Estimating HIV prevalence in sub-Saharan Africa: a brief story of a measure

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1980
emergence of an epidemic
1980
Several gay men in Los Angeles are suffering from immune deficiency.

1981
US physicians decide to call this disease Acquired Immune Deficiency Syndrome (AIDS).

1983
First numbers published by WHO: 153 cases diagnosed in 14 different European countries.
October 1985
First WHO workshop on AIDS in Africa in Bangui.
Only 9 countries represented.
(Burundi, Cameroon, Congo, Gabon, Uganda, Tanzania, Rwanda and Zaïre).

March 1986
New WHO workshop in Africa.
41 countries represented.
Only 7 declared AIDS cases.

November 1986
First African data published by WHO.
1069 AIDS cases reported in Africa,
i.e. only 3.1 % of the 34,448 cases in the World.
To be notified, AIDS cases require that:

• infected people are seen by a physician,
• are correctly diagnosed,
• the case is reported to Ministry of Health,
• Ministry of Health transmit numbers to WHO.

AIDS cases are inadequate to describe African epidemics.

In 1992, only **10 to 30 %** of individuals with AIDS were diagnosed in Africa. This proportion was still estimated by WHO to be **15 %** in 1997.
late 1980’s
HIV testing and sentinel surveillance
1985
With the first HIV tests, new surveys are designed for a new measure: **HIV prevalence**.

1987
The Center for International Research (CIR) of US Census creates the **HIV/AIDS Surveillance Database**. All results published or submitted to a conference are collected in a unique database.
Late 80’s

- variety of survey designs
- variety of populations (general population, specific sub-groups)
- variety of coverage (local, regional or national)
- variety of sampling methods

Comparisons are difficult, or even impossible.
1988
WHO, within the Global Programme on AIDS, decides to formalize principles of a sentinel surveillance.

“The main purpose of sentinel serosurveillance is to detect changes – i.e. to monitor trends and to provide a basis for evaluating preventive strategies and activities. However, it should be pointed out that sentinel populations need not to be ‘representative’.”

Slutkin, Chin et al. 1988 WHO
Hull 1988 *JAMA* • survey in USA
HIV prevalence of 1.0% among 782 STI patients accepting to be tested
HIV prevalence of 5.4% among the 167 refusals

Jenum 1988 *NIPH Annals* • survey in Norway
4 HIV+ on 36’053 (0.011%) pregnant women accepting to be tested
1 HIV+ on 50 (2.0%) pregnant women refusing to be tested

“Large-scale population serosurveys demand considerable time and resources, and their results may be of limited accuracy because of serious problems arising from selection and participation bias. (...) WHO has therefore recommended the development of sentinel systems for routine public health surveillance of HIV infection.”

Chin, 1990, Bulletin of the WHO
WHO differentiates two kinds of test diagnosis

The objective is to determine with accuracy the status of someone.

public health surveillance

Identity of surveyed participants is not required, nor the exact status if false positives compensate false negatives.

For surveillance, WHO recommends an approach called Unlinked Anonymous Testing (UAS):

Testing blood samples obtained for another purpose after removing all nominative data.

⇒ No more refusal bias.

Pregnant women constitute an ideal population because a blood sample is taken during prenatal visit.
Number of sub-Saharan African countries with a sentinel surveillance survey among pregnant women by year

Source: Garcia-Calleja 2004 STI
1990’s
modelling epidemics to estimate national HIV prevalence
early 90’s
HIV is becoming a pandemic
→ Evaluation of the global situation and impacts of the infection is needed.

late 1991
The Global Program on AIDS publish *EpiModel*, a simple mathematical model using only one measure of prevalence at one date and a starting year of the epidemic to estimate HIV prevalence at 3-4 years.

late 1995
The WHO’s *Weekly Epidemiological Report* publishes the first worldwide estimates of HIV prevalence by country. For sub-Saharan Africa, they were calculated using *EpiModel* and data from sentinel surveillance among pregnant women.

