally, direct standardization rates function to facilitate the comparison of disease rates between studies carried out in different countries. While, indirect standardization rates compares the disease rates for individual areas like countries with the rate shown by some overall reference such as an entire country. These two comparison methods were reported in a study by Esteve et al. (1994). The direct method of standardization requires age-specific rates for all studied populations and a defined standard population, while the indirect method of standardization requires the total number of cases. In this paper, the

Commonly, SMR is used as an index to measure relative risk, but at the same time, it has several disadvantages. As stated by Lawson et al. (2003), since it is based on a ratio estimator, the mean and variance of SMR are highly dependent on e_i. Its value is large

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in areas where the expected numbers of cases are small, while small for areas where the expected numbers of cases are large. Furthermore, SMR is necessarily zero in areas where there is no observed count data or cases. Hence, the interpretation of SMR is quite difficult and should be done cautiously. Meza (2003), who supported this view, identified that SMR is a reliable measure of relative risk for large geographical regions such as countries or states, but unreliable for small areas such as counties.

Some studies on estimating the risk using SMR, especially in epidemiology studies,were carried out by some researchers. Based on Jones and Swerdlow (1998), they found bias in the standardized mortality or morbidity ratio when using general population rates to estimate the expected number of deaths. Another recent study by Wong et al. (2002) determined the standardized mortality ratio corresponding to different causes of death in workers from polyvinyl chloride polymerisation factories in Taiwan. In addition, Goldman and Brender (2000) identified that the validity of using standardized mortality ratios and standardized rate ratios in public health data, in which the analysis showed that both methods had similar utility for analysing public health data and could be used to compare different geographical areas.

Application of SMR on Chikungunya Disease Mapping in Malaysia

In this study, SMR method was applied on the observed count data of Chikungunya disease in Malaysia in order to identify the distribution of high and low risk areas of Chikungunya disease. Figure 2 shows the time series plots for reported cases in Malaysia in the year 2010. From this figure, Sarawak had high number of cases in the beginning, but slowly decreased over the year. During epidemiology week 25, Sabah had the highest number of cases, which were 104. While, the remaining states had below 3 cases for most epidemiology weeks.

