Universiteit Utrecht

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WHO Commission on Social Determinants of Health

Comments from a mathematical modeller of infectious diseases and demography

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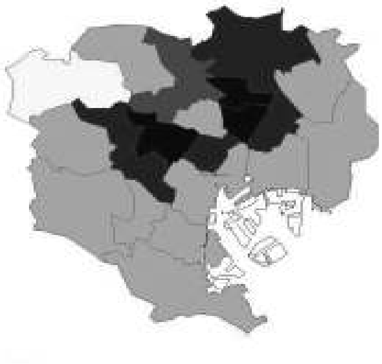
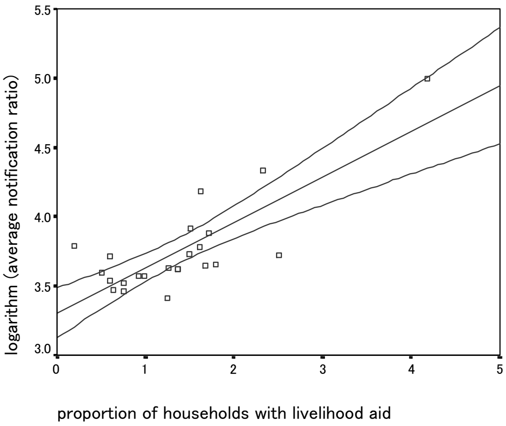
Introduction

Tuberculosis in Tokyo megacity





Nishiura H. Socioeconomic factors for tuberculosis in Tokyo, Japan –The effect of unemployment, overcrowding, poverty, and migrants. Kekkaku 2003; 78: 419-426

A critical question from my friend

"Okay, tuberculosis is associated with poverty, unemployment, and overcrowding. But what can you do about it?"

↓

I continued to work on other epidemiological studies of infectious diseases (with more of a theoretical and mathematical focus)

Three remarkable aspects of the CDSH final report

1. Inequality is discussed in a global context, emphasizing a need for comparisons both within and between countries.

2. Gender equity is explicitly documented and well discussed.

3. The web of causality in many diseases is considered

Critical view

1. **Lacking specific policies** with which we can be confident to achieve desired results

2. **Sharing evidence** will be particularly important from epidemiological standpoint

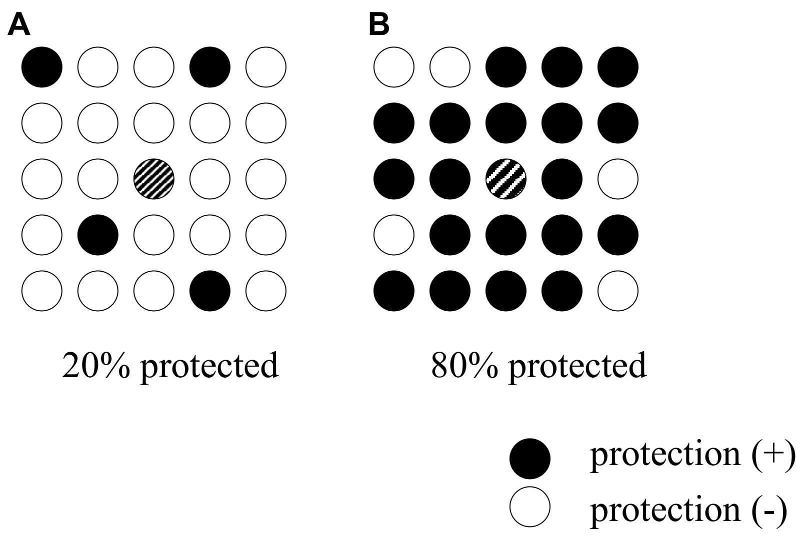
Rather than being too specific, two critical issues are discussed, in relation to the contents in Chapters 16 & 17.

Specific comment 1:

Chapter 16. Monitoring & Research

The immaturity of social epidemiology poses problems in
(i) identifying and accumulating **evidence**,
(ii) methodologically considering the **measurements of health**, and
(iii) motivating **data collection** on social equity through a recommended surveillance system.

A simple example



pp. 181: *"...with more complex measure of health inequity (such as the relative index of inequality)"*

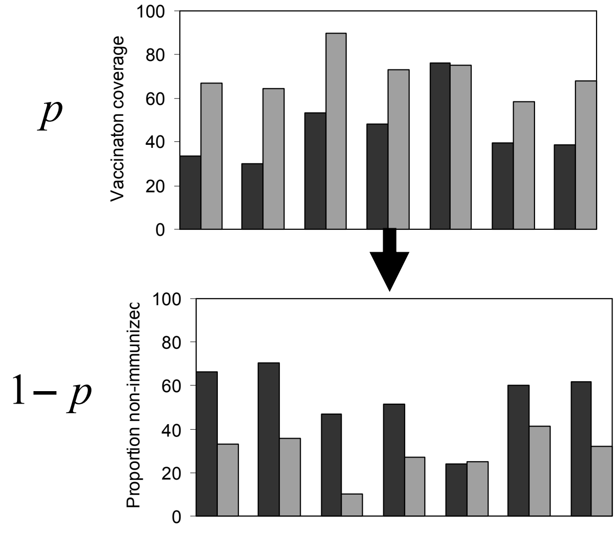
In infectious disease epidemiology

Let the effective reproduction number (i.e. the average number of secondary cases generated by a single primary case) be *R*, and we observe

$$a + aR + aR^2 + aR^3 + \cdots + aR^n = \frac{a}{1-R}$$

Only by transforming the observed data into *R* can a valid comparison between the social factor and transmission be made.

