NEIGHBOURHOOD-LEVEL RISK FACTORS AND SOCIAL DETERMINANTS FOR TUBERCULOSIS DISEASE IN METRO MANILA, PHILIPPINES: AN ECOLOGICAL STUDY USING CENSUS AND NOTIFICATION DATA

ABSTRACT

BACKGROUND

Evidence is lacking for tuberculosis (TB) risk factors and social determinants at the ecological level in developing country settings. The Philippines has high quality census and TB surveillance data creating a rich dataset for analysis. The TB burden in Metro Manila is the highest in the Philippines—which in turn is one of the 22 countries globally determined by the World Health Organization (WHO) to have a high burden of TB. Understanding risk factors at the neighbourhood (sub regional) level may help guide public health policy and practice and also suggest areas for focussed service delivery.

METHODS

Ecological data at the neighbourhood (barangay) level from the national census of 2000 and 2007 were combined with TB surveillance data from 2007 to 2010. Potential risk factors for TB in the areas of ethnicity, religion, education, housing materials, overcrowding, household size, registration, disability, mobility and overseas workers were calculated from the 2000 census data and categorized into quintiles. Population numbers were combined with TB surveillance data to calculate TB case notification rates per 100,000 person-years. Univariate linear regression was conducted for each variable and a multivariate negative binomial regression was created and analysed in order to identify the strongest predictors for higher TB rates.

RESULTS

All variables proved significant at the 95% confidence level in univariate analysis. Variables significant in the multivariate model with adjusted rate ratios for the quintile furthest from baseline were: *Reduced floor space per person* (1.35, 95% CI: 1.12–1.64), *Poorer housing materials* (1.54, 1.29–1.83), and *Increased proportion of heads of household with low education level* (1.31, 1.09–1.57). *Proportion Chinese* and *Proportion has not moved in five years* improved the model and were therefore included, but were not found to be significant risk factors.

CONCLUSIONS

Overcrowding, poor housing materials and low education were found to be significant predictors of TB disease rates. Of these, only overcrowding is considered a proximate risk factor, but all three can be seen as affected by poverty as an underlying social determinant. Public health policy makers for Metro Manila should continue the agenda of poverty alleviation in order to reduce the levels of risk factors and subsequently reduce TB rates.

Keywords: Tuberculosis, risk factors, social determinants, Philippines.

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BACKGROUND

INTRODUCTION

The Philippines ranks among the top 22 countries globally with the highest burden of tuberculosis (TB) with an estimated prevalence of 484 (uncertainty range: 425–546) cases per 100,000 population or 460,000 (range: 400,000–520,000) total cases in 2011.(1) While still very high, this prevalence is a significant drop from the estimated one million cases in 1990. This reduction is in large part due to immense efforts from public and private providers under the national TB programme (NTP).(2) As the burden is reduced by finding and treating cases primarily through passive case-finding, cases become increasingly more concentrated in high-risk and marginalised populations and the need for novel case-finding approaches increases. Despite the gains made in reduced prevalence of TB disease in the past decades, the rate of TB infection remains largely unchanged.(3,4) An important reason behind this sustained transmission is significant diagnostic and treatment delays which present hurdles to efficient case-finding.(5) In order to further reduce the TB burden in the Philippines, case finding among high-risk populations must increase.

The current opportunity for improving public health is immense as the country is experiencing a period of strong economic growth.(6) This growth will not only help fund government programmes, but can also be utilized to alleviate social determinants of poor health that underlie many risk factors for diseases such as TB.

Currently, little is known about which risk factors are most important in the Philippines context. More understanding is required in order to inform decisions and focus areas. This

study attempts to gather evidence on key risk factors for TB in Metro Manila, the region with the highest notification rate in the country.

REVIEW OF LITERATURE

RISK FACTORS AND SOCIAL DETERMINANTS OF TUBERCULOSIS

There is strong evidence supporting several risk factors for TB. Exposure to TB bacilli is a necessary element of TB infection and factors that intensify that likelihood can be considered proximate risk factors of exposure. Risk factors for TB infection include overcrowded social spaces,(7–9) and spaces with low ventilation.(10–12) Warmer drier air may also be an enabler for TB spread due to quicker evaporation.(13) Places with more coughing TB cases for more time logically have more droplet nuclei in the air increasing the amount of exposure for those encountering the same air space. People in confined areas such as prisons(14,15) and people frequently exposed to infectious patients such as TB health care workers(16,17) are at higher risk.