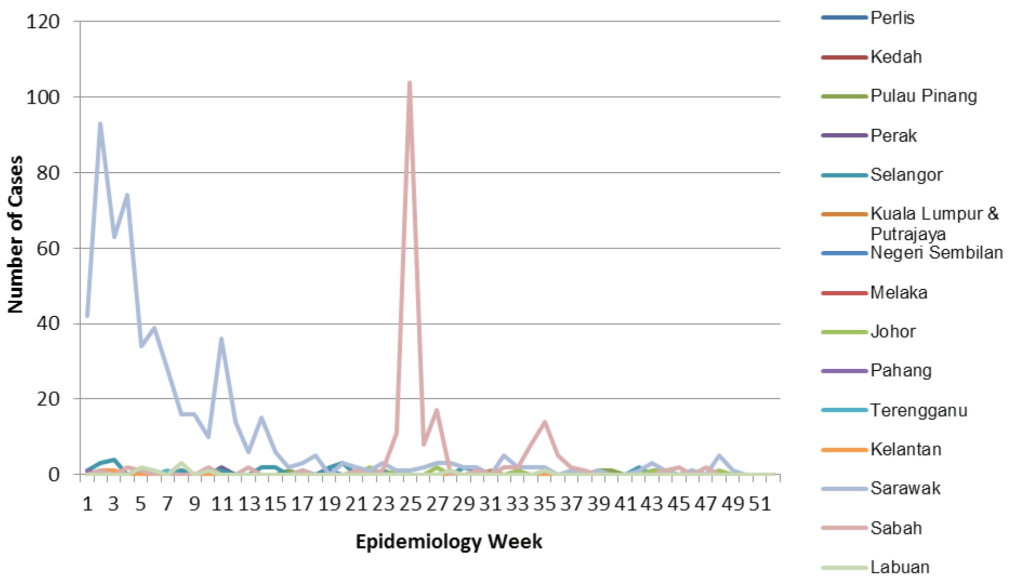

Figure 2 Time series plots for the number of cases for each state in Malaysia

Figure 3 represents the SMR for each state in Malaysia from epidemiology week 1 to epidemiology week 52 in the year of 2010. We can see clearly that the highest SMR was in the Federal Territory of Labuan. Compared to Figure 3, Labuan had a small number of Chikungunya cases. But, different result was obtained using SMR, which shows Labuan had the highest value of SMR. It was probably due to the number of populations considered in the calculation of expected cases, where the population size for Labuan was 76,067 compared to Sabah and Sarawak, which were 2,603,485 and 2,071,506 respectively. Among all states in Malaysia, three states had zero SMR, namely Perlis, Kedah and Melaka, which means that there was zero record of Chikungunya cases in these three states in 2010.

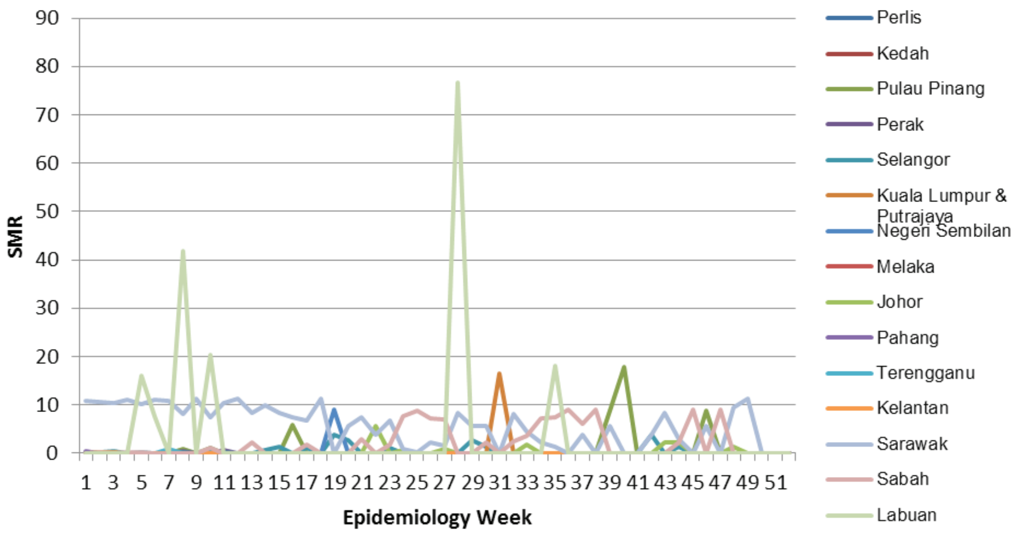

Figure 3 Time series plots for SMR for each state in Malaysia

Risk Map for Chikungunya Disease Mapping in Malaysia

In this section, disease maps were used to represent the high-low risk areas of Chikungunya disease covering all states in Malaysia. Figures 4 and 5 show thematic risk maps for Chikungunya disease based on the number of cases and SMR method. Both maps show the results for epidemiology week 28 in the year 2010 for each state in Malaysia. The relative risk was categorized into five levels, which were very low, low, medium, high and very high with the intervals of (<0.5), (0.5-1.0), (1.0-1.5), (1.5-2.0), and (2.0>), respectively. The darkest shade in the map means that the area is a very high risk area and the lightest shade show that the area is a very low risk area.

Figure 4 represents the risk map for Chikungunya disease based on the number of cases for epidemiology week 28. This figure, showed Sarawak as a very high risk area, followed by Labuan as a medium risk area. Other states were very low risk areas.

Figure 5 represents the risk map for Chikungunya disease based on SMR method for epidemiology week 28. This figure depicts that states with very high risk were Sarawak and Labuan. Other states were considered very low risk areas. Figures 4 and 5 give contrasting result for Labuan, which were discussed in the previous section. It was due to the number of population considered in the calculation of expected cases.

