

Spatial Analysis of Social Determinants for Tuberculosis in Thailand

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Objective: The present study aimed to investigate the association between social factors and spatial risk of TB in Thailand.

Material and Method: Ecological study and spatial statistics were employed to examine effects of social factors on age-standardized morbidity ratios of TB (SMR) in 76 provinces in Thailand during 2006-2009.

Results: The autoregressive model reveals similarity of TB risk in proximal areas (Moran's $I = 0.612$; $p < 0.05$). After adjusting for HIV epidemic and spatial autocorrelation ($\rho = 0.581$, $p < 0.001$), a spatial autoregressive model revealed significant relationship of unemployment rate ($\beta = 0.073$) and household income ($\beta = 0.134$) to spatial risk of TB with variance of explanation 55%.

Conclusion: The present study indicated the area at risk of TB is in areas with high employment rate and household income, which are specific characteristics of an urban area. Therefore, in urban areas that are vulnerable to TB transmission, a development of specific TB surveillance and prevention and control programs is need.

Keywords: Spatial autoregressive model Socio-economic Ecological study

J Med Assoc Thai 2013; 96 (Suppl. 5): S116-S121

Full text. e-Journal: <http://www.jmatonline.com>

The remarkably increase in tuberculosis (TB) incidences and the expansion of TB infected areas, after the pandemic of human immunodeficiency virus (HIV) infection in the 1980s, has called for the world public health attention⁽¹⁻⁷⁾. To minimize the TB problem, an improvement of diagnosis, curative treatments, directly observed therapy short-course (DOTS) have been recommended by World Health Organization (WHO) since 1990s. Up to now, incidence of TB has not yet been well controlled⁽¹⁻³⁾. Even though previous ecological studies revealed positive relationship between HIV epidemic and TB incidence in many areas⁽³⁻⁷⁾, some studies did not find effects of HIV, but social determinants such as high a proportion of poverty and overcrowded family that presented a positive relationship with high burden areas of TB⁽⁸⁻¹³⁾.

Thailand, classified by WHO as one of 22 countries with TB burden, has been faced with a high burden of TB since HIV epidemic in 1990s⁽¹⁴⁾. Accordingly, a TB control program, where there is a high epidemic of HIV, is a priority⁽¹⁴⁻¹⁶⁾. Despite great effort on TB control, TB incidence has continually

increased and become a major cause of illness in both high and low epidemic of HIV areas⁽¹⁴⁾. Understanding the geographical distribution of TB incidence and identifying related factors that may have contributed to the distribution of TB may assist public health authorities to improve micro-targeting for future TB control programs.

During past decades, geographical information system (GIS) has been widely used to visualize spatial distribution of infectious disease in many areas⁽¹⁷⁻¹⁹⁾. In addition, spatial analysis has been employed to explore cluster of high burden of diseases and to identify influencing factors of TB clusters; however, social interaction between cities did not take this into account.

The present study therefore aimed to investigate association between social factors, HIV epidemic areas and areas of high TB burden by conducting an ecological study and employing a spatial analysis.

Material and Method

Data sources

Age-specific TB cases during 2006-2009 were obtained from a surveillance database of Ministry of Public Health (MoPH) that all data were recorded by province and years. Data on numbers of all TB cases in

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14 age strata (≤ 4 , 5-9, 10-14, 15-24, 25-34, 35-44, 45-54, 55-64, and ≥ 65 years) in 76 provinces of Thailand were indirectly standardized using the entire Thai population in 2009 as a reference to obtain age stratum-specific morbidity rates as following formula;

$$SMR_i = \frac{\sum d_{ai}}{\sum d_{ai} \times R_a}; a = 1 \text{ to } 14 \quad i = 1 \text{ to } 76$$

SMR_i is the age-standardized morbidity ratio in province i d_{ai} is a TB case by age group and province i R_a is the age-specific morbidity rate of Thailand in 2009 obtained from MoPH, as a standard incidence rate. Social data, population density (number of population per km^2), poverty rate (percentage of household having income below poverty line), average monthly income per household, and the unemployment rate were obtained from National Statistical Office. HIV and AIDS cases were obtained from National Health Security Office and province-specific rates were calculated. All data were complemented with GIS-base data for provincial boundaries.

Data analysis

Each province defined its vicinity by K-nearest neighbor (KNN), at order-1 to order-10 (KNN-1 to 10) and each KNN was then used to construct a Spatial Weight Matrix (SWM), to determine which neighbors had a value of 1 and others 0^(20,21).

Natural logarithm of SMR was applied to a stepwise multiple linear regression analysis (MLR). The model with the smallest Akaike's Information Criterion (AIC) value and Variance of Inflation Factor (VIF) less than 5 was selected⁽²²⁾. The extracted residuals of selected MLR were then examined through spatial dependence by Moran's index at KNN-1 to 10. After that, the selected MLR proceeded in fitting the spatial autoregressive model (SAR). The SAR model was included a spatial autoregressive term $\rho w_{ij} Y$ in the fitted multiple regression model as following model⁽²⁰⁾.

$$\ln(v) = \alpha + \beta_1 X_1 + \dots + \beta_6 X_6 + \rho w_{ij} Y + \epsilon,$$

where v is the SMR in a province, $\beta_{1 \text{ to } n}$ are the regression coefficients of study variables $X_1 \text{ to } 6$, respectively, w_{ij} is the SWM between province i and j ($i = j$), ρ is the coefficient of spatial dependence, and ϵ is the spatial autoregressive error term.