The second group of proximate risk factors can be characterized by impairment of the host defence system both to becoming infected and to infection developing into disease. Age and sex(18–21) are key biological factors that indicate different levels of risk of TB disease along with genetic factors, of which much is still not understood.(22,23) Other internal factors affecting the performance of the immune system include HIV infection,(24–26) malnutrition,(27,28) alcohol abuse,(29,30) diabetes,(31) and various chronic illnesses.(13) Some environmental factors as well can impair the immune response and increase risk. Exposure to tobacco smoke(32–34) and indoor air pollutants from solid-fuel cooking reduce the body's ability to expel foreign bodies from the airway and thus increase infection

risk.(28,33) Outdoor air pollution may also have a similar effect although current evidence is limited.(33,35)

Behind these proximate risk factors lie several social determinants regarded as the "causes of the causes". Poverty and low socioeconomic status (SES) are the most important of these and the majority of proximate risk factors can be seen as lying on the causal pathway leading to TB infection and disease.(36–38) Education is a key component of SES and low education attainment is associated with high TB rates and affects treatment adherence.(39–41) Unhealthy practices and inappropriate health seeking behaviour also increase TB risk for individuals by pushing them toward the more proximate risk factors.(36,42) In the context of weak or less effective health systems, these risk factors gain strength and magnify their effect.(43)

Even further upstream, national and global policies and trends influence the direction of the other social determinants. Gross domestic product and level of egalitarianism contribute to the cascade of risk factors that follow.(44) Urbanization and globalization have also been implicated as key determinants fuelling risk factors for TB.(39,45) Dye et al. examined 32 potential factors at the national level to see if these were associated with the change in TB rates over ten years. While most of the factors examined held some correlation in a group of countries, only higher human development index, access to improved sanitation, and lower under-5 mortality were found to significantly correlate with higher declines in TB rate across all countries globally.(46) While this analysis relies on uncertain estimates of TB incidence, it does provide some insight into which upstream determinants may be contributing to TB rates, even from a distance. Although individual-level risk factors contribute the most to disease risk, factors in the community may also make a “substantial

independent contribution".(47) Social determinants for TB have been identified both at the national level(44,46,48) and at subnational levels(49–51), however evidence in developing countries in Asia is very limited.

This lack of evidence is due in part to the methodological challenges of conducting such studies. Stand-alone studies examining risk factors are the most robust, but also costly. Routine surveillance data can be used for these purposes (within the inherent limits of data collected programmatically) if data on risk factors are also collected. However, adding additional data to be routinely collected can be burdensome for those reporting.

Cross-sectional prevalence surveys provide an additional opportunity for detecting relevant risk factors in low-income high-burden countries, however due to the large scale and cost, these surveys are limited in the amount of data they can collect(52) and in detecting causal relationships. The prevalence survey conducted in the Philippines in 2007 collected some risk factor data on wealth (summary measure using principal component analysis), food security, household density, sleeping density, fuel for cooking, type of stove, indoor cooking and kitchen ventilation. The wealth measure was considered inadequate and not used. Of the remaining indicators only household crowding was found to be a significant risk factor for TB.(4)

Finally, combining data collected through routine surveillance with data collected through censuses provides an additional avenue for examining risk factors at the community level without the need to collect additional data. As it is generally not possible to link records at the individual level between these data sets, most of these studies are performed at the ecological level. Ecological studies use a group of individuals as the base unit for analysis rather than individuals. Studies of this nature have been conducted in a few settings with

mixed results. Four studies in the United States considered a wide range of potential predictor variables in multivariate models. Poverty was found significant in two studies,(51,53) but not included in the final model of another two.(49,54) The latter study included social capital as a predictor and perhaps did not see a strong link to poverty due to co-linearity of the two inputs. Conversely, between these two studies, one found income inequality as significant wherein another did not. Race was found to be a significant predictor in three studies along with the proportion of the population foreign-born.(49,51,53) Crowded housing, dilapidated housing, elements of social segregation, social capital, and Acquired Immune Deficiency Syndrome (AIDS) diagnosis rate were addressed by these studies (although not by more than one) and found to be significant. Diabetes, smoking and alcohol abuse were considered by Young and Strasser,(49) but excluded from the final model due to insignificance.

