WALAILAK JOURNAL
http://wjst.wu.ac.th Article

Mortality Rate due to Malaria in Thailand

Wattanavadee SRIWATTANAPONGSE, Sukon PRASITWATTANASEREE and Surin KHANABSAKDI

Biostatistics and Applied Statistics Research Unit, Department of Statistics, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand

(Corresponding author; e-mail: wattanavadee.s@cmu.ac.th)

Received: 6 March 2012, Revised: 10 April 2012, Accepted: 4 June 2012

Abstract

Malaria has been a leading cause of morbidity and mortality in Thailand for many decades. The objective of this study was to model and forecast malaria mortality rate in Thailand using death certificate reports. A retrospective analysis of the malaria mortality rate is reported. The data were obtained from the national vital registration database for the 10 year period from 2000 to 2009, provided by the Ministry of Interior and coded as cause-of-death using ICD-10 by the Ministry of Public Health. Multivariate linear regression was used for modeling and forecasting age-specific malaria mortality rates in Thailand. Malaria mortality increased with increasing age for each gender and was also higher in the Central and Northern provinces. The trends of malaria mortality are stable in most age groups with decreases in others and decreases during the ten-year period (2000 to 2009). Malaria mortality was higher in males and increase with increasing age. There is a need for malaria control measures to remain on a sustained and long-term basis for the high malaria burden rate of Thailand.

Keywords: Forecasting, mortality, multivariate linear regression, malaria

Introduction

Malaria is a potentially fatal tropical disease that's caused by a parasite known as Plasmodium. It's spread through the bite of an infected female mosquito. Malaria is ranked 5th on the list in the 10 leading causes of death in low-income countries [1]. There were 216 million cases of malaria and an estimated 655,000 deaths in 2010. Malaria mortality rates have fallen by more than 25 % globally since 2000 and by 33 % in the WHO African Region. Children living in Africa account for most of the deaths by malaria where a child dies every minute and the disease accounts for approximately 22 % of all childhood deaths [2].

Malaria has been a leading cause of mortality in Thailand. Especially, the border areas close to Myanmar and Cambodia are affected. Non-immune migrant workers occupied with gem mining in forests, logging, agriculture and construction are the most vulnerable and most affected. Malaria epidemics occurred periodically in high risk areas, especially along the international borders of Thailand and Myanmar, and of Thailand and Cambodia. The death rate from malaria for males is currently more than for females. Thailand has marked regional differences in the level of incidence of malaria [3].

Thailand is a country located at the centre of the Indochina peninsula in Southeast Asia. It is divided into 77 provinces, which are gathered into 4 regions [4]. These four regions are: Central, North, North-East and South. It is bordered to the North by Myanmar and Laos, to the East by Laos and Cambodia, to the South by the Gulf of Thailand and Malaysia, and to the West by the Andaman Sea and the Southern extremity of Myanmar. The estimated Thai population by the department of provincial administration is 65,480,000 [5].

Sriwattanapongse *et al.* [6] studied the patterns of hospital-diagnosed malaria incidences

by month, district and age-group for the two North-Western border provinces in Thailand. The model used linear regression, Poisson generalized linear regression and negative binomial generalized linear regression model to forecast malaria disease by the districts and age groups. Among the models fitted, the appropriate was the negative binomial generalized linear model. In addition, Sriwattanapongse and Kuning [7] studied the patterns of hospital diagnosed malaria incidences in districts and quarterly periods in the north-western region of Thailand which was described by regression models based on principal components. The results show that malaria incidence rates decreased substantially in most districts during the study period, but remained very high in border districts with Myanmar. Investigating regional and temporal patterns is commonly used to detect areas with malaria problems and to evaluate periods of likely epidemics for a variety of diseases. The forecasting of mortality and disease burden are essential for setting current and future health system priorities. The objective of our study was to model and forecast malaria mortality rates in Thailand.

