# Tuberculosis in the context of changing social determinants

TB-MAC meeting

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Centre international de TB McGill

McGill International TB Centre

# Overview of talk

- Ecologic analysis of TB trends and population health/health service indicators
- Describe the development of a TB transmission model that includes an indicator that captures changes in "population health"
- Application of the model to the setting of Peru
- Discuss the importance of including SDs in models in other contemporary settings

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# Global tuberculosis trends: a reflection of changes in tuberculosis control or in population health?

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Objective: To explore determinants of modern TB trends including TB specific and more general health and health service indicators (vaccine coverage etc)

# Methods:

- Ecologic analysis (country level data for 160 countries)
- Examined the association between modern changes in TB incidence and concomitant changes in general health and health service indicators
- Key independent variables: life expectancy, measles vaccination levels and under 5 mortality, HIV prevalence
- Univariate and multiple linear regression

# Results:

- Improvements in population health and health services were statistically significantly associated with improvements in TB outcomes

In adjusted analyses:

- increase in life expectancy was associated with a decline in TB incidence
- decrease in mortality rate in children under 5 was associated with a decrease in TB incidence
- increase in measles vaccination coverage (serving as a general health services indicator) was associated with a decrease in TB incidence.

- HIV prevalence was strongly associated with an increase in TB incidence in all models

- Improvements in treatment success were only associated with a decrease in incidence in lower HIV prevalence countries

# Trends in tuberculosis incidence and their determinants in 134 countries

C Dye,[a] K Lönnroth,[a] E Jaramillo,[a] BG Williams[a] & M Raviglione[a]

**Objective** To determine whether differences in national trends in tuberculosis incidence are attributable to the variable success of control programmes or to biological, social and economic factors.

**Methods** We used trends in case notifications as a measure of trends in incidence in 134 countries, from 1997 to 2006, and used regression analysis to explore the associations between these trends and 32 measures covering various aspects of development (1), the economy (6), the population (3), behavioural and biological risk factors (9), health services (6) and tuberculosis (TB) control (7).

**Findings** The TB incidence rate changed annually within a range of ±10% over the study period in the 134 countries examined, and its average value declined in 93 countries. The rate was declining more quickly in countries that had a higher human development index, lower child mortality and access to improved sanitation. General development measures were also dominant explanatory variables within regions, though correlation with TB incidence trends varied geographically. The TB incidence rate was falling more quickly in countries with greater health expenditure (situated in central and eastern Europe and the eastern Mediterranean), high-income countries with lower immigration, and countries with lower child mortality and HIV infection rates (located in Latin America and the Caribbean). The intensity of TB control varied widely, and a possible causal link with TB incidence was found only in Latin America and the Caribbean, where the rate of detection of smear-positive cases showed a negative correlation with national incidence trends.

**Conclusion** Although TB control programmes have averted millions of deaths, their effects on transmission and incidence rates are not yet widely detectable.

*Une traduction en français de ce résumé figure à la fin de l'article. Al final del artículo se facilita una traducción al español.* الترجمة العربية لهذه الخلاصة في نهاية النص الكامل لهذه المقالة.

ematical modelling suggests that such wide variation should be accompanied by a substantial and measureable difference in incidence (e.g. an increase in the detection rate of smear-positive cases from 42% to 82% should correlate with a decrease in incidence).[22] Thus, we conclude that TB diagnosis and treatment programmes, pre- or post-DOTS, have not yet become the principal determinants of TB transmission and incidence trends, though they may do so in the future. Recent trends in TB incidence are, by contrast, more strongly associated with biological, social and economic determinants that differ among countries and regions. The regional differences explain why only three general measures of development were dominant worldwide: the human development index, child mortality and access to improved sanitation.

