

# Tuberculosis in Asia and the Pacific: The Role of Socioeconomic Status and Health System Development

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Date of Submission: Sep 2, 2011

Date of Acceptance: Sep 17, 2011

**How to cite this article:** Wu J, Dalal K Tuberculosis in Asia and the Pacific: The Role of Socioeconomic Status and Health System Development. *Int J Prev Med*; 08-16

## ABSTRACT

**Objective:** To identify the relationship between socioeconomic status, health system development and the incidence, prevalence and mortality of tuberculosis in Asia and the Pacific.

**Methods:** Incidence, prevalence and mortality rates of tuberculosis and 20 variables of socioeconomic, health system and biological-behavioral issues were included in the study involving all 46 countries of the Asian Development Bank region (2007 data). Both univariate and multivariate linear regressions were used.

**Results:** The worst three tuberculosis affected countries were Cambodia, India and Indonesia, while the least affected was Australia. Tuberculosis incidence, prevalence and mortality rate were higher in countries with lower human development index, corruption perception index, gross domestic product (GDP) per capita and countries with more people under minimum food supplements. Among the health system variables, total health expenditure per capita, governmental health expenditure per capita, hospital beds, and access to improved water and sanitation were strongly associated with tuberculosis.

**Conclusions:** Socioeconomic determinants and health system development have significant effect on the control of tuberculosis in Asia and the Pacific region. The study has some policy implications by means of lowering the corruption and improving the sanitation.

**Keywords:** Asia and the Pacific, health system development, socioeconomic status, tuberculosis

## INTRODUCTION

Tuberculosis (TB) has been one of the major causes of death and disability in the world for several decades. Millennium Development Goals (MDGs) set the main target for global TB control for declining the incidence rate, halving TB prevalence and halving death rate for 1990 by 2015 (MDG Target 6c).<sup>[1]</sup> A Stop TB Strategy was initiated in 2006 by World Health Organization to achieve the MDGs' target, which was based on the policy of directly observed treatments (DOTS) in 1990. The

strategy also set the ultimate goal of eliminating TB by reducing the incidence to less than 1 case per million populations per year by 2050.<sup>[2,3]</sup>

According to data from WHO, in 2007, there were an estimated 9.27 million incident cases of TB globally, with an increase from 9.24 million cases in 2006, 8.3 million cases in 2000 and 6.6 million cases in 1990.<sup>[3]</sup> In terms of the prevalence and mortality rate, there were an estimated 13.7 million prevalent cases of TB in 2007 (206 per 100,000 population), a slight decrease from 13.9 million cases (210 per 100,000 population) in 2006, resulting in 1.3 million deaths.<sup>[3]</sup> TB incidence, prevalence and mortality rates are falling, but not fast enough to meet global targets.<sup>[1]</sup> Recent studies also suggested that the incident rate of TB in 2050 would still be about 100 times greater than the ultimate goal even if the Stop TB Strategy is successfully implemented.<sup>[4-6]</sup>

One common and useful way to contribute to the control of TB is to identify the important risk factors of TB. Issue of biomedical and behavioral risk factors associated with TB has been addressed for several years. It has been confirmed by previous studies that TB is associated with HIV,<sup>[7,8]</sup> diabetes,<sup>[9-12]</sup> malnutrition<sup>[13]</sup> and tobacco use.<sup>[14,15]</sup>

TB burden is linked with socioeconomic status. For instance, poverty has an association with the incidence of TB, and the poorest have the highest risk.<sup>[5,16,17]</sup> Health system strengthening is essential for achieving MDGs including “The stop TB Strategy/”

The last two-three decades have seen increasing interest in the quantitative study of socioeconomic factors and health system factors as determinants of health outcomes in the field of public health. However, statistical evidences about causal pathways connecting socioeconomic development and health system development with the situation of TB are still lacking, especially in specific high TB prevalence regions, such as within the regional members of Asian Development Bank (ADB).