Two studies in Hong Kong performed similar exploratory ecological analyses, although at slightly different aggregate levels.(55,56) They both found low household income to be a significant predictor and population density as not significant, but Chan-Yeung et al. found education to be significant whereas Pang et al. did not. Chan-Yeung also found elderly population to be significant and unemployment not. Pang et al. found marital status, birth outside Hong Kong to be significant and nationality, ethnicity, low-skilled occupation, and low personal income as not significant.

Finally, a similar study in Brazil found “urbanicity, population density, poor economic conditions, household crowding, non-white population and worse health and healthcare indicators” to be associated with high TB rates.(57) Although Brazil is considered an upper middle-income country,(58) this is one of the few examples of an ecological exploratory

study on the risk factors and social determinants of TB not from a high-income setting where the TB burden is comparatively low.(59) Generalizing these findings to low-income country settings presents a challenge especially for upstream social determinants which can be sensitive to different sociopolitical structures.

Lönnroth et al. call for more "analysis of factors determining variations in TB burden…across geographical areas within countries".(36) This evidence gap is especially present in developing countries and Asian countries.

Aims and Objectives

This study seeks to identify which census-collected characteristics of Metro Manila neighbourhoods are associated with increased notification of TB disease. With this information, the NTP can both advocate for progress on social determinants that underlie these risk factors, and also identify neighbourhoods at higher risk which could benefit most from programme efforts including targeted service delivery. The objectives, therefore of this study are:

- to identify risk factors of TB disease rates (as measured by case notification per 100,000 person-years); and
- to quantify the difference in TB disease rates between the levels of identified risk factors (as measured by rate ratios).

Materials and Methods

Ethical approval for this study was obtained from the London School of Hygiene and Tropical Medicine Research Ethics Committee (ref: 012-069), the World Health Organization Western

Pacific Region Ethical Review Committee (ID: 2013.15.PHL.2.STB), and the National Ethics Committee, Philippine Council for Health Research and Development, Department of Science and Technology. As this study utilizes only secondary data sources and no patient identifiable information, a full ethical review was waived from the latter two committees.

SECONDARY DATA

This cross-sectional study follows an ecological design with analysis at the neighbourhood or barangay level. Information on Metro Manila barangays was obtained from three sources, two national censuses (2000 and 2007) from the National Statistics Office (NSO) of the Philippines and routine surveillance data from the electronic recording and reporting system of the Philippines NTP. Censuses are normally conducted in the Philippines every five years.(60) However, the 2005 census was delayed for two years due to budgetary reasons.(61) Data from the 2007 census were the latest available for this study, but lacked many variables describing barangay characteristics, therefore data from the 2000 census was also used. The number of TB cases (all forms) per year from the NTP national surveillance system for the years 2007 to 2010 was used to calculate the outcome of interest, TB notification rate per 100,000 person-years.

Datasets were matched by barangay, district, and city name with non-matching barangays removed (see Table 1). Barangays with population size values of zero (n=5) were removed as well. The one barangay with a case notification rate greater than 5,000 per 100,000 person-years was deemed to be the result of a data error and was removed. An examination of the data on population size looking for outliers revealed that differences in population by barangay between the two censuses, was approximately normally distributed with a mean of +3.2% and standard deviation of 29.3% indicating most barangays grew in size during this

time. The distribution also showed long tails of values showing differences of 100% or more (n=21). These scenarios were likely due to the redefinition of boundaries rather than to a true increase or decrease in population. These reasons were not known with the evidence available, therefore these barangays were kept in the dataset as a conservative approach.

TABLE 1 NUMBER OF BARANGAYS BY DATASET

Census 2000	1,689
Census 2007	1,696
TB notification 2007–2010	1,693
Merged of above 3 datasets, with only matching records included	1,689
Merged with population size > 0 and TB rate < 5000 per 100 000	1,684

VARIABLES

The variables available in the final dataset are listed in Table 1. Demographic variables were calculated as the number of people with the attribute in the barangay divided by the barangay population. These variables included the proportion: Not Filipino, Chinese, and Not Roman Catholic. Socio-economic variables included the following.