TB incidence in most countries appears to be declining slowly. Few

# Implications

- Population health may be important in shaping modern TB trends

- This parameter should be included in models of TB prevention:
  - To enhance accuracy of model predictions
  - And quantify the contribution of population health to TB prevention

# The Challenge!

- Build a TB transmission model that incorporates changing "population health"
- Choose the best proxy for population health- meant broadly to capture background social determinants
- Be sure that there is data available for the indicator over multiple time periods and across different geographic locations
- Be sure that there is useful TB outcome data for these same time periods and locations
- Validate the model and apply it in different settings

# Developing a Tuberculosis Transmission Model That Accounts for Changes in Population Health

*Olivia Oxlade, MSc, Kevin Schwartzman, MD, MPH, Andrea Benedetti, PhD, Madhukar Pai, MD, PhD, Jody Heymann, MD, PhD, Dick Menzies, MD, MSc*

Objective: "To develop and validate a TB transmission model [using decision analysis] that explicitly incorporates a) a dynamic risk of TB infection and b) the changing general health of a population"

(Medical Decision Making 2011;31:53–68)

# Methods:

- Deterministic decision tree model with a cohort structure (TreeAge® Professional 2009)
- Markov state-transition model developed to predict outcomes of an untreated TB epidemic in a period of improving population health

General steps in model development:

Parameterization

⬇

Fitting/Calibration using observed data set

⬇

Validation using different observed data set

⬇

Sensitivity analysis

# Methods:

- **Model setting:** Western Europe, pre-antibiotic era (ie. 1901-1949)
- **Model Development**: data from England and Wales
- **Model Validation:** data from the Netherlands
- **Application of Model:** modern setting of Peru (where a good TB control program was implemented in the 1990s, and accurate data from 1980 until 2005 is available)

## Key Inclusions in Model:

1) Transmission from both smear positive and smear negative active TB cases- captured on a population level to generate a dynamic annual risk of TB infection

2) Changing background population health

# Incorporating changing background population health:

To incorporate population health we needed an indicator that captured changes in the "health and well being of groups of individuals"

Indicator selected: **life expectancy from birth**

Selected as a proxy because:

- Detailed year by year data were available for more than 40 years in the relevant period in both the UK and Netherlands;
- Data are available from all countries nowadays – allowing application of the findings to modern settings
- It is considered a valid indicator of general health, e.g. the World Bank, states *"changes in life expectancy reflect changes in the overall health of a country's population, in people's living conditions (environmental, economic, social) and in the quality of health care"* (Soubbotina, 2004)

# Incorporating changing background population health:

We adjusted life expectancy for TB mortality

Once adjusted- the ratio between the rate of increase in LE and the rate of decline in TB infection was used to estimate the concomitant change in five key TB pathogenetic parameters:

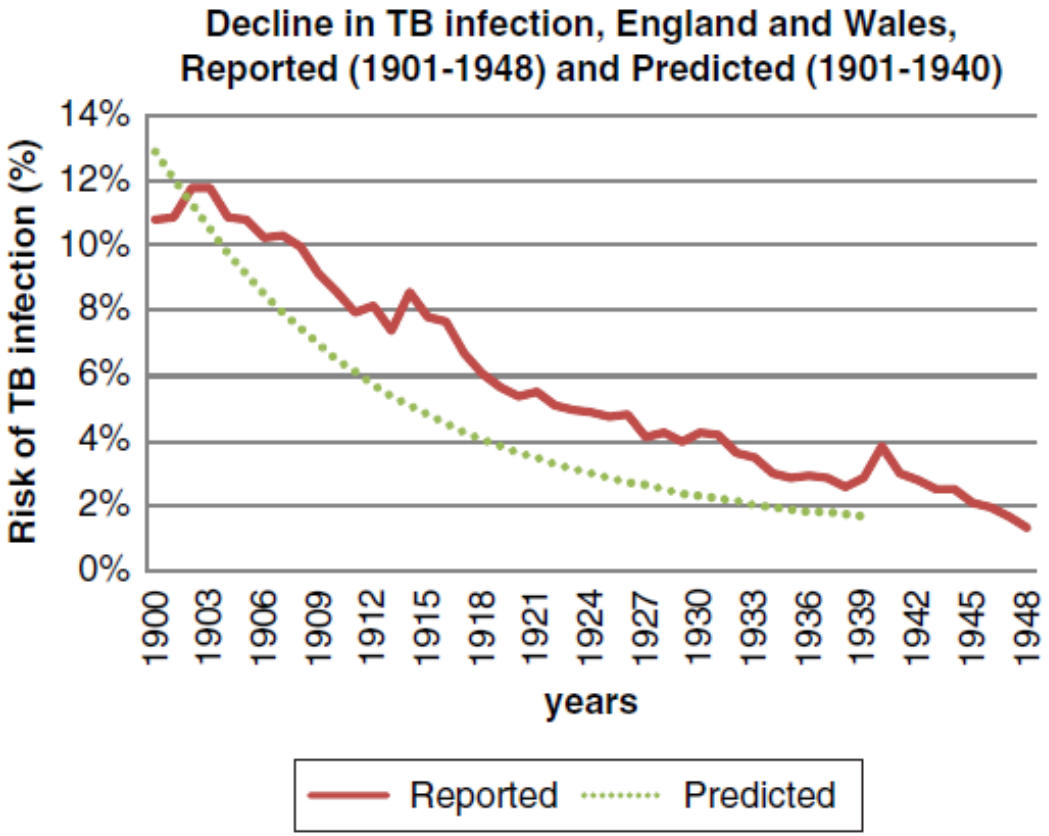
1) reactivation rate (from long standing infection)