Epidemiologically, the most serious situation about TB occurred in Asia; 55% of the total estimated number of cases in 2007<sup>[3]</sup> and seven economies in Central and West Asia, such as Kazakhstan, Tajikistan, and Uzbekistan, reported increased prevalence of TB.<sup>[18]</sup> Furthermore, the three countries that rank from first to third around the world in terms of total numbers of TB cases in

2007, i.e. India (2.0 million), China (1.3 million) and Indonesia (0.53 million), are all located in the ADB region.<sup>[3]</sup> ADB Strategy 2020 (adopted in 2008) also recognizes that health affects – and is affected by – poverty and social development.<sup>[19]</sup> It is reasonable and necessary to investigate the impacts of socioeconomic status and health system development on TB outcomes within ADB countries.

Statistical analysis was conducted to identify the relationships between socioeconomic determinants, health system development and TB outcomes. The hypothesis was that socioeconomic status and health system development have great effects on controlling TB in Asia and the Pacific.

## METHODS

### Data

Forty-six countries within ADB region were selected for the study.<sup>[20]</sup> Hong Kong, China and Taiwan were excluded from the study as most of the data were not available [Table 1]. Three health outcome indicators, TB incidence, prevalence and mortality rate, were collected from ADB statistics and used in the current analysis.<sup>[18]</sup> Reasons for considering these three health indicators are provided by the MDG and WHO strategies.<sup>[1,2]</sup>

**Table 1:** Classification of countries in Asia and the Pacific according to Asian Development Bank

Developing member countries	Central and West Asia	Afghanistan, Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyz Republic, Pakistan, Tajikistan, Turkmenistan, Uzbekistan
	East Asia	China, People’s Republic of Korea, Republic of Mongolia
	South Asia	Bangladesh, Bhutan, India, Maldives, Nepal, Sri Lanka
	Southeast Asia	Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Viet Nam
	The Pacific	Cook Islands, Fiji Islands, Kiribati, Marshall Islands, Micronesia, Fed. States of Nauru, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, Vanuatu
	Developed member countries	Australia, Japan, New Zealand

We selected 20 factors as independent variables in the analysis, all of which could be divided into three groups. As the contribution of composite development, political system and economy to a country's socioeconomic status, the socioeconomic variables included in the current study were as follows: Human development index (HDI), corruption perception index (CPI), gross domestic product (GDP) per capita (PPP\$), unemployment rate, poverty data such as proportion of population below the national poverty line, inequality data such as Gini-coefficient index and the data about hunger – the proportion of population below minimal level of dietary energy consumption. Data were obtained from ADB statistics.<sup>[18]</sup>

Health system development variables included data about under-five mortality rate, the significance of which to the control of TB was shown by a previous study.<sup>[21]</sup> The data were obtained from ADB statistics.<sup>[18]</sup> Health financing is also a significant indicator of health system development since poor countries may lack the financial resources to tackle public health problems, which influence the health outcomes.<sup>[22]</sup> It can be measured in terms of total health expenditure and government health expenditure per capita (PPP\$), and the proportion of them in GDP.<sup>[23]</sup> Most of the data were obtained from the United Nations (UN) Economic and Social Commission for Asia and the Pacific (ESCAP).<sup>[24]</sup> WHO also confirms that health workforce, which is at the heart of each and every health system, is important in improving health.<sup>[25]</sup> Data of number of physicians and health infrastructure data (number of hospital beds), which were collected from ADB statistics,<sup>[18]</sup> were also included. Moreover, as health-related MDG targets,<sup>[1]</sup> data about percentage of population using improved water and sanitation facilities were also included in the study, which were obtained from ADB statistics.<sup>[18]</sup>

Biological and behavior variables were the controlled risk factors in the study, such as HIV prevalence (age 15–49 years; obtained from ADB statistics),<sup>[18]</sup> diabetes prevalence (from International Diabetes Federation)<sup>[26]</sup> and the smoking-related data (from UN ESCAP).<sup>[24]</sup>

TB detection rate and treatment rate under DOTs – data related to the implementation and quality of TB control – from WHO were also

introduced.<sup>[2,3]</sup> Detailed data information could be found in Table 2. Not all data were available for all countries, which could be reflected by the value of *n* in the table.