- Proportion of heads of household with low education level (primary school education or lower)
- Housing index as a proxy for household wealth
    - Three characteristics of housing were utilized to create a housing index by principal component analysis.(62)
    - These characteristics included: building type (single, duplex, multiple, commercial, institutional, other); roofing materials (galvanized, claytile, wood, cogon, asbestos, makeshift roofing, other); and wall materials (concrete,

wood, wood and concrete, galvanized, bamboo, asbestos, glass, makeshift walls, no walls, other).

- Mean floor space per person
    - The census data categorized households into 10 floor space categories (with cut-off points of 10, 20, 30, 50, 70, 90, 120, 150, and 200 square metres). The mid-point of each range was used to calculate the total floor space per barangay.
    - This variable was calculated as the total floor space per barangay divided by the barangay population.
- Mean number of people in each household
    - Calculated as the total population in the barangay divided by the number of households in the barangay.
- Mean floor space for each household
    - Calculated as the total floor space per barangay (as above) divided by the number of households in the barangay.

The proportion of residents not registered in the civil registry, who were disabled, and who had moved in the last 5 years were also included as independent variables, along with the proportion of households where the head of household was disabled, and the ratio of Overseas Filipino Workers (OFW) per barangay resident. Barangays were grouped by variable into equal quintiles with the reference group as the lower case rate of the first and fifth quintile. These variables were treated as ordered categorical variables in the analysis.

MISSING DATA

Information on missing data was only available for two variables in the census dataset – *Floor space per person* and *Proportion of heads of household with low education level*. Missing data in the former were assessed by quintile and comprised 4.4%, 3.8%, 4.1%, 3.7%, and 3.6% of households respectively from the quintile with the lowest floor space per person to the highest. Missingness appeared to be mostly non-differential and households with missing values were assumed to have the same mean floor space per person as reporting households per barangay.

The information on households missing education data is from a variable meant to hold the value for the number of households without a value in one of the other mutually exclusive education levels. However, the sum of households in all these levels plus the missing category ranged from 123 below the total households in the barangay to 24 above (or -11% to +3.6%). This data on missing education was deemed unreliable and the difference between total households and the sum of education levels was used instead. Households with missing values were assumed to have the same proportion as reporting households per barangay.

As proportional input variables were calculated as the number of households in the barangay with the attribute divided by the total number of households in the barangay, any missing values were assumed to not possess the attribute except for the case where reciprocals were used (*Proportion not Filipino*, *Proportion not Roman Catholic*, and *Proportion has moved in last 5 years*), wherein missing values were assumed to possess the attribute.

Data, such as disaggregated TB case notification at the individual level, were not available to calculate case rates standardised by age and sex. The variables for proportion under five and over 65 were considered poor indicators of age structure and were not used.

Analysis

Univariate rate ratios

Crude univariate rate ratios comparing the TB rate between each quintile and the baseline quintile, were calculated for each predictor variable in the dataset. Simple t-tests were performed to determine the probability that rates differ from baseline by chance alone.

Multivariate analysis

A multivariate Poisson regression model was built using backwards and forwards regression analysis. At each step, models were calculated after dropping one more variable in turn or adding one variable already dropped. The model with the lowest value for the Akaike Information Criterion (AIC) was then kept and carried to the next step. The model was considered complete after no additional variables removed or added improved the model fit further as indicate by a reduced AIC. Interaction terms were not considered for this model.

A goodness-of-fit test was performed for the Poisson assumption of equal variance and mean, and it was found that the model violated this assumption resulting in substantial overdispersion. Therefore, a negative binomial model was built using the same step-wise approach. Predicted values and residuals were plotted in order to ascertain homoscedasticity and a QQ plot was created to assess the normal distribution of residuals.

From the final model, the adjusted rate ratio of each predictor was quantified and presented. Given the size of the dataset, enough study power should have been present to detect associations if they exist.

All analyses were made using R software version 3.0.2.(63)

RESULTS

DESCRIPTIVE AND UNIVARIATE ANALYSIS

The raw rates for TB notification per 100,000 person-years range from 0 to 539 with a median of 52.8 and a population-weighted mean of 66.8. The distribution is heavily skewed to the higher values even when the extreme outliers are removed. Population in 2007 is similarly distributed with a median of 1,834, mean of 6,732 and interquartile range of 1,012–4,520. The largest barangay population size in the dataset was 221,900.

