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Predicting tuberculosis among migrant groups

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SUMMARY

In industrialized countries migrants remain a high-risk group for tuberculosis (TB). Multiple linear regression analysis was used to determine the ability of indicators of TB incidence in the country of birth to predict the incidence of TB among migrants in Australia during 1997. World Health Organization total case notifications, new smear-positive case notifications and the estimated incidence of TB by country of birth explained 55, 69 and 87% of the variance in TB incidence in Australia, respectively. Gross national income of the country of birth and unemployment level in Australia were also significant predictors of TB in migrant groups. Indicators of the incidence of TB in the country of birth are the most important group-level predictors of the rate of TB among migrants in Australia.

INTRODUCTION

The control of tuberculosis (TB) in migrants remains a substantial challenge for industrialized countries. As a proportion of TB case notifications in Australia, TB among the overseas-born population is increasing. In 1997, 79% of new TB notifications in Australia were among overseas-born persons, and the total TB case notification rate among overseas-born populations was as high as 70·1 per 100 000 for the Vietnam-born resident population in Australia [1]. The high rate of TB among migrants (the terms migrants and overseas-born are used interchangeably as they cannot be differentiated in our datasets) is thought to be primarily associated with the high incidence of TB in the country of origin [2]. Most cases of active TB among migrants result from infection with *Mycobacterium tuberculosis* prior to migration [3], and most TB cases among migrants occur among recent arrivals [1, 4]. In 1979 Enarson and co-workers [5] observed that reported TB incidence rates among migrants in Canada paralleled that in their country of birth across 15 countries, although the strength of this association across migrant groups was not evaluated. We aimed to determine how well country-specific estimates of the incidence of TB derived from routinely collected data predict the risk of TB among migrant groups following migration.

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METHODS

We performed a cross-sectional group-level analysis to assess the relative ability of indicators of country-of-birth-specific TB incidence and sociodemographic factors to explain the variation in the rate of TB among migrant groups in Australia using published group-level data. The dependent variable in this analysis was the incidence of active TB disease (all forms, new and relapsed) per 100 000 overseas-born resident population by country of birth in Australia during 1997, as reported by Gilroy [1]. TB cases diagnosed in Australia are reported to State health departments, and national statistics are compiled through the National Mycobacterial Surveillance System (NMSS) database. Data were available for 28 overseas-country-of-birth groups.

The main independent variables in the analysis were three estimates of the incidence of TB in each country of birth. These were World Health Organization (WHO) total case notification rates for 1997 per 100 000, WHO new smear-positive case notification rates for 1997 per 100 000 [6] and the estimated incidence of TB during 1997 per 100 000 published by Dye and co-workers [7]. Dye et al.'s [7] estimates of the incidence of TB were based on WHO case notification data, tuberculin surveys and data on the prevalence of smear-positive pulmonary disease. These estimates are the most complete and up to date assessment of the TB burden by country available. Dye et al.'s estimates of TB incidence are not age standardized [7].

Multiple linear regression analysis was used to assess the amount of variance in TB rates among migrants in Australia that can be explained by three indicators of the incidence of TB in their country of birth. Sociodemographic variables were also included in the analysis to adjust for their confounding effects on the association between TB incidence rates in Australia and those in the country of birth. Sociodemographic variables included country-of-birth-specific *per capita* gross national income (GNI) for 1997 [8] in US dollars, as well as the following descriptors for country-of-birth-specific migrant groups in Australia; median age, gender, employment status and educational status (percentage that had completed a university degree or diploma) [9, 10]. As GNI was not available for the Federal Republic of Yugoslavia (Serbia and Montenegro), a published estimate [11] was used.

To limit the degree of uncertainty in estimates of the incidence of TB in Australia, country-of-birth-specific migrant groups with resident populations of less than 30 000 were excluded from the analysis. Migrant groups for which comprehensive sociodemographic data were not available also were excluded. Australian TB data for certain countries of birth (i.e. Hong Kong and Macau, United Kingdom and Ireland, and Former Yugoslav Republics) were aggregated, and weighted averages within these regional groups were used for independent variables in this analysis.

