MODELING FACTORS INFLUENCING MALARIA INCIDENCE IN MYANMAR

Cho-Min-Naing[1,4], Somrat Lertmaharit[2], Pirom Kamol-Ratanakul[3] and Allan Saul[1]

[1]Malaria and Arbovirus Unit, Queensland Institute of Medical Research Brisbane, Queensland 4029, Australia; [2]Department of Preventive and Social Medicine, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand; [3]Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand; [4]The National Malaria Control Project (NMCP), Department of Health, Insein PO, Yangon, Myanmar

Abstract. This is a documentary study to determine factors influencing malaria incidence in Myanmar. The period of study covered was from 1989 to 1998 using time series data. Multiple regression analysis was performed on the dependent variable, yearly incidence of malaria in Myanmar, with hypothesized independent variables including variables related to epidemiology, demography, service and socioeconomic status. Malaria incidence was inversely associated with the government budget for malaria control at the 5% level and with the case fatality rate of malaria at the 10% level. Other variables: yearly gross domestic product, yearly proportion of *Plasmodium falciparum* cases and yearly DDT use of spraying displayed expected signs but were not statistically significant.

INTRODUCTION

The prevailing reports reveal that malaria is a top public health problem in Myanmar. Malaria accounts for 7% of outpatients and 20% of inpatients admitted to hospitals (Ministry of Health, Myanmar, 1996). In 1996, 996,000 clinical cases of malaria and 3,766 deaths were estimated in Myanmar (National Malaria Control Project, Myanmar, 1999). About 85% of reported infections are due to *Plasmodium falciparum* and 15% are due to *P. vivax*.

The ultimate goal of malaria control is to prevent mortality and to reduce morbidity, and social and economic loss, through the progressive improvement and strengthening of local and national capabilities (WHO, 1992). For the achievement of this goal, efficient and effective planning for malaria control is fundamentally important. Planning of control measures for any disease requires prior knowledge about the seriousness of the problem and factors contributing to the development of the problem.

With malaria the development of a single case involves interactions of various factors: man, vector, parasite and environment. It is essential to reveal which factors are involved and to what extent these result in a clinical case of malaria so as to plan an effective and efficient malaria control strategy (Myint-Htwe, 1991). Study of multiple variables: epidemiological, biological and socioeconomic variables is a *conditio sine qua non* to get a true picture of malaria transmission. Examination of the link between epidemiology and economics will show the relation between disease risk (Hammer, 1993, cited by Brinkmann and Brinkmann, 1995) and resource allocation. Studies incorporating both epidemiologic and socioeconomic factors are limited. We therefore have attempted to fill such a gap in Myanmar.

Correspondence: Cho-Min-Naing
E-mail: chominN@qimr.edu.au

The objective of this study was to determine factors influencing malaria incidence in Myanmar so as to apply this knowledge to future planning of disease control. The perspective of the analysis is that of the national malaria control project (NMCP) of Myanmar, which is the responsible organization for planning and implementing nationwide malaria control services (Kamol-Ratanakul *et al*, 1993) within the context of the national health plan.

MATERIALS AND METHODS

This study is documentary in nature using time series data covering the period from 1989 to 1998 for econometric analysis. The dependent variable was the incidence of malaria in Myanmar, which is the number of new cases occurring during a given time including both out-patient and in-patient malaria cases. Among diverse factors, the selection of independent variables should be judiciously based on theoretical considerations. The explanatory variables were (i) epidemiologic variables: yearly proportion of *P. falciparum* cases, yearly case fatality rate (CFR); (ii) demographic variables: yearly proportion of population in risk areas; (iii) service variables: yearly amount of DDT used for spraying; and (iv) economic variables: yearly gross domestic product (GDP) per capita and government budget for national malaria control.

A semi-logarithmic regression model was introduced to satisfy the assumptions of linear regression analysis:

$$\begin{aligned}\mathrm{LnIncid}_t &= \alpha_0 + \alpha_1\mathrm{LnBudget}_t + \alpha_2\mathrm{GDPpc}_t + \alpha_3\mathrm{CFR}_t \\ &\quad + \alpha_4\mathrm{DDT}_{t-1} + \alpha_5\mathrm{Riskpop}_t + \alpha_6\mathrm{ProPf}_t + \varepsilon_t\end{aligned}$$

Where

t	=	subscript index for year (=1,2,3,4,5,6, 7,8,9,10)
Budget_t	=	total budget for the national malaria control in Myanmar in the year t
Incid_t	=	annual malaria incidence in the year t
$\mathrm{GDP}pc_t$	=	gross domestic product per capita in the year t
CFR_t	=	case fatality rate of malaria in Myanmar in the year t
DDT_{t-1}	=	DDT used (kg) in Myanmar for spraying in the year t-1
$\mathrm{Riskpop}_t$	=	proportion of population residing in risk area in the year t
ProPf_t	=	proportion of *P. falciparum* in the year t
Ln	=	logarithm to the base e of the relevant variable
$\alpha_{0....}\alpha_6$	=	parameters
ε	=	error terms