Crude rate ratios of TB notification show an observed relationship that is statistically significant (at the 95% confidence interval level) with the outcome for all input variables (see Table 2). The variables with the strongest association with the outcome are those for *Proportion of heads of household with low education level*, *Floor space per person*, and *Floor space per household*.

TABLE 2 CHARACTERISTICS AND UNIVARIATE ANALYSIS OF INDEPENDENT VARIABLES

					Univariate analysis		
Variable[A]	Number of barangays	Cases (4 year total)	Population	Rate per 100 000 person-years	Crude rate ratio	95% CI	p-value
Overall	1 684	30 311	11 343 030	67			
Proportion not Filipino							
0	563	3 988	1 305 520	76	1.0		
(0,0.00035]	110	6 404	2 645 432	61	0.8	0.76–0.82	<0.001
(0.00035,0.002]	337	12 648	4 309 553	73	1.0	0.93–1.00	0.028
(0.002,0.011]	337	5 681	2 174 886	65	0.9	0.82–0.89	<0.001
(0.011,0.64]	337	1 590	907 639	44	0.6	0.54–0.61	<0.001
Proportion Chinese[b]							
0	763	7 073	2 435 692	73	1.0		
(0,0.00086]	247	15 092	5 439 666	69	1.0	0.93–0.98	0.0016
(0.00086,0.0079]	337	6 667	2 600 882	64	0.9	0.85–0.91	<0.001
(0.0079,0.64]	337	1 479	866 790	43	0.6	0.56–0.62	<0.001
Proportion not Roman Catholic							
[0,0.064)	337	2 865	1 037 172	69	1.0		
[0.064,0.084)	336	5 971	2 070 133	72	1.0	1.00–1.09	0.057
[0.084,0.1)	337	7 123	2 698 661	66	1.0	0.92–1.00	0.040
[0.1,0.13)	337	9 829	3 452 197	71	1.0	0.99–1.07	0.15
[0.13,0.98]	337	4 523	2 084 867	54	0.8	0.75–0.82	<0.001
Proportion of heads of household with low education level							
[0,0.091)	335	1 679	1 126 800	37	1.0		
[0.091,0.13)	339	3 173	1 291 360	61	1.7	1.55–1.75	<0.001
[0.13,0.17)	337	4 889	1 901 922	64	1.7	1.63–1.82	<0.001
[0.17,0.23)	337	8 799	3 199 749	69	1.9	1.75–1.94	<0.001
[0.23,0.49]	336	11 771	3 823 199	77	2.1	1.96–2.18	<0.001
Housing materials							
[-1.5,-0.58)	337	5 716	2 764 659	52	1.0		
[-0.58,-0.29)	337	7 041	2 772 307	63	1.2	1.19–1.27	<0.001
[-0.29,0.018)	337	6 059	2 256 261	67	1.3	1.25–1.35	<0.001
[0.018,0.51)	337	6 293	1 978 389	80	1.5	1.48–1.59	<0.001
[0.51,4.7]	336	5 202	1 571 414	83	1.6	1.54–1.66	<0.001
Floor space per person (metres squared)							
[0.3,6.5)	336	4 314	1 380 021	78	2.0	1.90–2.10	<0.001
[6.5,8.4)	337	9 043	2 958 148	76	2.0	1.87–2.04	<0.001
[8.4,10)	337	9 448	3 394 806	70	1.8	1.70–1.86	<0.001
[10,14)	337	4 951	1 978 679	63	1.6	1.52–1.68	<0.001
[14,42]	337	2 555	1 631 376	39	1.0		
People per household							
[2.1,4.3)	337	2 774	1 307 887	53	1.0		