The normality of all indicators was assessed prior to their use in regression analysis. The square root transformation was used to normalize *per capita* GNI and educational status. WHO case notification data, the estimated incidence of TB in the country of birth, Australian TB notification data and employment status were transformed using a natural logarithm. The assumption of linearity was met for all independent-dependent variable pairs. The stepwise method was used for variable selection [12] with P to enter at 0·05 and P to exit at 0·10, followed by a manual check for alternative models. Outliers, collinearity and model fit were evaluated.

RESULTS

The Australian TB reporting category country of birth groups of Chile, Canada and Hungary were excluded from this analysis as the resident overseas-born population in Australia did not exceed 30 000. Chile and Canada did not record any TB notifications in Australia during 1997. The Australian TB reporting category 'Former USSR and Baltic States' was also excluded from the analysis, as comprehensive data on the sociodemographic characteristics of these migrants in Australia were not available. A total of 526 cases of TB disease were reported in Australia during 1997 among migrants from the remaining 24 country-of-birth groups. The specific country-of-birth groups included in this analysis are identified in Figure 1, with the exception of South Africa. Bivariate linear regression models indicated that South Africa was an outlier, having a regression standardized residual that exceeded three, and was excluded from this analysis.

Bivariate linear regression models were run for all independent variables in the analysis separately, and the results are summarized in Table 1. WHO total case notification rates, WHO smear-positive case notifications and the estimated incidence of TB explained 55, 69 and 87% of the variance in the incidence of TB among country-of-birth groups in Australia, respectively. The incidence of TB in Australia was not significantly associated with educational status. The association between the incidence of TB in Australia in 1997 and the estimated incidence of TB in the 23 country-of-birth groups are displayed in Figure 1.

A separate stepwise multiple linear regression analysis was performed for each of the three indicators of the incidence of TB in the country of birth to assess the relative ability of indicators of TB incidence, GNI and sociodemographic factors to explain variation in the incidence of TB among country-of-birth groups in Australia. In each of the three models all independent variables (GNI and sociodemographic variables) were entered into the model for selection. The final models are summarized in Table 2. In all three models, the indicator of the incidence of TB in the country of

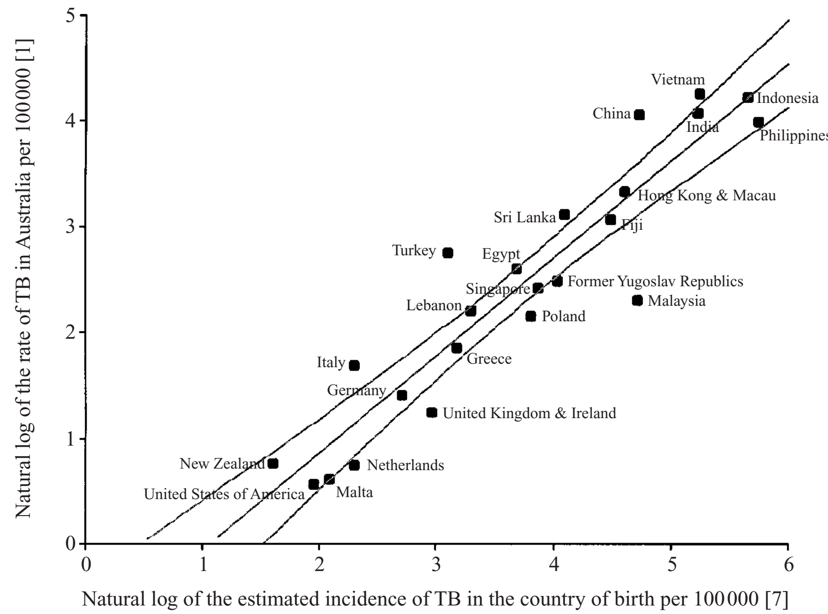

Fig. 1. The association between the rate of TB among country-of-birth-specific groups in Australia and the rate of TB in the country of birth. Estimates are based on the natural logarithms of the rate of TB in Australia in 1997 per 100 000 and the estimated incidence of TB in country of birth in 1997 per 100 000 and are shown as a scatterplot and regression line with 95 % confidence intervals.