The optimal SWM was selected by considering the turning point of the value of Moran's index^(20,21).

The present study was approved by the Ethic Review Committee for Research in Human Subjects at the Faculty of Public Health, Mahidol University.

Results

During 2006-2009, 112,830 TB cases were reported. SMR by province and years were calculated. Of 76 provinces, SMR ranged from 0.14 to 3.33 per 100 (Table 1).

By univariate analysis, incidence of HIV ($p = 0.022$), prevalence of AIDS ($p = 0.010$) and household income ($p = 0.009$) were positively associated with SMR, while unemployment rate ($p = 0.007$) presented negative association (Table 2). By stepwise regression analysis, household income ($\beta = 0.285$, $p = 0.001$) and squared power to unemployment rate ($\beta = 0.132$, $p = 0.001$) presented exponential relationship with SMR (Table 3). The latter model was then performed residual extract to explore the spatial correlation by Moran's index at KNN-1 to 10. The significant Moran's index, presented at KNN-1 to 6 (p -value < 0.05), indicated the need for a spatial autoregressive model. Household income and square power to the unemployment rate were included in SAR model at KNN-3, turning point of Moran's index (Fig. 1). The SAR revealed significant spatial dependence of SMR ($\rho = 0.581$, $p < 0.001$) (Table 3), indicating the presence of a neighborhood effect. After adjusting for the neighborhood effect, both household income ($\beta = 0.134$, $p < 0.05$) and unemployment rate ($\beta = 0.073$, $p < 0.05$) remained a significant exponential

Table 1. Age-standardized morbidity ratio of TB and predictors

Variables	Min	Median	Max
SMR	0.14	0.78	3.33
Incidence of HIV (per 100,000)	6.49	57.35	237.20
Prevalence of AIDS (per 100,000)	0.09	20.82	109.67
Population density (km^2)	19.07	121.89	3,643.85
Household income (Baht/month)	6,544	15 092	40,971
Unemployment rate (%)	0.09	1.33	3.76
Poverty rate (%)	0	6.43	65.16

effect on SMR. This model presented a better performance than the ordinary least square with the smaller AIC value. Finally, the model with adjusted neighborhood effect can explain the magnitude of SMR by 55% (adjusted $R^2 = 0.545$) (Table 3).

Discussion

To determine the associated factors, SMR,

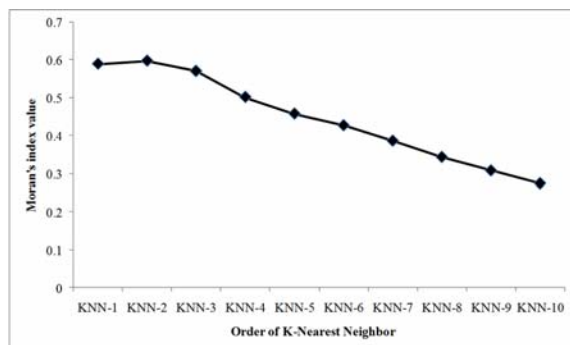


Fig. 1 Global spatial autocorrelation of residuals' stepwise regression model at KNN order 1 to 10. X-axis is the KNN order, Y-axis is the value of Moran index.

four social factors and HIV incidence during 2006-2009 in 76 provinces of Thailand were obtained and the association was investigated. The result revealed that household income and the unemployment rate are associated with SMR. Both factors revealed stronger effect of social determinants on TB risk areas than HIV. Moreover, the spatial autoregressive model expressed a significant neighborhood effect ($\rho = 0.581$, $p < 0.001$) and improved performance of estimated models with adjusted R^2 change from 0.071 to 0.545. The results implied that a province and its vicinity shared a similar risk of TB.

After adjusting for HIV incidence, the present study found the positive relationship between unemployment rate and the positive effect of the average monthly household income and SMR that are contrary to previous studies^(8,9,14,15). The results may indicate the high vulnerability of TB in urban areas. Previous studies in the economic field stated that a higher unemployment rate would likely occur in urban areas due to the rural-urban migration. The migration will continually occur as long as people in rural areas expect high income in urban areas⁽²²⁻²⁵⁾. The migration

Table 2. Univariate analysis of the association between study variables and age-standardized morbidity ratio of Tuberculosis

Variables	Regression coefficient	SE	p-value
Incidence of HIV (per 100,000)	0.002	0.001	0.022
Prevalence of AIDS (per 100,000)	0.003	0.001	0.010
Population density* (per km ²)	-0.032	0.033	0.343
Household income* (baht/month)	0.235	0.089	0.009
Unemployment rate (%)	-0.114	0.042	0.007
Poverty rate (%)	0.001	0.003	0.613