→ Antenatal surveillance designed to measure trends, were used to estimate national levels.
1\textsuperscript{st} December 1995
creation of \textit{UNAIDS}

June 1998 & June 2000
HIV prevalence estimates by country are updated in UNAIDS Global Report, still using EpiModel.

1999

2000
Quality and quantity of sentinel surveillance surveys is decreasing. Rural areas are under-represented. Few socio-demographic data.
\Rightarrow \textit{UNAIDS} launches a \textit{second generation surveillance} initiative.
Number of sub-Saharan African countries with a sentinel surveillance survey among pregnant women by year

Source: Garcia-Calleja 2004 STI
2000-2001

**EPP**
- Not a mathematical model but a simple epidemiological one, estimating HIV prevalence among 15-49 year olds.
- The population is divided into 3 groups: not at risk, at risk and infected.
- Prevalence curve is determined by 4 parameters and adjusted on available data, i.e. pregnant women in sub-Saharan Africa.
- Usually, prevalence is estimated separately for urban and rural.
Parameters of EPP model (1/2)

Source: from Alkema 2007 CSSS University of Washington WP69
Parameters of the model limit the possible shapes of the curve.
June 2002
Estimates of the new UNAIDS Global Report were calculated using EPP.

2004
The new UNAIDS Global Report publishes estimates at two dates (end of 2001 and end of 2003) to indicate trends. A new software, *Spectrum*, was used to estimate impacts (deaths, infected children...) from EPP prevalence results.

2006
New version of EPP, including a procedure called *level fit* to take into account the extension of sentinel surveillance within rural areas (second generation surveillance).
2000’s comeback of national population-based surveys
2001
First Demographic and Health Survey (DHS) with HIV testing in Mali.

Demographic and Health Surveys (DHS)
International program of national population-based surveys, existing since 1984. Most developing countries are conducting a DHS every 4-8 years.

during the 2000’s
Increasing number of DHS with HIV testing. For a majority of countries, HIV prevalence measured by DHS were lower than estimates from antenatal clinics data.
Several sources, several figures...
Example of Burkina Faso

HIV prevalence (%) estimate published in UNAIDS Global Report
6.4
Date of estimate/measure
Date of publication

HIV prevalence (%) measured by DHS
1.8

Extension of sentinel surveillance to more rural antenatal clinics.
New assumptions for estimating HIV prevalence in rural areas.

2000 2001 2002 2003 2004 2005 2006
During the 2000’s, UNAIDS estimates have changed quite a lot between global reports. These changes result mainly from a change in estimation methods, not the underlying epidemiology.

- HIV prevalence didn’t decrease from 6.5% in 2002 to 2.0% in 2006. The epidemic has been overestimated before 2005.

**Which source is better?**

In DHS, non tested rate (refusals and absence) are not insignificant.

- underestimation

Prenatal sentinel surveillance is under-represented in rural areas.

- overestimation
measuring bias in DHS and prenatal surveillance
Impact of non response rate in DHS

Analysis on 9 DHS conducted in 2003-2005. Prevalence of non tested people was estimated using logistic regressions on variables from the individual and/or household questionnaires.

If predicted prevalence is significantly higher among refusals, no significant difference among absent individuals.

Source: Larmarange 2007, PhD
## Adjusting DHS

Taking into account 5 kinds of bias: serological window; population not living in an ordinary household (including refugees); population changes since the last census; non surveyed households and non tested individuals.