Data collection

Malaria-related indices: the annual malaria incidence, the yearly CFR of malaria, the yearly proportion of *P. falciparum* cases, the yearly proportion of population in risk areas, and annual DDT used for spraying (both regular and selective spraying) were systematically collected from the documents of the Myanmar NMCP. These aggregate malaria data originated from the standard reporting forms of fourteen state/divisional malaria teams in Myanmar.

The budget for malaria control was obtained from the financing unit of the Myanmar Department of Health. The real figures were applied as in the original document rather than nominal figures. The GDP per capita was derived from the published data of GDP (International Monetary Fund, 1999).

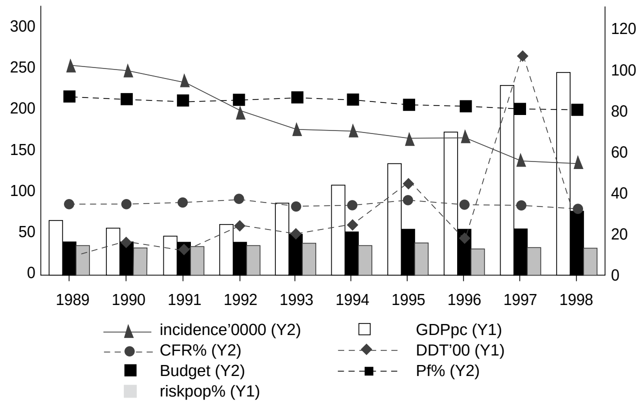
Data analysis

Data entry was made with Excel spreadsheet and multiple regression analysis was performed using SPSS version 9.00 for Windows. The dependent variable, the yearly malaria incidence in Myanmar, was analysed using a number of hypothesized explanatory variables.

Before completing the analysis, diagnostic tests taking account of the statistical pathology (Doessel, 1992) were investigated. Residuals were checked for a normal distribution (Kleinbaum *et al*, 1988). The Durbin-Watson statistic was observed for autocorrelation (Doti and Adibi, 1987). Values for the variance inflationary factor (VIF) were examined for evidence of colinearity among the set of explanatory variables (Armitage and Berry, 1994). The *F*-statistic was tested for the linearity of the model.

RESULTS

Fig 1 indicates the yearly distribition of incidence of malaria and the independent variables considered. It is noteworthy that the pattern of changes among the variables was random. Drastic saw tooth patterns (Myint-Htwe, 1991) were not evident.



GDP per capita = Kyats in 100
Budget = Kyats in 1,000,000

Fig 1–The distribition of malaria incidence and independent variables (1989-1998).

Table 1 provides the results of the regression model. The significant independent variable at the conventional 5% level was the budget for national malaria control in Myanmar. True p-values for entry into the model ought to be much smaller than the nominal value (Gujarati, 1995). If this is the case, the p-value in this study with six independent variables should be 0.008 (0.05/6 = 0.008) (Foster *et al*, 1998). If so, the budget for national malaria control is still a significant variable ($p < 0.001$) showing a negative coefficient. However, we applied the nominal p-value in our study. Holding other things constant, in the sample period, a decreased budget of kyats 1,000,000 (US$ 1.0 = Kyats 6.3, official exchange rate) (International Monetary Fund, 1999) was, on the average, followed by an increase of about 2,340 new malaria cases.

The CFR showed an expected positive coefficient at the 10% level of significance. The other variables, yearly proportion of *P. falciparum* cases, yearly proportion of population residing in risk areas, yearly DDT used and yearly GDP per capita were not significant variables, but many of these variables displayed the expected signs. Certain variables should be retained even though they have non-significant effects, because of their logical importance in the particular problem (Armitage and Berry, 1994).

As hypothesized, the estimated coefficient of proportion of *P. falciparum* cases was positive, while the DDT (kg) used and the GDP per capita had negative coefficients.

The residual statistics, Cook's distance and leverage value proved that there are no outliers (Kleinbaum *et al*, 1988). The Durbin-Watson statistic (DW = 1.86) showed that there is no significant positive autocorrelation (Doti and Adibi, 1987) in this time series data. VIF less than 10.0 suggested there is no multicolinearity between the dependent variable and the sets of independent variables (Armitage and Berry, 1994). The explanatory power of the model is 82% according to the adjusted R^2. F-statistics (37.05 at $p< 0.001$) assured linearity of the model.