[4.3,4.6)	337	8 004	2 793 558	72	1.4	1.29–1.41	<0.001
[4.6,4.7)	337	8 999	3 512 789	64	1.2	1.16–1.26	<0.001
[4.7,4.9)	336	8 036	2 701 362	74	1.4	1.34–1.46	<0.001
[4.9,7.2]	337	2 498	1 027 434	61	1.2	1.09–1.21	<0.001
Proportion not registered							
[0,0.028)	337	2 745	1 115 470	62	1.0		
[0.028,0.047)	336	7 309	2 856 136	64	1.0	1.00–1.09	0.080
[0.047,0.07)	337	9 701	3 483 804	70	1.1	1.08–1.18	<0.001
[0.07,0.11)	337	7 349	2 598 356	71	1.2	1.10–1.20	<0.001
[0.11,0.89]	337	3 207	1 289 264	62	1.0	0.96–1.06	0.68
Proportion disabled							
[0,0.0036)	337	1 658	669 531	62	1.0		
[0.0036,0.0059)	337	5 690	2 320 679	61	1.0	0.94–1.05	0.72
[0.0059,0.0084)	337	8 963	3 386 863	66	1.1	1.01–1.13	0.013
[0.0084,0.014)	336	8 466	3 057 071	69	1.1	1.06–1.18	<0.001
[0.014,0.28]	337	5 534	1 908 886	72	1.2	1.11–1.24	<0.001
Proportion of households with head of household disabled							
[0,0.016)	337	1 629	669 979	61	1.0		
[0.016,0.027)	337	5 927	2 282 196	65	1.1	1.01–1.13	0.018
[0.027,0.039)	337	8 362	3 290 810	64	1.1	0.99–1.10	0.1
[0.039,0.065)	336	8 893	3 169 204	70	1.2	1.1–1.22	<0.001
[0.065,1.1]	337	5 500	1 930 841	71	1.2	1.11–1.24	<0.001
Proportion has moved in last 5 years							
[0.053,0.16)	337	1 602	653 045	61	1.0		
[0.16,0.19)	337	3 878	1 311 690	74	1.2	1.14–1.28	<0.001
[0.19,0.22)	337	7 105	2 384 686	74	1.2	1.15–1.28	<0.001
[0.22,0.26)	336	11 175	4 142 677	67	1.1	1.04–1.16	<0.001
[0.26,0.99]	337	6 551	2 850 932	57	0.9	0.89–0.99	0.019
Ratio of Overseas Filipino Workers (OFW) per barangay resident							
[0,0.0099)	337	3 375	1 275 121	66	1.0		
[0.0099,0.014)	336	8 971	3 354 710	67	1.0	0.97–1.05	0.61
[0.014,0.018)	338	8 940	3 297 516	68	1.0	0.98–1.07	0.23
[0.018,0.025)	336	6 101	2 229 091	68	1.0	0.99–1.08	0.12
[0.025,0.22]	337	2 924	1 186 592	62	0.9	0.89–0.98	0.0047

[a] In quintile ranges, [indicates the endpoint is included in the range, and (indicates the endpoint is excluded.

[b] A large number of barangays (45%) have no Chinese population, therefore the lowest two quintiles make up the baseline.

MULTIVARIATE ANALYSIS

The final multivariate negative binomial regression model included five independent variables – *Floor space per person*, *Housing materials index*, *Proportion of heads of household with low education level*, *Proportion Chinese*, and *Proportion has moved in last 5 years*.

In the first step of building this model, all input variables were included. Using methods described above variables were dropped in the order of:

1. Ratio of Overseas Filipino Workers (OFW) per barangay resident
2. Proportion not Filipino
3. Proportion disabled
4. Proportion not Roman Catholic
5. Proportion not registered
6. Proportion of households with head of household disabled
7. People per household

No variables were added back into the model after being dropped.

Diagnostic plots for this model showed the distribution of residuals was approximately normal with no clear patterns. Similarly, the standard deviance of residuals held mostly linear across theoretical quantiles. These tests indicate a fairly good fit of the data.

Table 3 lists the baseline rate, model covariates, adjusted rate ratios and p-values from the final model. The baseline rate of TB disease was 126 cases per 100 000 person-years. There is strong evidence behind *Housing materials index* as a factor for increased TB rate. The poorer quintiles have rates 23–54% higher than the richest quintile. *Floor space per person*

and *Proportion of heads of household with low education level* showed strong evidence in the quintiles farthest from the baseline that these are significant predictors of increased TB rates. For all three of these variables, there is some indication of a gradient correlating increase in rates with increased value of the variable. The remaining variables *Proportion has moved in last 5 years* and *Proportion Chinese* did not have evidence for being significant predictors except for the highest quintile of *Proportion Chinese*.

