Population Size Estimation

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Harare

Elizabeth Fearon, LSHTM
Sungai Chabata, CeSHHAR Zimbabwe
Frances Cowan, CeSHHAR Zimbabwe

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Agenda

Day 1: Overview of Population Size Estimation

**Morning**
- Introductions and objectives
- Overview of Population Size Estimation: rationale, approaches, key issues

**Afternoon**
- PSE’s of female sex workers in Zimbabwe
- Planning a Population Size Estimation Study exercise
Agenda

Day 2: PSE for female sex workers in Zimbabwe and extrapolation to the national level

• Overview of extrapolation methodologies

• Developing a national PSE of female sex workers in Zimbabwe:
  • Introduction
  • Workshop

• Next steps and ways forward
Introductions

• Name, organisation, key responsibilities
• Why interested in population size estimation- how does it relate to your work?
• Review Agenda- anything to add?
The **Measurement and Surveillance of HIV Epidemics (MeSH) Consortium** strengthens data systems, data analysis, and data use by HIV programmes to drive programme improvement and enhanced strategic information to increase prevention and treatment coverage among target populations and accelerate the decline of HIV incidence in sub-Saharan Africa.

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Partners
**MeSH structure**

**Mortality**
- How to estimate mortality among people commencing HIV antiretroviral therapy?
- How to estimate HIV attributable mortality in the general population?

**Case-based surveillance**
- Are systems in place that are context appropriate, feasible, scalable, and sustainable for CBS in SSA?
- How to establish and conduct HIV CBS in SSA?

**Key Populations**
- How to optimise extrapolation and triangulation for population size, prevalence, and incidence estimation?
- How to measure HIV prevention cascades?
- How to characterise metrics of stigma to track stigma reduction?

**Guidelines & dissemination**
- Care & prevention cascade training
- Guideline development
- Agenda setting and dissemination
Working Group 3: among key populations estimate size and location, prevention and treatment coverage, and prevalence and incidence

- Extrapolation and Triangulation
  Use observed direct estimates plus contextual data (available from all areas) to learn about areas without direct estimates
- Prevention cascades
- Metrics to track progress on stigma
Introductions

Name, organisation, role

Why interested in population size estimation - how does it relate to your work?

Review Agenda - anything to add?

• Do you currently use estimates of the size of key populations in your work?
• Where do these estimates come from?
• How much do you trust these estimates? How important is it that the estimates are very accurate?
Population Size Estimation: Overview
What populations are we talking about?

HIV risk context

Do not appear in a census or difficult to sample

- Problems with self-reporting -> social stigma, marginalised populations, criminalised populations
- Mobile populations, across geographies
- Mobile definition, across time (eg moving in and out of periods of risk)
Why do we want to estimate the number of sex workers at sites, regions and countries?

• Service delivery targeting and planning
  • What populations are at high risk of HIV?
  • Where do services need to be located?

• Programme monitoring (‘denominator’)
  • Provide a ‘denominator’ for services uptake
  • Use routinely collected data to estimate programme coverage and evaluate reach

• Epidemic prediction
  • Input estimates into models such as SPECTRUM

• Allocation of funding

• Advocacy
Methods for Population Size Estimation

• Literature review
• Mapping methods: census and enumeration
• Multiplier methods
• Population survey methods
• New approaches
Methods for Population Size Estimation

- Literature review
- Mapping methods: census and enumeration
- Multiplier methods
- Population survey methods
- New approaches

No ‘gold standard’
Methods: Literature Search

Review estimates from other sites, likely range

Convert to prevalence

Multiply by population size

Estimates of the number of female sex workers in different regions of the world

J Vandepitte, R Lyeola, G Dallabetta, F Crabbe, M Alary, A Buve

Objective: To collect estimated numbers of female sex workers (FSW) and present proportions of FSW in the female population (FSW prevalence) in different regions of the world.

Methods: Subnational and national estimated numbers of FSW reported in published and unpublished literature, as well as from field investigations in research or interventions targeted at FSW, were collected. The proportion of FSW in the adult female population was calculated. Subnational estimates were extrapolated to national estimates if appropriate. Population surveys were scanned for proportions of adult women having sex in exchange for money or goods.

Results: In Sub-Saharan Africa, the FSW prevalence in the capitals ranged between 0.7% and 4.3% and in other urban areas between 0.4% and 3.7%. Population surveys from the same region yielded even higher proportions of women involved in transactional sex. The national FSW prevalence in Asia ranged between 0.2% and 2.4%, in the ex-Soviet Union between 0.0% and 1.5%, in East Europe between 0.4% and 1.4%, in West Europe between 0.1% and 1.4%, and in Latin America between 0.2% and 7.4%. Estimates from rural areas were only available from one country.