2&3) progression rate after initial or re-infection

4&5) infectivity of smear positive and smear negative active cases

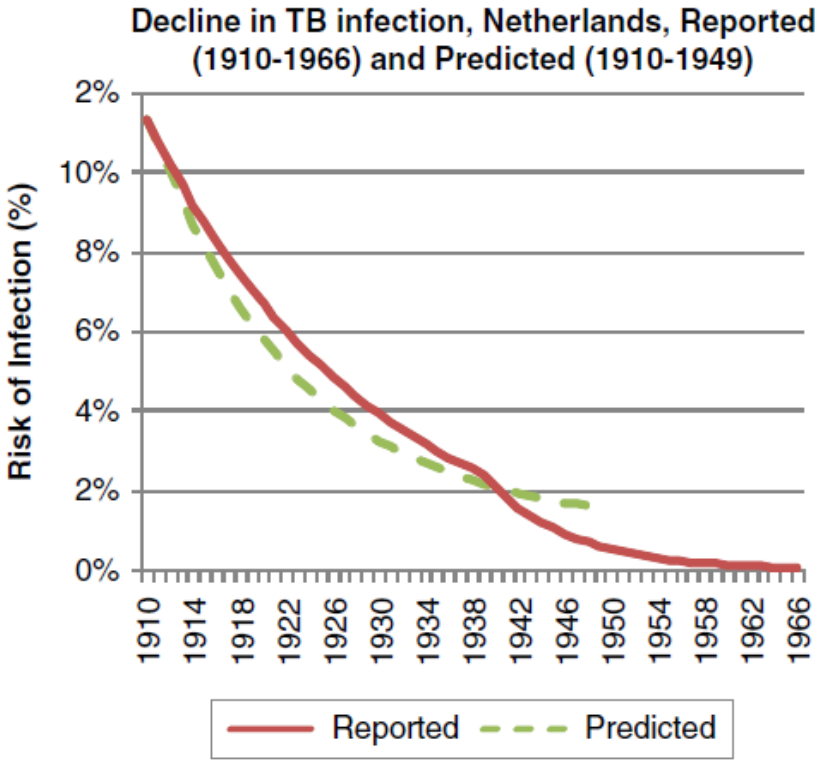
# Results- Western Europe in Pre-antibiotic era

- Model Developed in setting of England and Wales



# Results- Western Europe in Pre-antibiotic era

- Predicted TB annual risk of infection and mortality in the Netherlands accurately