### Statistical analysis

Incidence, prevalence and mortality rate (dependent variables) were described to reflect the overall situation of TB within ADB countries, and 95% confidence interval was used to calculate the average rates of TB outcomes. Both univariate and multivariate linear regressions were used to investigate the links between TB outcomes and independent variables. Before the analysis was run, we tried to transform the data into a near-normal form based on statistical tradition.<sup>[27]</sup> Logarithmic transformation of the data was used for the variables that country averages differed by a factor of 10 or more (incidence, prevalence and mortality rate of TB, CPI, GDP per capita, unemployment rate, under-five mortality rate, total and governmental health expenditure per capita, numbers of physicians and hospital beds, HIV prevalence, diabetes prevalence, and adult male and female smokers). Arcsin square root transformation was used for several data expressed as a proportion (gini-coefficient, total and governmental health expenditure as a proportion as GDP, the proportion of people access to improved water and sanitation and TB treatment success rate under DOTs) in order to remove skew and to stabilize the residual variation in the analysis.<sup>[27]</sup>

Univariate linear regressions were carried out to identify the crude relationships between each independent variable and TB incidence, prevalence and mortality rate, respectively. Significance in univariate correlation was defined as  $r^2 > 0.2$  and  $P < 0.05$  in two-sided. The factors that were statistically significant in crude associations were included in the multivariate linear regression models to identify the dominant factors which influenced the TB outcomes. Significance was also defined as  $P < 0.05$  in 2-sided. PASW Statistic Version 18.0 (Copyright SPSS Inc.) was used to do the analysis.

## RESULTS

The most severe situation about TB within Asia and the Pacific in 2007 occurred in Cambodia, with an incidence rate of 495.10 per

**Table 2:** Independent variables that were included in the analysis

Independent variable	Value range	n
Socioeconomic variable		
Human development index (0–10, 0=least developed) (2006)	0.483–0.965	=38
Corruption perception index (0–10, 0=most corrupt) (2007)	1.4–9.4	=32
GDP per capita (PPP\$) (2006)	677.537–49392.453	=39
Population below the national poverty line (%) (1996–2008)	5–34	=35
Gini-coefficient (2001–2006)	0.168–0.473	=25
Unemployment rate (%) (2006)	0.2–30.906	=30
Population below minimal level of dietary energy consumption (%) (2003–2005)	3.6–44.4	=39
Health system development variable		
Under-five mortality rate (per 1000live births) (2007)	3–257	=46
Total health expenditure per capita (PPP\$) (2005)	26–3001	=46
Government health expenditure per capita (PPP\$) (2005)	4–2047	=46
Total health expenditure as a % of GDP (%) (2005)	2–15.4	=46
Government health expenditure as a % of GDP (%) (2006)	0.267–9.165	=25
Physicians per 1000 population (2006)	0.020–4.650	=40
Hospital beds per 1000 population (2007)	0.1–13.980	=42
Population using improved water sources (%) (2006)	22–100	=43
Population using improved sanitation facilities (%) (2006)	25–100	=41
Biological and behavioral variables		
HIV prevalence (age 15–49 years) (%) (2007)	0.1–1.5	=25
Prevalence estimates of diabetes mellitus (%) (2010)	1.3–30.9	=46
Adult male smokers (%) (2005)	23.6–65.9	=32
Adult female smokers (%) (2005)	0.9–52.4	=33

100,000 people, a prevalence rate of 664.5 per 100,000 people and a mortality rate of 89.5 per 100,000 people. The least serious country about TB was Australia (incidence rate: 6.2 per 100,000 people; prevalence rate: 6.3 per 100,000 people; mortality rate: 0.6 per 100,000 people). The average incidence rate was 135.2 per 100,000 people in 2007 (95% confidence interval: 104.408–165.992;  $n=46$ ) and the median rate was 116.95 per 100,000 people, with the skewed distribution. Moreover, the average prevalence rate was 180.78 per 100,000 people in 2007 (95% confidence interval: 136.925–224.63;  $n=46$ ) and more than 20 out of 100,000 people in this region died in 2007 due to TB (mean=20.77; 95% confidence interval: 15.272–26.277,  $n=46$ ).