Conclusion: Although it is well known and accepted that FSW are a highly vulnerable group in the scope of the HIV epidemic, most countries in the world do not know the size of this population group. The estimates of the prevalence of FSW presented in this paper show how important this hard-to-reach population group is in all parts of the world.

In many countries, the HIV epidemic is concentrated among subgroups of the population whose behaviour exposes them to a high risk of acquiring HIV infection. These subgroups include injecting drug users, men who have sex with men, and commercial sex workers—female and male. Numerous studies have documented significantly higher rates of HIV infection in women infected by sexual intercourse with men, who have sex outside of known venues for sex work. Therefore they are even more difficult to reach than women known as direct sex workers. As a consequence, the absolute size of the FSW population remains largely unknown. In many countries data are available on HIV prevalence among sex workers, however in estimating national HIV burden one must consider the numbers of FSW outside of known venues for sex work.
Methods: Wisdom of the crowd

How many female sex workers do you think there are in this town?
Methods: Wisdom of the crowd

Strengths
• Easily added to a survey
• Special knowledge
• If ask a large group, less likely to be affected by outliers

Weaknesses
• Everyone might have the same tendency to be wrong (systematic bias)
• Think about size of site
• Segregated population
Mapping Methods: Census and Enumeration

Construct map of where the population congregates
• Key informants, peer educators, focus groups

Census: use map as a tool to count ALL members of the population

Enumeration: use map as a sampling frame to select venues; count all of the population in the sampled venues and extrapolate to all venues.
• Stratify venues, apply averages to strata
• Time/place
Mapping Methods: Census and Enumeration

Strengths
• Provides a minimum number
• Easy to understand and communicate
• Good check alongside other methods

Weaknesses
• Miss members of population not at these venues
• Need to consider time/space
• Very time intensive for large sites
Methods: Multiplier Methods

Uses two sources of data

1. Register or count of the target population (received service, visited programme, received token) \( \rightarrow M \)
2. Representative survey of the target population \( \rightarrow P \)

\[ N = \frac{M}{P} \]
Service Multiplier Method

Programme

300 FSW in records
Service Multiplier Method

Programme

- 300 FSW in records

Representative survey

- 30% report attending
Service Multiplier Method

\[ N = \frac{M}{P} \]

Clinic service: 300 FSW in records

Representative survey: 30% report attending

\[ 1000 = 300 \times \frac{1}{0.3} \]
‘Unique Object’ Multiplier Method

Representative survey

N

Tokens

300 tokens distributed

M

30% report receiving a token

P

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Multiplier Method: Other multipliers

• Membership of community groups, social clubs

• Membership of social networking sites (if can get list)
  • Online dating profiles
  • Facebook groups
  • What’s App groups

• Attendance at population-specific events

• Arrest data (where applicable)
Multiplier Method: Assumptions

1. All members of the population being counted should have a non-zero probability of being included in both data sources.
2. Individuals should not be counted more than once in each data source.
3. The two data sources should be independent of each other.
4. The representative data source should be a random sample of the target population.
Multiplier Method

Strengths
• Simple calculation
• Use existing service data
• Survey questions relatively easy/low burden

Weaknesses
• Can give very variable results
• High uncertainty
• Independence of data sources challenging in practice
• Inconsistencies in population definition
Methods: Capture Re-Capture

- Captured List 1
- Captured List 2
- Overlap: captured both Lists
- Not captured

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Methods: Capture Re-Capture

N = \text{Overlap Captured both lists}

\text{Captured List 1} \times \text{Captured List 2}
## Methods: Capture Re-Capture

### Strengths
- Simple calculation
- Less time-intensive than census and enumeration
- No representative survey required
- Recommend multiple captures

### Weaknesses
- Misses those not present at venues
- Difficult to meet assumptions in practice:
  - Two ‘captures’ must be independent
  - Identify individuals accurately
Population Surveys: asking about behaviours

- Question to define population in representative population survey
  - Lifetime behaviour
  - Recent behaviour
Population Surveys: asking about behaviours

**Strengths**

- Provides estimates at different levels (given power) or at least a framework for extrapolation
- Provides other information about the population

**Weaknesses**

- Statistical power
- Social desirability bias
- Question to define population
- Likelihood of inclusion in survey
- Time (ever/now)
Population Surveys: Network Scale-Up

Proportion of hidden population members in the total population can be estimated from the proportion within the personal networks of a random sample of the population.

\[ m/c = e/t \]

Obtainable from a population survey.

Network Scale-Up Assumptions

• Members of population are known to be members
  No transmission bias

• Equal network size between members and non-members
  No popularity bias

• Random mixing or even distribution of populations
  No barrier effect

• Reporting is accurate
  No reporting bias
Network Scale-Up

**Strengths**
- Improved ‘sample size’
- No self-report
- Methods in development, lots of interest

**Weaknesses**
- Assumptions difficult to meet
- Personal network size difficult to measure
- Transmission bias likely-> ‘Game of Contacts’
Methods: RDS-Successive Sampling

• Based on theoretical decline in network size over sampling wave
• Imputed ‘network visibility’
• Bayesian framework
RDS-Successive Sampling

**Strengths**

- Requires only an RDS survey (though better with additional estimates to compare, inform prior)
- Framework for synthesising estimates?