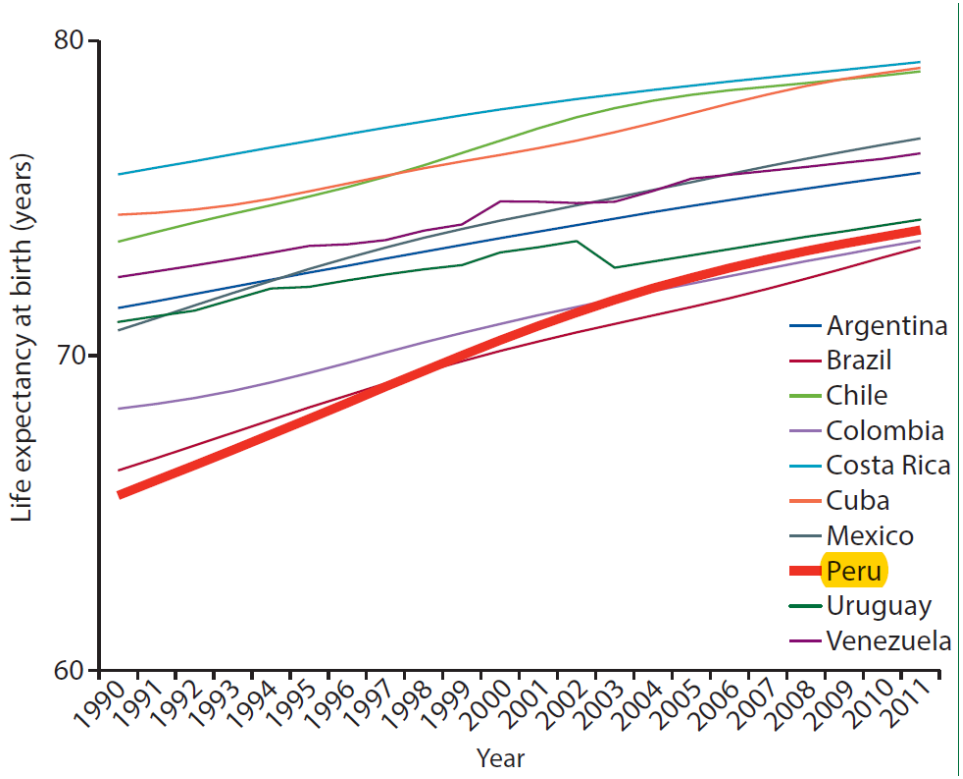
# Peru Models

# PERU: Life expectancy by year

Universal health coverage in Latin America 1

## Health-system reform and universal health coverage in Latin America

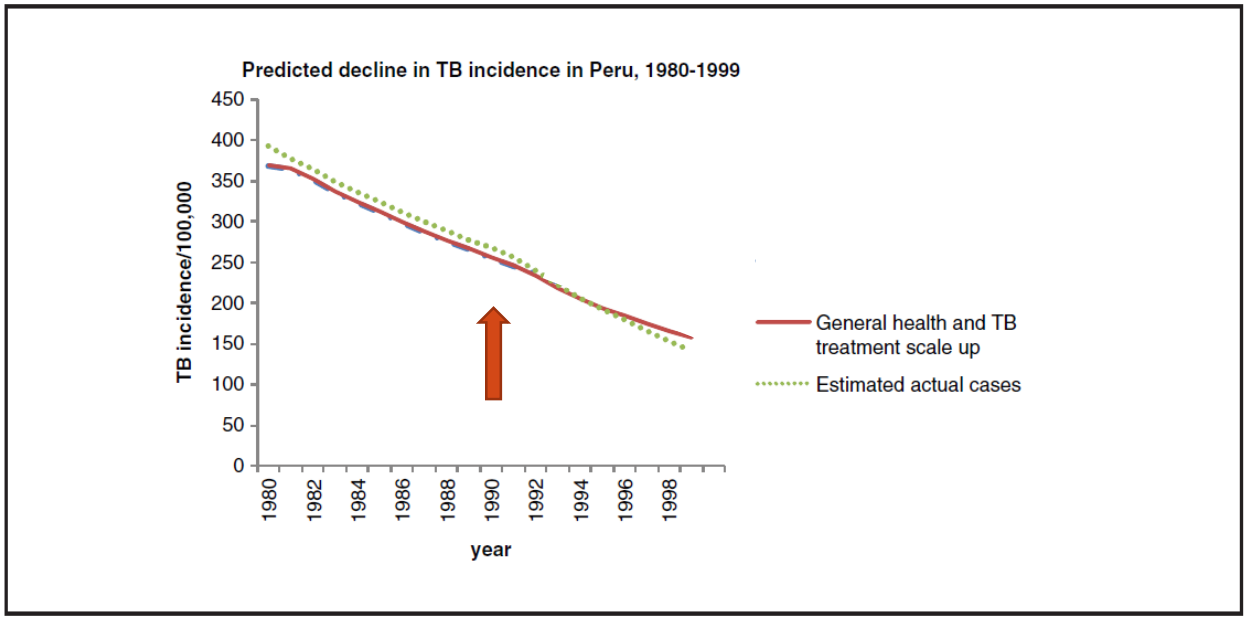
Rifat Atun, Luiz Odorico Monteiro de Andrade, Gisele Almeida, Daniel Cotlear, T Dmytraczenko, Patricia Frenz, Patrícia Garcia, Octavio Gómez-Dantés, Felicia M Knaul, Carles Muntaner, Juliana Braga de Paula, Felix Rígoli, Pastor Castell-Florit Serrate, Adam Wagstaff