Table 1. *Bivariate linear regression analysis of the predictors of TB incidence rates per 100 000 population among country-of-birth-specific migrant groups in Australia, 1997*

Independent variables	Adjusted R^2	Partial regression coefficient (B)	P value
Country of origin factors			
Estimated incidence of TB*	0·87	0·92	$<$0·001
WHO smear positive case notifications*	0·69	0·79	$<$0·001
WHO total case notifications*	0·55	0·79	$<$0·001
Gross national income	0·52	−0·02	$<$0·001
Migrant group factors			
Employment status	0·22	1·61	0·01
Median age	0·22	−0·07	0·01
Gender	0·14	−0·14	0·04
Educational status	0·07	0·27	0·12

* Pertain to rates per 100 000 population.

birth was the most important predictor of the incidence of TB in Australia by country of birth. Gross national income of the country of birth was the only additional significant predictor of the incidence of TB in Australia by country of birth in both WHO case notification models. There were no serious problems with the models due to collinearity. The addition of interaction terms did not produce significant contributions to the models. Exclusion of the Former Yugoslav Republics category from the analysis, which required extensive averaging of independent variable data (data not shown), did not alter the main findings of this analysis.

DISCUSSION

Based on an investigation of three indicators of the incidence of TB in the country of birth, our findings suggest that the incidence of TB in the country of birth is the single most important group-level predictor of the rate of TB among migrants in Australia. WHO smear-positive case notification rates were highly

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Table 2. *Stepwise multiple linear regression analysis of the predictors of TB incidence rates among country-of-birth-specific migrant groups in Australia, 1997*

Model	Model adjusted R^2	Partial regression coefficient (B)	P value
Model 1. WHO total case notifications			
WHO total case notifications*	0·74	0·55	<0·001
Gross national income		−0·01	0·001
Intercept		1·56	0·012
Model 2. WHO smear positive case notifications			
WHO smear positive case notifications*	0·77	0·59	<0·001
Gross national income		−0·008	0·007
Intercept		1·88	<0·001
Model 3. Estimated incidence of TB			
Estimated incidence of TB*	0·90	0·85	<0·001
Employment status		0·68	0·007
Intercept		−2·36	<0·001

* Pertain to rates per 100 000 population.

predictive of the incidence of TB in Australia despite limitations in the comparability of notification data across countries. WHO case notification rates are imperfect indicators of the incidence of TB by country, as these indicators are confounded at the group level by factors associated with the detection and reporting of disease. For instance, only eight countries included this analysis have implemented standard WHO TB control strategies covering over 90% of their populations [6].

The stronger association between the estimated incidence of TB indicator [7] and the incidence of TB in Australia is likely to be due to decreased group-level confounding associated with this indicator, and provides support for the validity of these estimates. Overall, the strength of the association between group-level indicators of the incidence of TB in the country of birth and in migrants in Australia is high given that the current year's risk of TB in the country of birth may not reflect the migrants risk of exposure; particularly if the migrants have spent a considerable amount of time away from their country of birth or if the incidence of TB has been changing rapidly in the country of birth.

Models of the association between TB incidence in the country of birth and the incidence of TB in migrants have the potential to provide an alternative means of validating national TB notification data. WHO smear-positive case notification rates were highly correlated with the rate of TB in Australia among migrant groups, although most notably, smear-positive notification rates for Indonesia did not predict the rate of TB in Australia as closely as Dye et al.'s estimates [7]. Discrepancies between the estimated incidence of TB [7] and WHO notification rates [6] also indicate that WHO case notifications are not a good indicator of the burden of TB in all countries.