**Weaknesses**

- Assumptions about degree decay over sample waves
- New method: little tested in practice so far
Issues with population size estimation

• No gold standard method
• All methods prone to bias
• Widely variable depending on method
• Definition of the population
• Fluctuations over time: migrations, moving in and out of risk
• Extrapolation to different level (usually site to national level)
• Difficulty assessing time trends
High variability

Sources of uncertainty

• Random error: wide confidence intervals
  • Sample size calculations

• Assumptions of methods difficult to meet in practice -> biases
  • Some assumptions can be investigated (Chabata et al)

• Combining estimates from different methods

• Extrapolation method or lack thereof

→ lack of certainty should be reflected in how PSE’s are used
Systematic biases by method

• Systematic review found 341 published KP size estimates, 25 had multiple methods for side by side comparison

• No evidence of “best” method, all could be biased up or down by theory or observation
  • Literature tends to the middle
  • Wisdom of the crowd tends to be low
  • Delphi tends to the middle
  • Mapping estimates tend to be low
  • Multiplier methods and capture-recapture estimates can be wildly high or low

MSM population size estimates, median and plausibility bounds, Nairobi, 2010.

Plausibility

• Minimum estimates
  • Census
  • Population Service data (eg attendance at sex worker’s clinic)

• Maximum estimates

• Comparison to other settings

• Relative plausibility: Site A versus Site B
Recommendations

For those conducting size estimations:

• Use multiple methods, triangulation
• Sample size calculations for survey-based methods (this afternoon)
• Use and explain a principled method for extrapolation (tomorrow)

For those using population size estimates:
Use upper and lower plausibility bounds- do not rely on point estimate
Discussion

Do you think the way in which population size estimates are used currently reflects the uncertainty around them?
Planning a Population Size Estimation Study

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Who is the population?

- Behaviours versus people
- Periods of risk
- Place/mobility questions
- Seasonality
Defining your site

- What are the boundaries?
- Does your population reside there permanently or temporarily?
- Do you intend to update findings again in the future?
- Do you intend to use your findings to extrapolate to another site?
Choosing appropriate methods

• What are the estimates for?
• Characteristics of the population- venued based? Well ‘networked’?
• Existing data, resources for new data collection
• Size of site(s)
• Levels of representativeness (small truck stop, town, city, country)
Stakeholder involvement

• Who are the estimates of benefit to?

• Who can help you understand your population?
  • Representatives from your population of interest
  • National/regional government
  • Programme planners, service providers, NGO’s
  • Others with data
Ethics

• Vulnerable, often criminalised populations

• Security around mapping

• Identification via unique objects, RDS coupons

• Publication of site names and numbers? (Feedback)

• Benefit to whom?
Communication of Findings

• Incentives to choose higher or lower figures
• Ethics and communication of findings
• How to communicate uncertainty in estimates
Sample Size Calculations

• Decisions about surveys
  • Population-based surveys
  • Target population surveys: Respondent Driven Sampling, Time/Location

• Decisions about multipliers
  • (eg no. unique objects distributed)

• Decisions about captures

• Mapping decisions, sites within strata

• Extrapolate to regional/national level estimate?
Sample Size for Multiplier Method Studies with RDS

• Important to obtain estimates with reasonable precision for study aims (random variation), lack of current guidance
• Estimate P (proportion using service) using RDS survey, \( N = M / P \)
• Higher variance in RDS surveys than in a simple random sample survey, Design Effects (DEFF’s) of 2-4 or higher
• Using Delta method combining variance in M and P, estimate effect of sample size on the width of 95% Confidence interval for different assumed values of M and P

Example: Sample Size for PSE of female sex workers in Harare

Table 1: Number of FSW attending the Sisters programme and effect on P, given the total population of FSW 15,000 in Harare (mid-point estimate based on literature, Vandepitte 2006)

<table>
<thead>
<tr>
<th>Reference Period, to April 23, 2015</th>
<th>Number of Unique FSW Visiting, M</th>
<th>Estimated P, assuming population = 15,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 month</td>
<td>85</td>
<td>0.006</td>
</tr>
<tr>
<td>3 months</td>
<td>560</td>
<td>0.037</td>
</tr>
<tr>
<td>6 months</td>
<td>952</td>
<td>0.063</td>
</tr>
<tr>
<td>12 months</td>
<td>1542</td>
<td>0.103</td>
</tr>
<tr>
<td>24 months</td>
<td>2227</td>
<td>0.148</td>
</tr>
</tbody>
</table>