# Results

- When the model was re-calibrated and applied to Peru the predicted decline in incidence *prior to the expansion* of the DOTS strategy was 3.7%/year (vs. observed of 3.9%/yr)

- Post DOTS expansion (ie. TB treatment scale up post 1990), the predicted decline in TB incidence was 5.7%/yr - very similar to the observed decline of 5.8%/yr



# Results-Peru

- Estimated the rate of decline in the ***absence*** of treatment scale up (ie. with improving population health only)
  - decline in incidence with improved population health alone=4.0%/yr
- Suggests that improvements in general health may have been responsible for approximately 70% of the total decline in TB incidence between 1990-1999

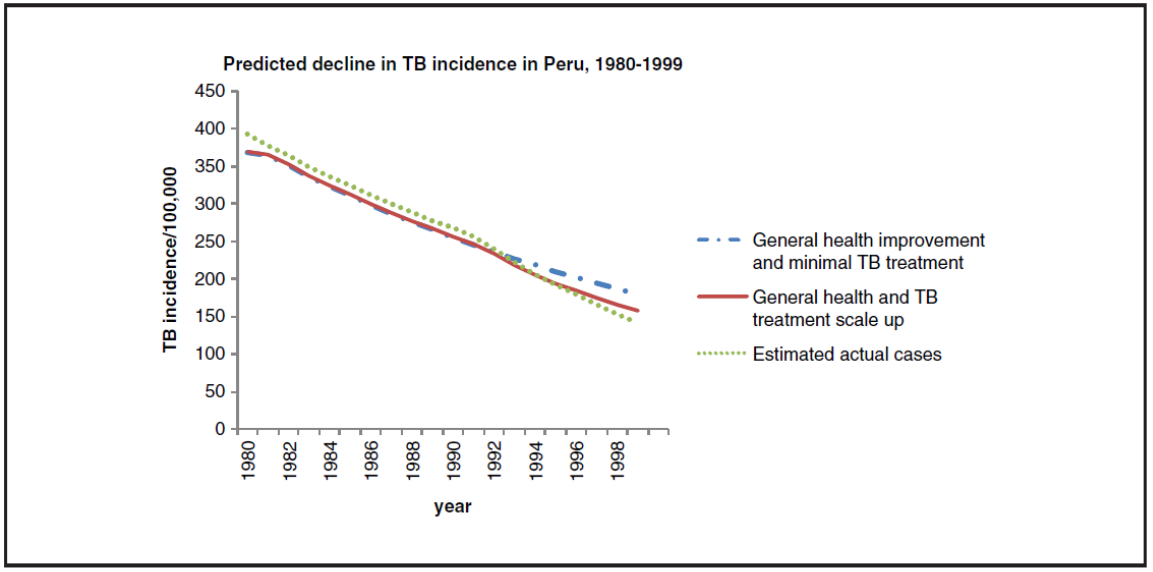



*Figure 7 Predicted decline in tuberculosis (TB) cases, with observed improvements in general health and no change in treatment or with the same improvements in general health plus observed improved treatment outcomes after introduction of DOTS in 1990.*

# Implications of findings

- Models that incorporated population health (using life expectancy as a proxy) could accurately predict TB outcomes such as TB infection

- In the setting of Peru, where there were concomitant improvements in population health and DOTS expansion, models predicted that improved population health could have been responsible for much of the observed gains in TB outcomes

What about other settings where social determinants are important (and changing)?