DISCUSSION

In Myanmar, the national malaria control budget is allocated for three main activities: disease management, disease prevention and program management. For provision of services to the community, the budget for national malaria control was allocated from central-pooled sources. Any disease control measures are resources-dependent in practice. Limited resources will be a constraint for

Table 1
The regression results of malaria incidence in Myanmar (1989-1998).

Variables	Coefficient[a] (standard error)	*t*-statistics	p-value
Constant	8928.0 (1.51)	22.16	<0.001
Case fatality rate (%)	-0.328	-2.18	0.07
DDT (kg)	-0.123	-0.79	0.46
% of risk population	-0.08	-0.08	0.94
Proportion of *P. falciparum*	0.23	1.14	0.3
GDP per capita	-0.39	-1.08	0.32
Budget for national malaria control	-2.34 (1.15)	-6.09	<0.001
Diagnostic tests:			
Cook's distance[b] = 0.26			
Leverage value[c] = 0.1			
Durbin-Watson = 1.86			
Adjusted R^2 = 0.82			
F-statistic = 37.11 ($p< 0.001$)			

[a]Transformed back to normal of the logarithmic to the base e
[b]critical value = 0.76 (Kleinbaum *et al*, 1988)
[c]critical value = 0.68 at the 5% level (Kleinbaum *et al*, 1988)
Number of observations = 10 (From 1989 to 1999)

implementation of malaria control activities with a consequence of potential increase of incidence of malaria in the community. So we hypothesized that incidence of malaria is inverse to the budget for national malaria control. Our findings supported this hypothesis. Any effective malaria control can only be assured if a regular budget is provided and maintained over the whole duration of the project (Giles and Warrel, 1993).

The CFR was used as a proxy for the degree of seriousness of malaria cases in Myanmar. The negative sign illustrated that the less the CFR, the more the malaria incidence. Our exploration is in the context of the sociobehavioral perspective. Deaths due to malaria may act as an alarm to the community leading to an awareness of the disease and motivation to seek early diagnosis and treatment from the nearest health facility. This motivation will be attributed to higher utilization of formal health services with possibility of more malaria cases detected. The resultant was the less CFR, but the higher number of clinical malaria cases attended. This so-called paradoxical affect can happen in the same year due to the relatively short incubation periods of malaria in mosquitos and man. Secondly, it can be explained indirectly in that non-fatal cases are important for transmission of malaria leading to the genesis of new cases. The first exploration is more obvious, if it is coupled with the positive sign of the proportion of *P. falciparum* cases. This does not mean that fatality due to malaria is not our concern. Severe and complicated malaria with a high probability of mortality is a serious consequence of *P. falciparum* infection and focusing on early diagnosis and prompt treatment on those most at risk (WHO, 1992) is essential. We have showed that the higher the proportion of *P. falciparum* cases, the greater the incidence to be expected. Though it was not statistically significant evidence, it is of public health significance. Here our concern was development of a mosaic of small transmission areas (Saul, 1996). The proportion of *P. falciparum* cases was considered to be an important factor in the transmission of malaria in the community partly due to their involvement as a reservoir of infection for transmission, when they were not provided with correct treatment. However, our concern was not to include immune individuals who may still be parasitemic, since such people no longer contribute to transmission (Saul, 1996).

Selective vector control refers to the application of targeted, site-specific control methods that are cost-effective (WHO, 1992). If there was less insecticide spraying in the lag year, a higher incidence of malaria would be expected according to the negative coefficient in our study. The desirable outcome of vector control by insecticide spraying is the reduction of the levels of transmission by shortening of the longevity of the vector. This fact does not mean that we are not considering issues of environmental deterioration brought about by the DDT spraying. We only mean that insecticide spraying can influence changes in malaria incidence in Myanmar: selection of insecticide with bio-safety appeals to our concern, but is outside our present objective.

To determine the current welfare status of people in the community, it is appropriate to consider the yearly GDP per capita. Our assumption was that GDP per capita is half average worker income (Filmer and Pritchett, 1999). In the communities, access to any malaria control measures is a household affair and depends on the individual or household income. Though the services rendered for malaria at the public clinics are free of charge, there is out-of-pocket expenditure for indirect costs such as traveling, food etc. The less per capita income, the less consumption of health care services with the further consequence of greater transmission of malaria is to be expected. Our key assumption is that individuals have their own budget constraints. Thus a strategy for socioeconomic development is desirable and will be significant for changes in the magnitude of malaria in Myanmar. The less GDP per capita relating to the higher incidence of malaria in our study is also explained indirectly. Malaria is a disease of socioeconomic relevance. If health is a consumption commodity (Grossman, 1972), then family and national economy may be negatively affected by the occurrence of malaria. If health is an investment commodity (Grossman, 1972), then a lower GDP may contribute to diminishing resources-dependent malaria control activities. Put otherwise, malaria- poverty-malaria is recognizable as an economic vicious cycle (Murti, 1998), but which comes first could not be explained from our study. The causality is of course two-sided (McCarthy *et al*, 2000).