Rather than directly comparing coverage, non-immunized fraction should be compared



because

Under vaccination (with coverage *p*), case series is replaced by

$$a + aR_v + aR_v^2 + aR_v^3 + \cdots + aR_v^n = a\frac{1-R_v^{n+1}}{1-R_v}$$

The fraction unimmunized (1-*p*) directly influences the reproduction number, and the reduction in the number of cases which occurs in the *n*-th generation is equal to the reduction in the first generation to the power of *n*.

Nishiura H, Dietz K, Eichner M. The earliest notes on the reproduction number in relation to herd immunity: Theophil Lotz and smallpox vaccination. J Theor Biol 2006; 241: 964-967.

Specific comment 2 (pp. 197):

Part 6. Building a global movement

Target 1: Reduce by 10 years, between 2000 and 2040, the **LEB gap** between the one third of countries with the highest and the one third of countries with the lowest LEB levels

Target 2: Halve, between 2000 and 2040, **adult mortality rates** in all countries and in all social groups within countries.

Target 3: Reduce by 90%, between 2000 and 2040, the **under-5 mortality rate** in all countries and all social groups within countries.

If the desired results are achieved through policy actions, we will observe a considerable number of rapidly growing populations around the world.

In a stationary population,

Critical coverage of mass vaccination p for eradication is

$$c > p = \frac{1}{\varepsilon}\left(1 - \frac{1}{R_0}\right)$$

ε, efficacy ($0 < \varepsilon < 1$); R_0, basic reproduction number

Example: Measles
$\varepsilon = 0.98$, $R_0 = 15$

$$p = \frac{1}{0.98}\left(1 - \frac{1}{15}\right) = 0.952$$

Smith CE. Factors in the transmission of virus infections from animal to man. Sci Basis Med Annu Rev 1964; 125-150.

However, in a growing population,

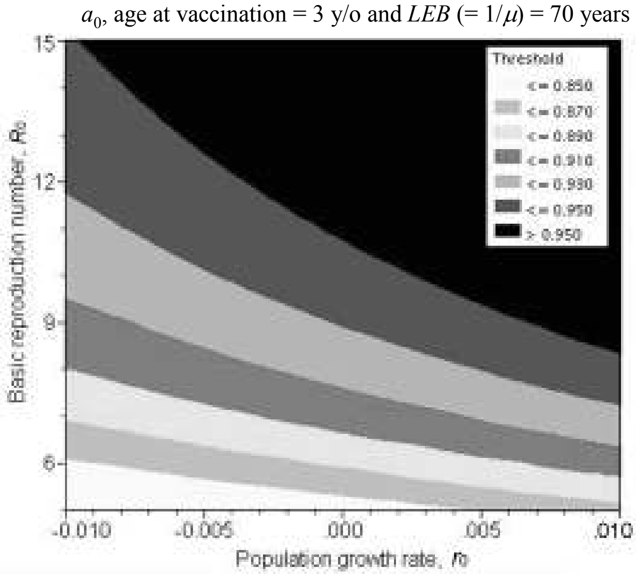
$$c > p_g = \frac{1}{\varepsilon}\left(1-\frac{1}{R_0}\right)\frac{1}{\exp(-(r_0+\mu)a_0)} \gg p$$

ε, efficacy ($0 < \varepsilon < 1$); R_0, basic reproduction number
r_0, population growth rate, μ, natural mortality rate
a_0, age at vaccination

A rapid demographic transition caused by closing the gap of mortality in a generation will increase the susceptible fraction of the population, and consequently elevate the eradication threshold of an infectious disease

Inaba H, Nishiura H. The basic reproduction number of an infectious disease in a stable population: The impact of population growth rate on the eradication threshold. Math Model Nat Phenom 2008; 3: 194-228.

a_0, age at vaccination = 3 y/o and *LEB* (= $1/\mu$) = 70 years



Inaba H, Nishiura H. The basic reproduction number of an infectious disease in a stable population: The impact of population growth rate on the eradication threshold. Math Model Nat Phenom 2008; 3: 194-228.

Finding

Extremely high mass vaccination coverage at an early age would be required to control childhood vaccine-preventable diseases in the growing population.

When we take aim at closing the health gap within a generation, the population growth rate would have to be extremely high.

McLean AR, Anderson RM. Measles in developing countries. Part I. Epidemiological parameters and patterns. Epidemiol Infect 1988; 100: 111-33.
Inaba H, Nishiura H. The basic reproduction number of an infectious disease in a stable population: The impact of population growth rate on the eradication threshold. Math Model Nat Phenom 2008; 3: 194-228.

Summary of specific comment 1

1. Without being specific about the necessary evidence, and without fundamental improvements in social epidemiological studies, data collectors will not be **effectively motivated** to conduct equity surveillance.

2. The situation of **limited evidence in presenting appropriate policy actions** was discussed. Fundamental pitfalls in data analysis were also mentioned.

Summary of specific comment 2

In any case, reducing health inequities will **accelerate demographic transitions**. A mathematical model was employed to consider an increase in the eradication threshold of vaccine-preventable diseases in a growing population. In particular, the importance of **predicting the negative impacts of social equality** on health has been emphasized, and I point out the need to put in place countermeasures against those adverse events.