#### Univariate methods used to test the associations between independent variables and tuberculosis outcomes

As demonstrated in Table 3, univariate regressions showed that 11 of the 22 independent variables were correlated with both the TB incidence rate and prevalence rate, and 12 of the

21 independent variables were correlated with TB mortality rate.

TB incidence, prevalence and mortality rate were higher in countries with lower HDI, CPI, and GDP per capita. Strong correlations could be found between hunger and TB outcomes in that countries with more people below minimal dietary level had higher values of TB outcomes. With respect to the variables unemployment rate, gini-coefficient and population below the national poverty line, no associations were detected between those variables and TB outcomes.

With regard to the health system development variables, under-five mortality rate was positively correlated to TB outcomes. Negative associations applied to both total health expenditure per capita and governmental health expenditure and TB incidence, prevalence and mortality rate; however, no statistical significance could be detected in terms of the other two variables about health expenditure, i.e. total health expenditure and governmental expenditure in relation to GDP. When health resources were considered, countries

**Table 3:** Independent variables and tuberculosis outcomes (univariate linear regressions)

$\beta$ Independent variable	Incidence rate			Prevalence rate			Mortality rate		
	Coefficient ( $\beta$ )	$r^2$	$P$	Coefficient ( $\beta$ )	$r^2$	$P$	Coefficient ( $\beta$ )	$r^2$	$P$
Socioeconomic variable									
Human development index	-0.731	0.535	<0.001	-0.744	0.554	<0.001	-0.744	0.554	<0.001
Corruption perception index (log10)	-0.637	0.406	<0.001	-0.619	0.383	<0.001	-0.613	0.376	<0.001
GDP per capita (log10)	-0.681	0.464	<0.001	-0.694	0.482	<0.001	-0.697	0.486	<0.001
Population below national poverty line									
Gini-coefficient (arcsin square root)									
Unemployment rate (log10)									
Population below minimal level of dietary energy consumption	0.591	0.349	<0.001	0.598	0.357	<0.001	0.607	0.368	<0.001
Health system development variables									
Under-five mortality rate/1000live births) (log10)	0.664	0.44	<0.001	0.662	0.438	<0.001	0.669	0.448	<0.001
Total health expenditure per capita (log10)	-0.684	0.468	<0.001	-0.697	0.485	<0.001	-0.709	0.502	<0.001
Govt. health expenditure per capita (log10)	-0.628	0.394	<0.001	-0.635	0.403	<0.001	-0.638	0.406	<0.001
Total health expenditure % of GDP (arcsin square root)									
Govt. health expenditure % of GDP (arcsin square root)									
Physicians per 1000 population (log10)									
Hospital beds per 1000 population (log10)	-0.469	0.22	<0.005	-0.495	0.245	<0.005	-0.49	0.24	<0.005
Population using improved water sources (arcsin square root)	-0.473	0.223	<0.005	-0.508	0.258	<0.005	-0.53	0.281	<0.001
Population using improved sanitation facilities (arcsin square root)	-0.645	0.416	<0.001	-0.661	0.436	<0.001	-0.635	0.403	<0.001
Biological and behavioral variables									
HIV prevalence (age 15-49 years) (log10)									
Prevalence of diabetes mellitus (log10)							-0.456	0.208	<0.005
Adult male smokers (log10)									
Adult female smokers (log10)	-0.463	0.215	<0.01	-0.454	0.206	<0.005	-0.497	0.247	<0.005

with fewer hospital beds had higher values of TB outcomes, but no significant association could be detected about the numbers of physicians and TB outcomes. Moreover, access to improved water and sanitation was statistically significant to TB incidence, prevalence and mortality rate. Negative associations were indicated by the analysis.

Furthermore, there were less severe situations

about TB in the countries with more adult female smokers. Inverse effects of diabetes prevalence only applied to one of the three TB outcomes, i.e. TB mortality rate, but not to TB incidence and prevalence rate. No crude relationship could be found about the HIV prevalence and TB outcomes in Asia and the Pacific. Also, the effects of TB programs on TB outcomes could not be detected from the study.

### Multivariate methods used to test the association between independent variables and tuberculosis outcomes

Three models were constructed in the analysis. Variables which were statistically significant in univariate regressions were only included in the models.