We are aware of the caveats of our analysis. Environmental factors such as changes in temperature, rainfall etc, are determinants for development of breeding sources and these could affect transmission of malaria. We have assumed these factors to be constant in this study because there was a lack of data at the time of our analysis. A future study incorporating environmental factors coupled with seasonal variation of transmission of malaria in the community is desirable. In addition, since this study relies heavily on secondary data, we are aware of the possibility of underestimation or overestimation. We have assumed that these were happening in the same manner throughout the study period from 1989 to 1998.

Furthermore, this study was performed using pooled time series data from fourteen states/divisions of Myanmar. Since malaria is neither uniformly endemic nor equally prevalent (Myint-Htwe, 1991), if macro and micro economic data of individual states/divisions were available, further study on the specific states/divisions would be valuable. Nevertheless, this analysis can serve two useful functions. First, it indicates a guide to the decision-maker in malaria endemic countries in general. Secondly, it provides a framework around which to develop more detailed econometric analysis.

ACKNOWLEDGEMENTS

This study was completed while Cho-Min-Naing was in receipt of a training fellowship from UNDP/World Bank/WHO Research and Training in Tropical Diseases (ID 980949). The help of U Kyaw-Htay of the Myanmar Department of Health for providing necessary data is much appreciated. The views expressed are those of the authors, not of the Myanmar National Malaria Control Project.

REFERENCES

Armitage P, Berry G. Automatic selection procedures and colinearity. In:Statistical Methods in Medical Research, 3rd ed. Oxford: Blackwell Scientific Publications, 1994; 321-3.

Brinkmann U, Brinkmann A. Economic aspects of the use of impregnated mosquito nets for malaria control. *Bull WHO* 1995; 73: 651-8.

Doessel DP. Demand equations for diagnostic services of the gastrointestinal tract. In:The Economics of Medical Diagnosis: Technological Change and Health Expenditure. Avebury Aldershot, England. 1992: 114.

Doti JL, Adibi E. Identifying and correcting econometric problems. In: Econometric Analysis: An Application Approach. New Jersey: Prentice-Hall, 1987; 203-65.

Filmer D, Pritchett L. The impact of public spending on health; does money matter? *Soc Sci Med* 1999; 49: 1309-23.

Foster DP, Stine RA, Waterman RP. Summary regression case. In:Business Analysis Using Regression: A Case Book. New York: Springer-Verlag, 1998; 227.

Gilles HM, Warrell DA. Bruce-Chwatt's essential malariology. 3rd ed. London: Edward Arnold, 1993; 36, 265.

Grossman M. On the concept of health capital and the demand for health. *J Polit Econ* 1972; 80: 223-55.

Gujarati DN. Test of specification errors. In: Basic econometrics. 3rd ed. Singapore: Mcgraw-Hill, 1995: 461.

International Monetary Fund. Myanmar. In: International financial statistics. Washinton DC: International Monetary Fund, 1999; LII: 534-5.

Kamol-Ratanakul P *et al*. Cost-effectiveness analysis of three short course anti-tuberculosis programs compared with a standard regimen in Thailand. *J Clin Epidemiol* 1993; 46: 631-6.

Kleinbaum DG, Kupper LL, Muller KE. Regression diagnostics. In: Applied regression analysis and other multivariable methods, 2nd ed. Boston: PWS-KENT publishing 1988: 181-225.

McCarthy FD, Wolf H, Wu Y. The growth costs of malaria. http://www.malaria.org/literature.html 27th January 2000.

Murti B. Consultant report. SEA/MAL/201. World Health Organization. South East Asia Region. 1998: 2 (Unpublished document).

Ministry of Health, Myanmar. National Health Plan (1996-2001), Yangon, 1996.

National Malaria Control Project, Myanmar. Annual report, 1996, Yangon, 1999: 3 (unpublished).

Myint-Htwe. Stratification of malarious areas in the union of Myanmar. The School of Hygiene and Public Health. PHD John Hopkins University, Baltimore Maryland, 1991. Thesis PhD.

Saul A. Transmission dynamics of *Plasmodium falciparum*. *Parasitol Today* 1996; 12: 74-79.

World Health Organization. The implementation of the Global Plan of Action for Malaria Control 1993-2000. *WHO Tech Rep Ser* 1992; 839.