Sisters programme clinic visit data up to April 2015
Figure 1: Effect of reference period on $P$, width of the 95% CI around the PSE and sample size required for estimating the number of FSW in Harare

Developing a National Estimate of the Number of Female Sex Workers in Zimbabwe

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Approaches to Extrapolation in other settings

• Assume exchangeability: prevalence from sampled sites = prevalence non-sampled sites

• Stratification: urban/rural, regional, type of sites (tourist, mining, truck-stop, etc)

• Matching

• Regression-based approaches
  • Model to correlate FSW prevalence with other district co-variates
  • Model for district sampling probabilities
  • Bayesian models
Review of PSE’s for Key Populations in LMIC’s 2010-2016


Fig 1. Categorization of population size estimates of female sex workers, men who have sex with men, people who inject drugs, and transgender women in low- and middle-income countries, 2010–2014.
1. **Nationally adequate:**
   - PSE’s derived using 1) multiplier; 2) capture–recapture; 3)mapping/ enumeration; 4)Network scale-up or population survey; 5)RDS-SS
   - National-level estimates or extrapolated from multiple sites with a “clear approach” to extrapolation
   - Two key population groups

2. **Nationally inadequate but locally adequate in selected cities**
   - PSE’s derived using 1) multiplier; 2) capture–recapture; 3)mapping/ enumeration; 4)Network scale-up or population survey; 5)RDS-SS
   - Estimates are only from sites where targeted programs are available but are insufficient for national program use.
   - Two key population groups

3. **Documented estimates but inadequate methods**
   - estimates are derived from 1) expert opinions; 2) Delphi; 3) wisdom of crowds; 4) programmatic results or registry or 5) regional benchmarks.
   - Estimates may or may not be national

4. **Undocumented or untimely:** estimates are reported but not documented or were derived prior to 2010.

5. **No data:** no size estimates are reported
Table 2. Application of methods in estimating population size estimates for female sex workers (FSW), men who have sex with men (MSM), people who inject drug (PWID) and transgender women in low- and middle-income countries, 2010–2014.

<table>
<thead>
<tr>
<th>Methods</th>
<th>FSW</th>
<th>MSM</th>
<th>PWID</th>
<th>Transgender women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiplier</td>
<td>29</td>
<td>31</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>Capture re-capture</td>
<td>19</td>
<td>17</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Census &amp; enumeration</td>
<td>19</td>
<td>10</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Programmatic mapping</td>
<td>27</td>
<td>23</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Network scale up method or population-based survey</td>
<td>4</td>
<td>11</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>RDS-SS successive sampling</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Administrative registry/programmatic results</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Regional benchmark</td>
<td>3</td>
<td>7</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Population-based survey</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Expert opinion (wisdom of crowds/literature/ Delphi/key informants)</td>
<td>13</td>
<td>10</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Wisdom of crowds</td>
<td>6</td>
<td>10</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Not Reported</td>
<td>9</td>
<td>6</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Total number of countries</td>
<td>87</td>
<td>88</td>
<td>53</td>
<td>17</td>
</tr>
</tbody>
</table>

1. Proportion of adult males or females: national estimates are calculated based on a proportion or a range of proportions of adult males or females, who are key population community members.

2. Summed up: national estimate is the sum of site-specific estimates with no adjustment.

3. Regression or probability formula: regression models were used to estimate populations in areas without an estimation exercise using information from those areas where estimations are available.

4. Based on one selected number: national estimate is extrapolated based on one estimate among a number of estimated numbers.

5. Delphi or consensus: a formal process considering different factors to arrive at an estimate.

6. No extrapolation.
Table 5. Approaches used for extrapolations to national population size estimates in countries with known estimation methods for female sex workers (FSW), men who have sex with men (MSM), people who inject drug (PWID) and transgender women in low- and middle-income countries, 2010–2014.

<table>
<thead>
<tr>
<th>Approaches for extrapolations</th>
<th>FSW</th>
<th>MSM</th>
<th>PWID</th>
<th>Transgender women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of adult population</td>
<td>21</td>
<td>30</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Based-on one selected estimate</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Summed up from site-specific results</td>
<td>8</td>
<td>7</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Regression or models</td>
<td>9</td>
<td>13</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Delphi/consensus</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Total number of countries with extrapolations</td>
<td>58</td>
<td>57</td>
<td>29</td>
<td>10</td>
</tr>
</tbody>
</table>

Information in Zimbabwe to develop a National PSE for Female Sex Workers

We have a lot of high quality data:

• 20 sites with direct PSE’s, most with more than one method (+RDS surveys and programme data)
• 16 sites with in-depth programme data
• Coverage across the country
• 2012 Census
• National surveys, ZIMPHIA

How shall we use this to develop a national PSE?