*Log transformation

Table 3. Spatial regression analysis for predictors of age standardized morbidity ratio of Tuberculosis

Variables	MLR		SAR	
	Regression coefficient ^a	SE	Regression coefficient	SE
Household income* (Baht/month)	0.285 ^b	0.088	0.134 ^c	0.063
Unemployment rate** (%)	0.132 ^b	0.040	0.073 ^c	0.029
Neighborhood effect (Rho)			0.581	
AIC	405.20		252.13	
Adjusted R ²	0.071		0.545	

*Log transformation; **Quadratic term

^aAdjusted for incidence of HIV, prevalence of AIDS, Population density and Household poverty; ^bp-value <0.001; ^cp-value <0.05

will likely increase socio-economic disparity in urban areas that created clusters of rich and clusters of poor, even though TB is recognized a disease of poor, in urban areas both rich and poor share the same setting. Moreover, clusters of poor in urban areas are likely to increase unhealthy living conditions such as slum areas, crowded households with poor sanitary conditions that facilitate TB transmission. However, the issue of migration has not been investigated yet in this study and it needs further investigation. As well, the association between monthly income and TB incidence needs further investigation in smaller scale study such as in sub-districts or villages.

After adjusting for social factors, neither HIV incidence nor AIDS prevalence was significantly associated with spatial risk of TB, contradictory to previous studies^(3,4,6). The disappearance of an HIV effect on TB incidence in the present study may confirm that the TB/HIV situation in Thailand influenced case fatality rather than case morbidity^(17,19).

Furthermore, the present study revealed a significance of spatial autocorrelation that means a similar risk of TB in the neighborhood. A similar neighborhood TB risk is likely explained by the similarity of culture and social contexts that inhibits or prohibits TB transmission^(8-10,12).

The major limitations of the present study are the utilizing of TB reported cases that did not cover TB patients who were not able to assess (editor suggests) access the health care service, particularly migrant workers and refugees. Moreover, this study used registered population which under estimated the population density and led to non-significant effects of these factors. Furthermore, the results of the present study, as an ecological study, cannot infer individual risk. Further studies should investigate the proportion of migrants⁽²⁵⁾.

Conclusion

The present study found that areas with a high unemployment rate and high household incomes positively associated with SMR, which might indicate the higher vulnerability of TB in urban areas rather than in rural areas.

Acknowledgement

The present study was supported by a China Medical Board of New York (CMB) grant PHCMB 2010/009 to MT, and also supported for publication by CMB, Faculty of Public Health, Mahidol University, Thailand. The authors would like to express their gratitude to

Associate Professor Amonrath Podipak for her kind comments on this manuscript. The authors also appreciated the kind support from all staff of the National Statistics Office and National Health Security Office.

Potential conflicts of interest

None.

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การวิเคราะห์เชิงภูมิศาสตร์ของปัจจัยทางสังคมของวัณโรคในประเทศไทย

มธุรส ทิพยมงคลกุล, จงกมล โพธิ์แดง, สุกนธา สิริ

วัตถุประสงค์: เพื่อค้นหาความสัมพันธ์ระหว่างปัจจัยทางสังคมและพื้นที่เสี่ยงของวัณโรคในประเทศไทย

วัสดุและวิธีการ: การศึกษาเชิงนิเวศและสถิติเชิงพื้นที่นำมาใช้เพื่อวิเคราะห์อิทธิพลของปัจจัยทางสังคมและอัตราป่วยของวัณโรคปรับปรุงปรับด้วยอายุจำแนกตามจังหวัดของประเทศไทยตั้งแต่ปี พ.ศ. 2549-2552

ผลการศึกษา: แบบจำลองสหสัมพันธ์เชิงพื้นที่ระบุลักษณะการเกิดวัณโรคในแต่ละพื้นที่ที่มีความคล้ายคลึงกับพื้นที่ใกล้เคียง (Moran's $I = 0.612$; $p < 0.05$) เมื่อควบคุมอิทธิพลของสัดส่วนการติดเชื้อไวรัสเอชไอวีและสหสัมพันธ์เชิงพื้นที่ ($\rho = 0.581$, $p < 0.001$) การศึกษานี้พบว่าอัตราว่างงาน ($\beta = 0.073$) และรายได้เฉลี่ยของครอบครัว ($\beta = 0.134$) มีความสัมพันธ์กับอัตราป่วยของวัณโรคปรับปรุงปรับด้วยอายุโดยมีค่าสัมประสิทธิ์จำแนก ร้อยละ 55

สรุป: การศึกษานี้พบปัจจัยที่มีอิทธิพลต่อพื้นที่เสี่ยงของวัณโรคคือพื้นที่ที่มีอัตราว่างงาน และรายได้ครัวเรือนสูงซึ่งเป็นลักษณะเฉพาะของพื้นที่เขตเมือง ดังนั้นในพื้นที่เขตเมืองซึ่งมีความเปราะบางต่อการแพร่กระจายวัณโรค ควรพัฒนาโครงการเฝ้าระวัง ป้องกัน และควบคุมวัณโรคให้เกิดความเหมาะสมกับพื้นที่