Materials and methods

Data for registered deaths due to malaria were obtained from the national vital registration database for the 10 year period from 2000 to 2009. The database is provided by the Ministry of Interior and coded as cause-of-death using ICD-10: B50-B64 by the Bureau of Policy and Strategy, Ministry of Public Health.

Age, gender, residential area by region in Thailand and year were selected as the explanatory variables in studying the mortality rates of malaria. Age was divided into nine groups (0-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79 and above 80 years). Various approaches have been developed to improve for forecasting morbidity and mortality rates. This study focuses upon the model proposed by Lee and Carter [8] and Lee and Miller [9] used initially for projections of the age-specific mortality rates in the United States. The Lee-Carter-based modeling framework is viewed in the current literature as among the most efficient and transparent methods of modeling and projecting mortality improvements [10]. This method is also regarded as the state-of-the-art in mortality forecasting and became more and more popular for long-run forecasts of age-specific mortality rates.

Since malaria death counts based on small cells are often zero cases, it is necessary to make some adjustment to take transformation of 0, we replaced zero counts by a suitably chosen small constant greater than 0: the method we use is to define the mortality rate as

$$m_{x,t} = \left(\frac{(0.5 + n_{x,t})}{P} \times 100{,}000 \right)^{1/3} \quad (1)$$

where $n_{x,t}$ is the number of malaria dead cases in the cell, P is the population at risk.

For each region and gender combination; multivariate linear regression model was used to investigate and forecast malaria mortality by age group and year. The original principal component of the Lee-Carter model is expressed as

$$\log(m_{x,t}) = a_x + b_x k_t + \varepsilon_{x,t} \quad (2)$$

where $m_{x,t}$ is the central death rate (per 100,000) in age group x and year t for the specified in each gender and geographical region. The factors a_x and b_x describe the level and annual increase, respectively of the age-specific mortality rate, k_t is time of year where Lee-Carter chose constraints to be $\Sigma k_t = 0$ and where $\varepsilon_{x,t}$ is a set of random disturbances.

The multivariate linear regression model takes into account correlation in the data between age groups. The R program was used for all statistical analysis and graphs [11].

Results and discussion

For each year these data were obtained from the national vital registration database for the 10 year period from 2000 to 2009, provided by the Ministry of Interior and coded as cause-of-death using ICD-10 by the Ministry of Public Health and fields comprising characteristics of the subject and cause-of-death diagnosis, including dates of dead and, the subject's age, gender, and address.

Out of 2,436 malaria cases, about 72 % were male. The majority of the study subjects were aged 30 - 39 years (28.53 %). The maximum malaria mortality incidence rate/100,000 was male (2.201) in the Northern region.

To log-transform the counts, we replaced zeros by 0.5 before fitting the model. The 2 left panels of **Figure 1** show the malaria mortality rates plotted by age group for each year in each gender; the 2 right panels show the trends for 2000 - 2009 for each age group in each gender, together with the forecasts based on the model.