Multivariate linear regressions indicated significant associations between these variables and TB incidence rate [ $r^2=0.843$ ;  $F(11, 13)=6.341$ ;  $P<0.005$ ], prevalence rate [ $r^2=0.819$ ;  $F(11, 13)=5.361$ ;  $P<0.005$ ] and mortality rate as well [ $r^2=0.845$ ;  $F(12, 12)=5.467$ ;  $P<0.005$ ].

In terms of the role of each variable in explaining the models, many of the indicators which were statistically significant in crude associations did not persist in multivariate models, and the only indicator, CPI, was correlated with TB outcomes in all three models. Country with higher level of corruption had more severe situation of TB. Moreover, access to improved sanitation was also an important indicator, though it had no contribution to the mortality model. The regressions showed that country with fewer people

gaining access to improved sanitation had higher incidence and prevalence rates of TB [Table 4].

### DISCUSSION

The study confirmed the hypothesis that socioeconomic determinants and health system development have significant effects on the control of TB in Asia and the Pacific region.

By using univariate method, it was found that socioeconomic determinants such as HDI and hunger had great impacts on TB outcomes in Asia and the Pacific. This is in accordance with previous studies.<sup>[21,28]</sup> Our study also found the association between corruption and TB outcome, while another study investigating the relationship between CPI and the trends of TB incidence rate at a global level did not find any significant results.<sup>[21]</sup> However, as CPI was significant in the multivariate models, corruption is considered among the most important determinants of TB control within Asia and the Pacific. It could be stated that corruption affects the structure of public sectors, and as a pervasive problem in the health sector, corruption affects the infrastructure construction, drug and

**Table 4:** Independent variables and tuberculosis outcomes (multivariate linear regressions)

$\beta$	Model 1 (Incidence)		Model 2 (Prevalence)		Model 3 (Mortality)	
	Coefficient ( $\beta$ )	<i>P</i>	Coefficient ( $\beta$ )	<i>P</i>	Coefficient ( $\beta$ )	<i>P</i>
Socioeconomic variable						
Human development index						
Corruption perception index (log10)	-0.724	<0.01	-0.65	<0.05	-0.587	<0.05
GDP per capita (log10)						
Population below minimal level of dietary energy consumption						
Health system development variable						
Under-five mortality rate (per 1000live births) (log10)						
Total health expenditure per capita (log10)						
Government health expenditure per capita (log10)						
Hospital beds per 1000 population (log10)						
Population using improved water sources (arcsin square root)						
Population using improved sanitation facilities (arcsin square root)	-0.641	<0.05	-0.582	<0.05		
Biological and behavioral variables						
Prevalence estimates of diabetes mellitus (log10) <sup>a</sup>						
Adult female smokers (log10)						

<sup>a</sup>This variable was only used in multivariate analysis of mortality rate based on the significant result obtained in univariate analysis

equipment procurement, and the regulation of quality in products, services, and facilities and professionals, which has inverse effects on health status and social welfare.<sup>[29,30]</sup>

An earlier epidemiological research conducted in China indicated that TB was negatively correlated with GDP per capita.<sup>[31]</sup> This study concurred with the association in the setting of Asia and the Pacific. This could also be explained by the fact that income may affect people's care-seeking behavior. One qualitative study in Indonesia indicated that most TB patients took over a month to reach a DOTS facility after symptoms appeared due to the lack of affordability.<sup>[32]</sup> However, no relationship has been detected between unemployment rate, Gini-coefficient and TB outcomes within ADB countries, which is contrary to prior researches conducted in other settings such as South Africa and United States.<sup>[28,33]</sup>

It is proposed that health system development has impacts on TB outcomes. The implementation of the policy of DOTS and the Stop TB Strategy critically depends upon the capacity of health system and the availability of health workers and hospital infrastructures.<sup>[3,34,35]</sup> One Russian study analyzed the impact of health system on the delivery of DOTS and indicated that financing and provider-payment mechanisms of the Russian Federation health system impeded the control of TB.<sup>[36]</sup> China saw the progress in TB control under the strengthened public health system.<sup>[37]</sup> Our study also found similar crude associations in the setting of Asia and the Pacific. The health system development which relies on health financing and infrastructures such as health expenditure and hospital beds is important to the control of TB. Measure of access to improved sanitation should be taken into account since it strongly affected the TB incidence and prevalence rate after all the factors were adjusted in the regression models. This study can also be supported by the WHO study on the socioeconomic determinants influencing the trends of tuberculosis.<sup>[21]</sup>