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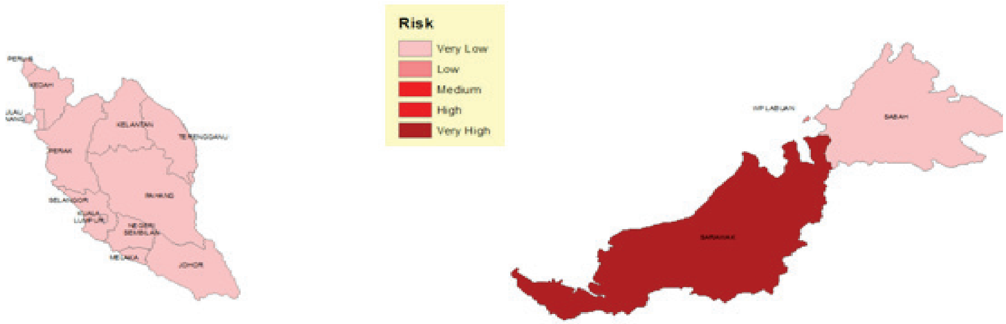

Figure 4 Risk Map for Chikungunya disease based on number of cases for Epidemiology Week 28

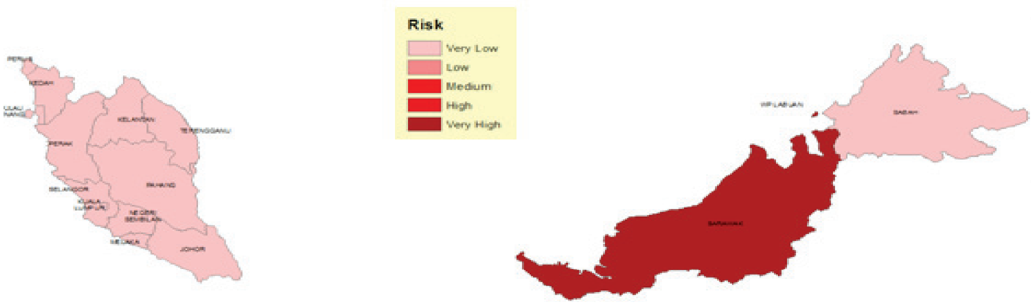

Figure 5 Risk Map for Chikungunya disease based on SMR method for Epidemiology Week 28

Conclusion and Future Work

The production of good disease maps relies on modelling to estimate and predict the risks. Hence, better estimation and prediction of risk could produce more accurate maps of disease risk. In this research study, it was shown that different methods for risk calculation gave different appearances in the mapping of the Chikungunya disease. From the findings, it was shown that SMR was a suitable method for estimating relative risk, instead of the method that uses the number of Chikungunya disease alone. Furthermore, future research must be done to investigate other alternative methods that can be used to estimate the relative risk of Chikungunya disease in order to overcome the problems and disadvantages using SMR. Subsequently, SMR can provide a suitable and better estimation of relative risk especially in each state of Malaysia. Results of the analysis show that SMR gave better values of relative risk compared to mapping the disease based on the number of cases because it took into account the total human population for each state.

From the study of Lawson et al. (2000), the researchers classified the alternative methods into four different approaches. They introduced the first approach as the smoothing models, which try to smooth out the noise based on the functions of the data in neighbouring areas, for instance, non-parametric regression. The second approach was based on a linear function of SMR known as the linear Bayes method. The third approach assumes that the relative risks are realizations from some distribution through the Bayesian models. The fourth approach uses the observed data to estimate prior distribution ofthe relative riskcalled the empirical Bayes model, which is similar to Bayesian models.

In order to inform and help the government to monitor and control the Chikungunya virus, future work based on this research must be done to improve the current model. Based on this future work, it is expected that an improved statistical method for Chikungunya disease mapping and a map of Chikungunya disease for the states of Malaysia could be obtained ultimately.

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