# Determinants of tuberculosis trends in six Indigenous populations of the USA, Canada, and Greenland from 1960 to 2014: a population-based study

*Kianoush Dehghani, Zhiyi Lan, Peizhi Li, Sascha Wilk Michelsen, Sean Waites, Andrea Benedetti, Pierre Lejeune, Jill Torrie, Elizabeth Robinson, Berenica Vejvoda, Muhammad Mullah, Diana Redwood, Michael Cooper, Anne Fanning, Wadieh Yacoub, Gonzalo G Alvarez, Bolette Søborg, Richard Long, Dick Menzies*

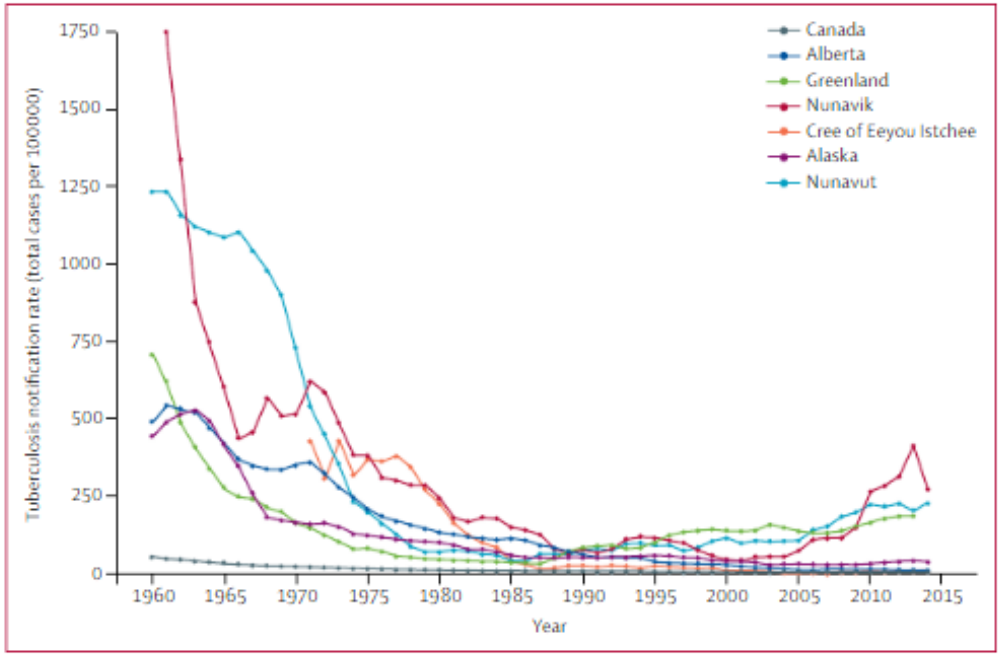
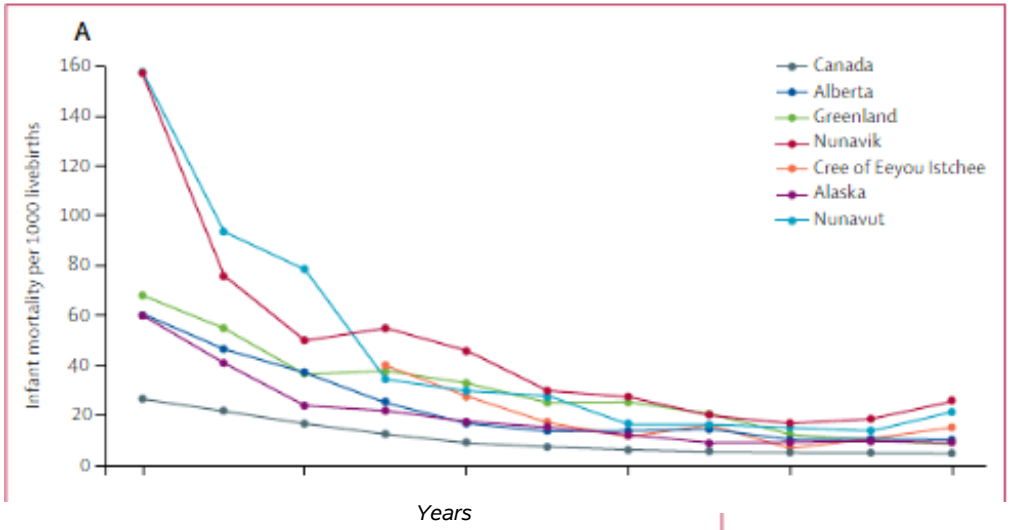