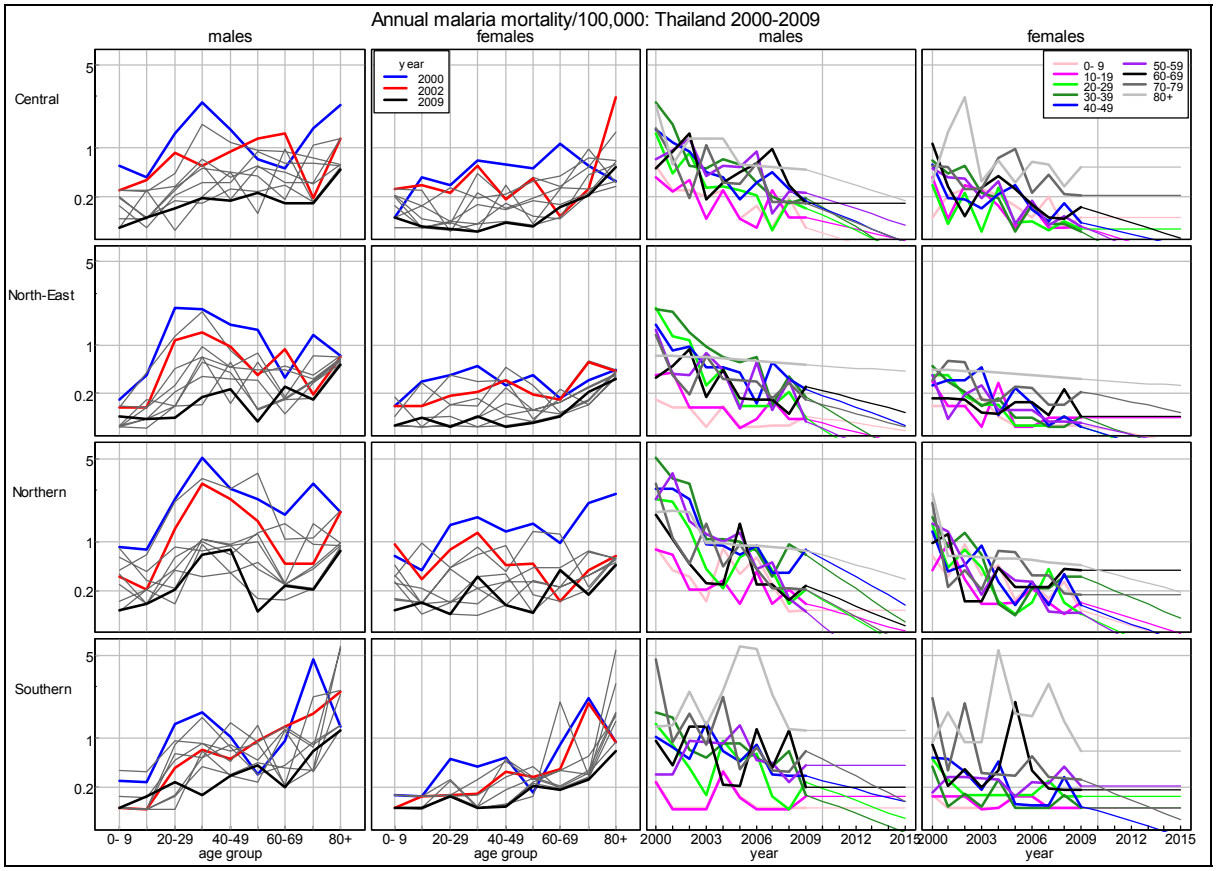

Figure 1 Plot of malaria mortality rates by age group for each year in each gender (2 left panels) and trend with forecasts: 2010 - 2015 for each age group in each gender (2 right panels) for the four regions of Thailand.

Figure 1 shows that mortality increases up to age group 30 - 39 years and decreases slightly before increasing in the higher years age groups, except in the Southern region, it increases up to 70 - 79 age group. However, the time trends shown in the 2 right panels indicate that malaria mortality decreased over the 10 years period in all age group especially after 2009, and actually decreased for 40 of the 79 combinations of age group, gender and region.

The correlation varied substantially between age groups. The highest correlation (0.85) was observed between 30 - 39 years in male and 80+ years in female of the Northern region as well.

We found that mortality was highest in age groups of 30 - 39 years in the Northern region and year 2000 in male and over 80+ in Central year 2002 in female. Co-morbidity and decrease immune function are important factors in the increasing malaria mortality among the elderly. In the ten-year period (2000 to 2009), the trends in malaria mortality fluctuation in most age groups decrease and tend to decrease overall. In the Central and Northern regions, there was a

pronounced bulge in mortality among male between 30 and 39 years of age. However, in the South, there was a pronounced bulge in mortality among males between 70 and 79 years of age. In addition, there was an increase in malaria mortality fluctuation in most age groups in between 20 and 80+ years of age for females.