TABLE 3 ADJUSTED RATE RATIOS FOR RATES OF TB DISEASE IN METRO MANILA BARANGAYS BY RISK FACTOR

Baseline rate per 100 000 person-years (95% CI)	126 (102–157)

COVARIATES[A]	ADJUSTED RATE RATIOS (95% CI)	P-VALUE
Floor space per person (metres squared)		
[1.2,6.8)	1.35 (1.12–1.64)	0.0020
[6.8,8.8)	1.41 (1.17–1.69)	<0.001
[8.8,11)	1.29 (1.08–1.54)	0.0044
[11,14)	1.32 (1.11–1.57)	0.0014
[14,47]	1.00 (ref)	
Housing materials index		
[-1.5,-0.58)	1.00 (ref)	
[-0.58,-0.29)	1.23 (1.04–1.45)	0.015
[-0.29,0.018)	1.30 (1.10–1.54)	0.0019
[0.018,0.51)	1.29 (1.09–1.53)	0.0031
[0.51,4.7]	1.54 (1.29–1.83)	<0.001
Proportion of heads of household with low education level		
[0,0.0909)	1.00 (ref)	
[0.091,0.13)	1.22 (1.03–1.45)	0.022
[0.13,0.17)	1.22 (1.02–1.45)	0.026
[0.17,0.23)	1.27 (1.06–1.51)	0.0089
[0.23,0.49]	1.31 (1.09–1.57)	0.0045
Proportion Chinese[b]		
0	1.00 (ref)	
(0,0.00086]	0.90 (0.78–1.05)	0.17
(0.00086,0.0079]	0.90 (0.78–1.03)	0.11
(0.0079,0.64]	0.77 (0.66–0.90)	<0.001
Proportion has moved in last 5 years		
[0.053,0.16)	1.00 (ref)	
[0.16,0.19)	1.22 (1.04–1.44)	0.015
[0.19,0.22)	1.18 (1.00–1.39)	0.044
[0.22,0.26)	1.17 (0.99–1.38)	0.064
[0.26,0.99]	0.99 (0.84–1.18)	0.98

[a] In quintile ranges, [indicates the endpoint is included in the range, and (indicates the endpoint is excluded.

[b] A large number of barangays (45%) have no Chinese population, therefore the lowest two quintiles make up the baseline.

DISCUSSION

This exploratory analysis indicates that at the barangay level, the strongest predictors of higher TB incidence are housing materials, overcrowding, and education. Mobility and Chinese ethnicity improved the model, but there was no evidence found that they were significant risk factors for rates of TB. While strong evidence was seen for the highest quintile of *Proportion Chinese*, this association is likely confounded by wealth as ethnic Chinese families in Metro Manila tend to be wealthier than average.(64) The three significant predictors are examined here in turn.

HOUSING MATERIALS

This variable served as a proxy of wealth in lieu of direct measurements of mean household income per barangay. Income is obviously a main component of socioeconomic status, which has been seen as one of the most important risk factors for TB disease at the individual and population levels.(37) Among countries (a higher ecological level), GNI per capita is also closely correlated with rates of TB disease.(36) Poorer countries have higher disease rates and the most dramatic changes in rates of TB disease are seen with dramatic changes in national economies.(1) (Examples can be seen in China and Latvia.) Other ecological studies at the subnational level found similar association between wealth and TB. In Russia the odds of people in the lowest wealth quintile was 16.7 times the odds in the highest.(65) The causal pathway between wealth and proximate risk factors for TB is not completely known, however, it is reasonable that higher income allows individuals to avoid some known risk factors such as overcrowding,(7) indoor air pollution,(66) and malnutrition.(28) Unequal wealth distribution within barangays was not assessed in this

study, however it has been implicated in other studies as a social determinant behind the spread of TB.(36) Temporality was also not assessed in this analysis, however with the evidence from other studies, if income is increased for the poor in the barangay and equality is maintained or increased, these findings suggest rates of TB will likely decline.

Overcrowding

This is the only risk factor in the model which can be considered proximate. The barangays with the highest rate ratio had mean floor space per person of only 1.2 to 6.8 square metres compared to over 14 square metres per person at baseline. Overcrowding at the individual level has been associated with TB incidence in various developing countries.(67–70) In addition, ecological studies in the United States,(49,51) the United Kingdom,(71,72) and New Zealand(7) have confirmed similar results. These findings add to this existing evidence that overcrowding is a risk factor for TB at the neighbourhood level in a developing country setting as well.