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<thead>
<tr>
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<tbody>
<tr>
<td>Observed national prevalence</td>
<td>1.77</td>
<td>5.44</td>
<td>6.88</td>
</tr>
<tr>
<td>95% Confidence Interval</td>
<td>1.49-2.11</td>
<td>5.00-5.91</td>
<td>6.27-7.54</td>
</tr>
<tr>
<td>75% Confidence Interval</td>
<td>1.59-1.96</td>
<td>5.18-5.71</td>
<td>6.51-7.27</td>
</tr>
<tr>
<td>Adjusted prevalence (high scenario)</td>
<td>1.86</td>
<td>5.84</td>
<td>7.16</td>
</tr>
<tr>
<td>Adjusted prevalence (low scenario)</td>
<td>1.82</td>
<td>5.43</td>
<td>6.55</td>
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Adjusted prevalence are included in 95% confidence interval. Impact of bias is smaller than uncertainty of the measure.

Source: Larmarange 2007, PhD
Local comparison of pregnant women and all women in general population

HIV prevalence

- Pregnant women in antenatal clinics
- Women in general population

Source: Gregson 2002 AIDS
Local comparison of antenatal clinics and general population (men and women)

HIV prevalence

- Pregnant women (antenatal clinics)
- General population (men + women)

Sources:
at local level
Prevalence observed among pregnant women underestimates prevalence of all women in the general population. Nevertheless, due to male prevalence being usually lower than female, observed prevalence in antenatal clinics is more or less the same than prevalence in adult general population (men and women).

at national level
Antenatal clinics for sentinel surveillance are not randomly selected. Although they might be an indicator of local levels, there is no guarantee that they will reflect national levels.
mapping regional trends of HIV prevalence from DHS
DHSs use similar stratified two-stage sample design.

Firstly, enumerations areas (or clusters) from the last census are selected according to their number of households.

Secondly, in each cluster, eligible households are sampled.

Most of DHSs provide coordinates of surveyed clusters.

The scatter plot of clusters reflects variations in population density.
Surveyed clusters in Burkina Faso 2003 DHS

Survey clusters by type
- urban (n=90)
- rural (n=310)
Estimating regional trends of HIV prevalence

The number of tested people by cluster (10 to 40 depending on the DHS) is too small to calculate a prevalence by cluster. Due to irregularity of spatial cluster distribution, classic smoothing techniques based on fixed bandwidth are not adapted to estimate spatial variations of prevalence.

We developed a method using kernel density estimators with adaptive bandwidth size of equal number of observed persons. We implemented this method in prevR, a bilingual R package available on CRAN: http://cran.r-project.org/web/packages/prevR/

Larmarange et al. (2011) Cybergeo. DOI: 10.4000/cybergeo.24606
Calculating the surface of observations

» Each dot represents a cluster.
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» For each cluster, a circle is drawn such that the number of persons surveyed within is at least equal to a fixed minimum N.
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» An intensity surface is generated with a bandwidth depending on its radius and a height proportional to the number of observations.
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» Where the clusters are widely dispersed, the circle is therefore larger.
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» The smoothing adapts to the local spatial distribution of the clusters.
Calculating the surface of observations

» An intensity surface is calculated for each cluster.
Calculating the surface of observations

» An intensity surface is calculated for each cluster.

» They are summed to produce an intensity surface of observed people.
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» The same process is used to calculate the intensity surface of positive cases, using the same bandwidths.
The ratio of the 2 surfaces (cases / observations) yields a prevalence surface.

This map doesn’t show accurate estimates of local prevalence, but regional trends.

Interpretation needs to take into account the variations of the smoothing circle radius.

Source: Larmarange et al. (2011) Cybergeo
local comparison of DHS and prenatal surveillance
Prevalence of 3.6% in antenatal clinics.

Only 0.7 to 1.2% in DHS.

Gold mining, seasonally migrant males and sex workers.

Peak not measured by antenatal data.

Source: Larmarange et al. (2011), Cybergeo
Although local estimates from antenatal clinics are sometimes close to regional estimates from DHS (usually for small cities), they can differ greatly.