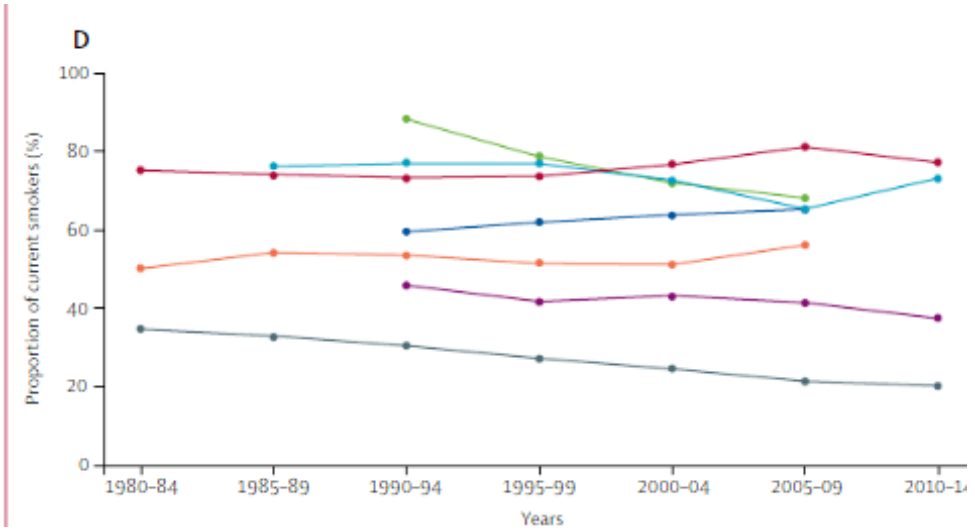

*Figure 1:* Tuberculosis notification rates (per 100 000 population) from 1960 to 2014 in six Indigenous populations and the general population of Canada

Declining tuberculosis notification rates were significantly associated with increased life expectancy and decreased infant mortality in all six Indigenous populations

# Indicators over time in Indigenous populations




Infant mortality rate over time, in 6 indigenous populations




Proportion of current smokers over time, in 6 indigenous populations

© International Epidemiological Association 2002 Printed in Great Britain International Journal of Epidemiology 2002;31:940–945

# The association of housing density, isolation and tuberculosis in Canadian First Nations communities

Michael Clark,[a] Peter Riben[a] and Earl Nowgesic[b]

**Table 3** Tuberculosis (TB) notification rate (per 100 000) and 95% CI, by strata of community housing density (1997–1999)

| ppr[a] (1996) | Person-years (1997–1999) | TB incidence, per 100 000 (1997–1999) and 95% CI |
|---|---|---|
| 0.4–0.6 | 227 415 | 18.9 (13.3–24.6) |
| 0.7–0.9 | 420 066 | 39.0 (33.1–45.0) |
| 1.0–1.2 | 140 733 | 113.0 (95.4–130.5) |
| 1.3+ | 11 073 | 225.8 (137.3–314.3) |
| Overall | 799 287 | 48.9 (44.1–53.7) |

[a] Average persons per room.

# Key messages

1) The "general health" of the population captures important background social determinants which are key contributors to modern TB trends, as was the case in the pre-antibiotic era

2) "General health" may be especially important to take into account in models in settings where social determinants are changing

3) Their effect could counter, or enhance, ongoing TB prevention efforts and thus should be explicitly taken into account when evaluating and modeling TB prevention efforts