Education

Similar to the housing materials index, education contributes to socio-economic status which underlies many proximate risk factors for TB. In addition to wealth, education may bring awareness of proximate risk factors and may enable individuals to partially avoid them especially if TB awareness campaigns targeted at the uneducated are absent.(73) These results indicate that barangays with low educational attainment are key intervention areas.

Findings for these three input variables agree with the large body of existing evidence linking poverty with TB disease. (5,49,50,56,65,74–76) Other high TB prevalence settings in developing countries might expect similar results. It is highly likely that social policies in

Metro Manila that serve to reduce poverty and inequality will also reduce the level of TB seen in communities.

In comparison with similar ecological studies mentioned earlier, these findings agree with the crowded and dilapidated housing association with TB seen by Acevedo-Garcia(51) and Harling and Castro.(57) Education as a significant predictor agrees with Chan-Yeung et al.(55) and does not agree with the findings of Pang et al.(56) Race and ethnicity were seen as important predictors in the United States,(49,51,53) and Brazil,(57) but not found to be significant in this study similar to the results from Hong Kong.(56) Migration patterns and sources in Manila are perhaps more similar to Hong Kong than those in the Americas.

LIMITATIONS

This study has several limitations that affect both internal and external validity.

DATA QUALITY

For the variable on floor space, data were missing for approximately 3.9% of households. It is unknown if the respondent was asked to estimate this value or if the census taker actually measured. There may be many reasons why census takers systematically neglected to collect data on floor space (e.g. in large dwellings which would take more time to measure), which would introduce bias into these results. This level of missing data is somewhat low and it is probable that complete data would show similar results. Other variables might have a similar or higher level of missing data, which might also introduce bias.

As these data were collected through periodic governmental practice rather than through rigorous scientific means for research purposes only, it is certainly possible that census takers missed key areas, such as squatter areas and informal dwellings within

neighbourhoods. Although the data on the number of registered heads of household indicate that many non-registered people were contacted as well. It is also possible that key information was withheld from census takers by respondents as seen in other censuses.(77) Similarly, with TB surveillance data, notification is not the same as incidence, and while this analysis uses notification rates as a proxy for incidence, there are many reasons why incident TB cases may not be notified.(78) Any systematic differences in the methods of data collection could introduce bias. For example, in Metro Manila, people tend to seek care from health practitioners in the private sector if they can afford it.(5) These practitioners are less likely to notify cases than public health facilities especially without obligatory reporting.(79) This bias could lead to an overestimation of the effect of education and wealth on TB rates.

Additionally, the variables examined in this study were restricted to those collected previously. It was not possible to calculate rate ratios standardized by age and sex in order to control for differences in the demographic makeup between barangays. Other important potential confounders such as HIV infection, tobacco and alcohol use, and air pollution were also not considered due to lack of availability. These variables have been shown in other studies to be important risk factors for TB.(24,80)

As this is an ecological study, results here cannot be interpreted at the individual level and further research is required to investigate these predictors for individuals. Similar to other ecological studies, this study utilizes available secondary data and proxy indicators which make for weak indicators and a lack of indicators of potential confounders. Strong associations often exist between exposure indicators at the group level and it is challenging to quantify the effect of specific exposures independent of confounding variables. Within

these limitations these results may be applicable to similar large cities in developing country settings. The methodology of using census data for secondary analysis may also be useful to others seeking to find a relatively inexpensive way to analyse at the aggregate level.

Further research in this area might include the effects of policy changes and intensified case-finding efforts on TB rates. Evidence of risk factors for TB and their social determinants at the population level in developing country settings is currently lacking and further research is critical to inform public policy.

CONCLUSIONS

This study found three risk factors with an underlying social determinant of poverty that are strong predictors of high TB rates. The NTP and other partners can use these predictors (characteristics) for planning and implementation of TB control policies and projects including targeted service delivery. Policy makers for Metro Manila should continue the agenda of poverty alleviation (possibly using education and improved housing as markers) in order to reduce the levels of risk factors and subsequently reduce TB rates.

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