Z_Annex_2

HIV indicators - natural course of an HIV epidemic or results of sociobehavioral changes? What metric to gauge progression of epidemics ? A review of common indicators used and proposal for a new metric

Importance of choosing a correct indicator

Indicators to gauge effectiveness of programme implementation vs. indicators to compare different epidemics (epidemics across countries in different contexts, or simply different sub-populations within the same epidemic)

Difficulty in choosing a basic HIV indicator to compare HIV epidemics across countries and across time

What HIV indicators should we use to compare the epidemics across countries & what HIV indicators give us a sense of where the epidemic is?

HIV incidence:

- Expectation: Lower numbers of new HIV infections per year is a good sign
- Contextualization: HIV incidence depends on multiple factors and cannot be directly compared across countries or time
- Example: Country A has a slightly higher HIV incidence than country B, but country A has 100% higher HIV prevalence than country B, how can we tell which is better in terms of the HIV epidemic?

HIV prevalence:

- Expectation: Lower HIV prevalence means less people living with HIV and should be a good sign
- Contextualization: HIV prevalence depends on both new HIV infections and mortality of HIV/AIDS patients making it difficult for direct comparison
- Example: Take again country A with 100% higher HIV prevalence than country B, but country A has very little HIV/AIDS mortality thanks to widespread use of ART while country B has very little use of ART and relatively high HIV mortality. Again how can we tell which is better?

HIV mortality:

- Expectation: Lower HIV mortality means less people are dying of HIV/AIDS
- Contextualization: HIV mortality is depends on HIV prevalence and ART coverage
- Example: Country A above has little HIV/AIDS mortality for its HIV prevalence, but country B has similar HIV mortality simply because HIV prevalence is low

A very simple compartmental model for HIV

SID model:

Of course many simplifying assumptions are made here (that are not correct in real life):

- No births (but we focus on 15-49 population anyways)
- No deaths other than HIV/AIDS related deaths (this can probabbly be hedged)
- Binary infectious status based on ART
- etc (anything not specifically discussed below is assumed not to exist..)

S –> Susceptible state: An S individual is simply someone susceptible to the disease, meaning anyone in the population who is not immune to the disease.

I –> Infectious state: Once an individual is exposed to the disease, he will become infectious (unless suppressed with ART).

D –> Death state: HIV infections eventually become AIDS and lead to death (unless suppressed with ART).

SID compartmental model disease dynamics

S → I

Individual-level Going from S to I for an indivudal in a particular year depends on three things:

- the proportion of infectious people in the population that year:

$$i(t) = Prevalence$$

Although with ART the equation may become:

$$i(t) = (1 - ART_{coverage}) * Prevalence$$

- the number of exposure events the individual has per year (this means number of drug injections, number of sexual partners, etc etc):

$$r$$

- the chance for an S to contract the disease after such an exposure event :

$$\rho$$

which combines many factors into one, including:

- Male circumcision
- Use of condoms
- Other STDs
- Use of $PrEP$
- It can also incluse $ART_{coverage}$ (if not already included above)
- and so on..

We can combine the last two into

$$\beta = \rho * r$$

Population level On a population-level however, the number of S that will become I also depends on the proportion of S itself in the population (obviously if there are no S in the first place, no one will can become I).

Note, any factor impacting susceptibility of an individual ($PrEP$, condom use, etc) is already factored into β.

So we add the following requirement:

- the proportion of susceptible people in the population that year:

$$s(t) = 1 - HIV_{Prevalence}$$

So the change in the number of S in a population in a given year is :

$$-\beta * i(t) * s(t)$$

and so HIV incidence can be given by:

$$HIV_{Incidence} = \beta * i(t) * s(t)$$

$$\iff HIV_{Incidence} = \beta * HIV_{Prevalence} * (1 - HIV_{Prevalence})$$

or if we take into account $ART_{coverage}$ separately:

$$\iff HIV_{Incidence} = \beta * (1 - ART_{coverage}) * HIV_{Prevalence} * (1 - HIV_{Prevalence})$$

A new HIV indicator to compare across countries

As we have data from UNAIDS on $ART_{coverage}$, $HIV_{Incidence}$, and $HIV_{Prevalence}$ from 1990 on, we can easily calculate this β as follows:

$$\beta = \frac{HIV_{Incidence}}{HIV_{Prevalence} - HIV_{Prevalence}^2}$$

$$or$$

$$\beta = \frac{HIV_{Incidence}}{(1 - ART_{coverage}) * (HIV_{Prevalence} - HIV_{Prevalence}^2)}$$

And from the description above, β can be a proxy factor representing all socio-behavioral characteristics.

The raw number of new infections in a given year is

$$\text{New infections[n]} = \beta[n] * \frac{I[n]}{N[n]} * S[n]$$

where:

- $S[n]$ = number of susceptible in given year
- $I[n]$ = number of infected in given year
- $N[n]$ = total population in given year
- $\beta[n]$ = effective contact rate

But the data I have (from UNAIDS) gives $HIV_{Incidence}$ in "per 1000" so:

$$HIV_{Incidence}[n] = \text{New infections[n]} * \frac{1000}{N[n]}$$

$$\iff HIV_{Incidence}[n] = \beta[n] * \frac{I[n]}{N[n]} * \frac{S[n]}{N[n]} * 1000$$

- $\frac{I[n]}{N[n]} = HIV_{Prevalence}$ is the prevalence that I have from UNAIDS as a proportion (from 0 to 1)
- $\frac{S[n]}{N[n]} = 1 - \frac{I[n]}{N[n]} = 1 - HIV_{Prevalence}$ (same from 0 to 1 depending on above)

I let β absorb the factor of 1000 and I end up with:

$$\beta = \frac{HIV_{Incidence}}{HIV_{Prevalence} * (1 - HIV_{Prevalence})}$$

Example:

2 countries with same $\beta = 10^{-3}$ and $HIV_{Prevalence} = 20\% = 0.2$ but different total populations:

- Country A has population $N_A = 10^9$
- Country B has population $N_B = 10^5$

New infections:

- Country A then has $10^{-3} * 0.2 * 0.8 * 10^9 = 1.6 * 10^5$ new infections
- Country B then has $10^{-3} * 0.2 * 0.8 * 10^5 = 16$ new infections

Incidence in "per 1000":

- Country A has $1.6 * 10^5 * \frac{10^3}{10^9} = 0.16$
- Country B has $1.6 * 10^1 * \frac{10^3}{10^5} = 0.16$