Our analysis indicates that socioeconomic conditions are likely to be an important factor underlying TB incidence, and are in part incorporated in indicators of TB incidence. The inclusion of GNI in both WHO case notification models is also likely to indicate particular difficulties in obtaining accurate notification data in resource-poor settings. The influence of GNI was accounted for more fully in the estimates of Dye and co-workers [7], although after controlling for the likely exposure to TB in the country of birth, the level of unemployment among overseas-born persons in Australia was also an important correlate of TB incidence in migrants in Australia at an ecological level. Exploration of the associations among independent variables in this analysis found *per capita* GNI of the country of birth to be highly related at a group-level to unemployment among migrants in Australia. The important influence of socioeconomic factors on the incidence of TB at an ecological level has also been described in other low-incidence countries [13], and is consistent with evidence on the association between TB and indicators of poverty [14].

South Africa was excluded from the analysis due to the unusually high level of discrepancy between the characteristics of migrants to Australia and those of the South African population [15] associated with self-selection for migration. The majority of migrants to Australia from South Africa are white and have a high level of education. As such, the incidence of TB in South Africa is a poor indicator of the level of exposure to *M. tuberculosis* among South African migrants to Australia. The spread of HIV has also had a major influence on the incidence and distribution of TB in South Africa, having a devastating effect on the black population [16]. We acknowledge that a number of selection factors will determine the composition of migrant populations. Unfortunately the influence of various selection factors on the incidence of TB is frequently difficult to determine. Although selection factors for migration often tend to favour younger and healthier migrants, the strong association between estimates of the rate of TB in the country of birth and the rate of TB among migrants in Australia indicates that many common selection factors for migration may be reasonably independent of exposure to *M. tuberculosis* across a large number of countries.

Problems associated with ecologic analysis limit the conclusions that can be drawn from this investigation. Group-level indicators of TB incidence and socio-demographic characteristics are not representative of all individuals in each group, and there is likely to be considerable heterogeneity within country-of-birth groups. Groups are also unlikely to be homogenous with respect to confounders, although we have been unable to identify a confounder that would explain the significant association between the incidence of TB in migrants in Australia and in the country of birth. The use of crude estimates of TB incidence in this analysis may also introduce some error into the analysis due to the different age structures of the populations being compared.

Our results have quantified a previously documented phenomenon, and indicate that routine data collected on the incidence of TB worldwide can be used to estimate the relative group-level risk of TB among country-of-birth-specific migrant groups with reasonable precision. Australia's TB profile is becoming increasingly dependent upon the influences of immigration, and TB among migrants from high-incidence countries is becoming the predominant contributor to the TB burden in many low-incidence countries. Under these circumstances an ecologic approach to tuberculosis control, which uses group-level predictive factors to identify groups at high risk of TB, appears to have considerable public health potential.

Low-incidence countries that receive migrants from countries with a high incidence of TB should consider the importance of country of birth in the design of screening policy. Ecologic data can provide a valid basis for group-level interventions which can direct targeted screening programmes, preventive therapy, educational programmes and other control strategies to country-of-birth-specific migrant populations at high risk of TB. As most cases of TB among migrants to low-incidence countries are a result of latent infection acquired prior to migration [3], efforts to decrease the current rate of TB among migrants must directly address the problem of latent infection as well as active disease among high-risk groups. This requires an active approach that extends into the post-migration period and includes interventions designed to facilitate the early detection of disease and prevention of disease transmission among high-risk groups. Focusing of these strategies on high-risk country-of-birth-specific migrant groups appears to provide the greatest potential to enhance the effectiveness of TB prevention and control strategies in low-incidence countries. Ultimately, a global approach to TB control with particular attention to improved TB control programmes in countries with high rates of TB is required. Investing in such programmes could benefit both original and destination countries.

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