**rural site of Kaya**

It corresponds to 3 rural clinics. In one of them, a high prevalence was measured (7.1%) while it was lower in the two others (1.6 and 2.4%). Estimated prevalence from DHS with a 60 km smoothing radius: 0.7 to 1.2%

**big cities: the example of Douala (Cameroon)**

In 2002, prevalence of 8.0% observed in 3 antenatal clinics: 3% (n=100), 6.5% (n=200) and 16% (n=100). DHS 2004: prevalence of 4.4% (n=931 – 43 clusters).

**Antenatal clinic estimates are very dependent on their catchment area.**
new EPP approach since 2005/2006
DHS

- Representative at national and regional level.
- Possible biases (underestimation) but limited.
- Sample size too small for local estimates.
- Conducted only every 5 to 10 years.

Sentinel surveillance in antenatal clinics

- Local indicator of the order of magnitude.
- Not representative at national level.
- Dependent on the clinics’ catchment area.
- Usually repeated every year.
- Data available since the 90’s

New approach used by EPP since 2005/2006

- Estimating the shape of the curve with antenatal data.
- Calibrating the curve using a population-based measure.
Calibrating the curve with a population-based measure

Data source: sentinel surveillance among pregnant women, by clinic

Fitting the curve to obtain its shape.

Population-based observed prevalence (usually from DHS) at a specific date.

Calibration: the DHS determines the height of the curve.
June 2006
UNAIDS Global Report estimates at end of 2005 integrates calibration using population-based surveys (if available).

June 2008

November 2010
For the first time, the Global Report is not published before the international AIDS conference. The Report is completed by online AIDS Info Database and Country Fact Sheets providing the complete estimated prevalence curves with confidence intervals.
issues and perspectives
Complex epidemics

With uptake of ART, prevalence curves are more complex. Possible shapes in EPP are limited and not able to fit complex trends like a second increase after a first decrease (as observed in Uganda).

The 2011 version of EPP allows the $r$ parameter (infection rate) to vary over time. The model is more flexible but uncertainty is higher.

Sub-group trends

In Western and Eastern Africa, while the epidemics are generalised, they are also concentrated in sub-groups (sex workers, men having sex with men or drug users...). There is a need of specific estimates in these sub-groups, but data gap in Africa.
Are antenatal data a good indicator of trends?
Antenatal surveillance currently used to estimate trends.
There may be differences in trends in antenatal clinics compared to DHSs.
Catchment area of clinics could change over time, for example when a PMTCT program is implemented in a clinic.

Regional trends
More and more countries need regional trends to adapt their strategies accordingly.

⇒ More frequent repeated DHS’s are needed.
Correcting estimates from DHS for non participation

A paper published in 2011 by Bärnighausen et al. compares correction for non participation in the 2007 Zambia DHS using classic imputation models (as models presented before) and Heckman-type selection models (trying to take into account unobserved factors).

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<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
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<tbody>
<tr>
<td>Observed prevalence</td>
<td>12 (11-13)</td>
<td>16 (15-17)</td>
</tr>
<tr>
<td>Adjusted prevalence (imputation model)</td>
<td>12 (11-13)</td>
<td>16 (15-17)</td>
</tr>
<tr>
<td>Adjusted prevalence (selection model)</td>
<td>21 (20-22)</td>
<td>18 (17-19)</td>
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</table>

Further analyses are currently ongoing by the UNAIDS Reference Group (on 30 DHSs) to investigate this issue, identify the best model and selection variables to use. Depending on results, implementation in EPP and Spectrum is planned for the 2013 round of estimates.
to conclude
UNAIDS estimates can’t be compared from one Global Report to another. Changes in estimates this last years are mainly explained by changes in methods rather than changes in the epidemiology.

For each new Global Report, the complete prevalence curve is re-estimated, giving trends.

Estimates are always imperfect, based on the available data. They should not be considered as a definitive fact. It’s also important to keep in mind the uncertainty of the estimates.

Finally, HIV prevalence is only one indicator, which needs to be considered with others like incidence or mortality.
thank you for your attention