Several observations should be taken into account. There was a negative correlation between diabetes prevalence and TB mortality in the region, which contradicts previous reports.<sup>[10]</sup> Moreover, the negative association between adult female smokers and TB patients was also striking. The reason behind them might

be that socioeconomic determinants override the associations. Adult female smokers and diabetes patients are more prevalent in higher-income countries in this region, which has lower TB incidence, prevalence and mortality rate.<sup>[5,21]</sup> Measures of HIV prevalence had no relationship with the outcomes, which was another surprising observation from the study and was contrary to many existing evidences. Epidemiologically, there were 456,000 deaths among HIV-positive incident TB cases in 2007, which accounted for 33% of HIV-positive incident cases of TB and 23% of the estimated 2 million HIV deaths.<sup>[3]</sup> However, some studies also stated that the picture was more complex. HIV is mostly transmitted through sex, which also depends on country's culture and people's own choices about sexual behavior.<sup>[38,39]</sup>

Several methodological limitations are to be considered in interpreting the study. Since statistical significance depends on the magnitude of the sample size, there might be bias in identifying the key risk factors in this region. Several measures contained lot of missing data, such as measures of HIV prevalence, unemployment rate and gini-coefficient. This might be one of the reasons due to which no associations could be found between these factors and TB outcomes. Furthermore, we could not find sufficient information about the data of TB control programs, for instance, the national expenditure on TB control. No statistical analysis was conducted in our study. We could not conclude whether these measures might also have some influence on the control of TB.

The accuracy and completeness of the data information could lead to another consideration which should be taken into account. The possibilities that the country-level data were not collected and measured accurately cannot be excluded. In terms of the TB incidence, prevalence and mortality rates, data were collected via National Tuberculosis Programs (NTP) or other relevant public health authorities within each country.<sup>[3]</sup> There are broadly two approaches to estimate TB incidence – direct measurement through longitudinal cohort studies and indirect estimation from other resources.<sup>[40]</sup> Nonetheless, the data collection processes are costly and require reliable systems, which were lacking in most of the countries with highly endemic TB.<sup>[40]</sup>

This calls for more evaluation on detailed specific data, which warrants further investigation.

The selected variables are correlated directly or indirectly in ways that are not always predictable and this could cause another bias in the analysis. For instance, four measures of health expenditure – total health expenditure per capita, government health expenditure per capita and their relationships with GDP – are usually correlated. Several biological and behavioral variables were also expected to correlate with the variables about GDP per capita. It is not clear, therefore, whether this bias would affect the result of the multivariate analysis in our study. However, we did not exclude the influence of the crude relationship obtained from the univariate methods in our study. To some extent, it could still add some implications on policy making.

The strengthening of other public sectors and the cooperation with health sector should be emphasized following WHO strategies for TB control. However, as shown by the study, many public sectors are responsible for the improvement of most of the upstream socioeconomic determinants of TB. For instance, the corruption issue requires the strengthening of political system, and raising social development level lies on the overall involvement of civil society.

Socioeconomic status and health system development are playing a crucial role in TB situation within ADB countries and should be paid more attention by each country. Several areas of research are still of interest and require attention: (i) since the research was based on national data, community-level and individual-level research are needed to investigate the socioeconomic determinants of TB; (ii) analysis of the relationship of socioeconomic factors and the change in TB burden in specific areas needs to be done; (iii) the applicability of the observations found in this study requires further investigation in different geographic regions.

Overall, this study is one of the few studies conducted to test the relationship between socioeconomic status, health system development and TB outcomes in Asia and the Pacific region, which adds several new insights in policy making by means of improving the sanitation and lowering the corruption.

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**Source of Support:** Nil **Conflict of Interest:** None declared.

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