After 2009, the malaria rate declined in all age groups due to the Bureau of Policy and Strategy, Ministry of Public Health strong control measures and prevention of malaria morbidity in the previous 10 years. For this investigation, the data have been interpreted accurately and objectively. The Ministry of Public Health can use the result of this study to continue to observe and survey malaria especially in the border areas.

The limitation of this research is that the data has many zero cases in small cells. In total 40,360 of 42,300 (94.5 %) cells are zero cases. In further studies, we should use the multiple imputations technique to solve this problem [12].

Conclusion

The multivariate linear regression was suitable to model the malaria mortality in Thailand. Although the Lee-Carter model is often used for forecasting, this non-linear model cannot be fitted by ordinary regression methods, and thus does not routinely provide standard errors for estimated parameters. Booth *et al.* [13] use of the Lee-Carter method with Australian data is compromised by significant departures from linearity in the time component and changes over time in the age component. The model is also expanded to take account of age-time interactions by incorporating additional terms, but these are not readily incorporated into forecasts. Delwarde *et al.* [14] attempted to forecast future mortality rates. The result shows that it is possible to smooth the estimated β_x's in the Lee-Carter and Poisson log-bilinear models for mortality projection. Finally, penalized least-squares or maximum likelihood analysis is performed. The optimal value of the smoothing parameter is selected with the help of cross validation.

The multivariate linear regression has the additional advantage that it takes account of correlations between data in different age groups. Therefore, this method was to forecast disease mortality.

The graphical method provides an informative display of the variation in mortality by gender, age group and region. Such graphs can be used by public health authorities for applying preventive measures to control malaria outbreaks by focusing on groups at high risk.

Acknowledgements

We thank the Ministry of Public Health and Ministry of Interior for providing the data. This research was funded by the Faculty of Science, Chiang Mai University. We are grateful to Professor Don McNeil who supervised our research.

References

[1] WHO, Malaria Bulletin 2008, Available at: http://www.who.int/mediacentre/factsheets/fs310/en/index.html.

[2] World malaria report 2011, Available at: http://www.who.int/malaria/world_malaria_report_2011/en/.

[3] S Wibulpolprasert. *Thailand Health Profile 2005-2007*. *In*: The War Veterans Organization of Thailand, Printing Press, Bangkok, 2007.

[4] Online Resources, Available at: http://en.wikipedia.org/wiki/Provinces_of_Thailand.

[5] National Statistics Office. 100th anniversary of population censuses in Thailand: Population and housing census, 2010.

[6] W Sriwattanapongse, M Kuning and N Jansakul. Malaria in North-Western Thailand. *Songklanakarin J. Sci. Technol.* 2008; **30**, 207-14.

[7] W Sriwattanapongse and M Kuning. Modeling malaria incidence in North-Western. *Chiang Mai J. Sci.* 2009; **36**, 403-10.

[8] RD Lee and LR Carter. Modeling and forecasting U.S. *Mortality Am. Stat. Assoc.* 1992; **87**, 659-71.

[9] RD Lee and T Miller. Evaluating the performance of the Lee-Carter method for forecasting mortality. *Demography* 2001; **38**, 537-49.

[10] Z Butt and S Haberman. *A Collection of R Functions for Fitting a Class of Lee-Carter Mortality Models using Iterative Fitting*

Algorithms. Sir John Cass Business School, London, 2009.

[11] WN Venables, DM Smith and the R Development Core Team. An Introduction to R: Notes on R:A Programming Environment for Data Analysis and Graphics Version 2.6.2, 2008.

[12] JAC Sterne, IR White, JB Carlin, M Spratt, P Royston, MG Kenward, AM Wood and JR Carpenter. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *Br. Med. J.* 2009, DOI: 10.1136/bmj.b2393.

[13] H Booth, J Maindonald and L Smith. Applying Lee-Carter under conditions of variable mortality decline. *Popul. Stud.* 2002; **56**, 325-36.

[14] A Delwarde, M Denuit and P Eirlers. Smoothing the Lee-Carter and Poisson log-bilinear models for mortality forecasting. *Stat. Model.* 2007; **7**, 29-48.