Introduction to population size estimation (PSE): purpose and use

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Introduction

Population size estimation (PSE) is an essential part of any robust HIV surveillance system. Especially in the countries with low-level or concentrated HIV epidemic, estimating the size of especially vulnerable, hard-to-reach populations is important for: (a) policy reasons (PSE strengthens advocacy and enables proper response planning and resource allocation); (b) estimations of number of individuals infected with HIV and projections of the burden of HIV/AIDS; and (c) planning interventions and high-quality bio-behavioral surveillance studies. To conclude, without PSE it would be hard if not impossible to assess the needs for adequate services, and to convince decision-makers that these needs ought to be met.

The main objectives of this section are:

1.   To understand the basic idea of PSE

2.   To understand the need for PSE

3.   To acknowledge the existence of various methods for PSE

4.   To encourage the use of and experimentation with PSE.

◇**Questions to discuss**

Some evidence suggests that a substantial proportion of injecting drug users (IDUs) in the city X share needles and other injection equipment, which makes them vulnerable to HIV infection. What information would you need to start planning an outreach intervention program? How can you obtain the information you need? What information about the population would be needed for carrying out a behavioral surveillance study on IDU in the city X? Explain why?

Why bother with PSE?

Simply put, unless we have some idea about the size of vulnerable populations (characterized by HIV-related risk behaviors) we can not understand the extent of the potential HIV/AIDS problem. Size estimations enable persuasive advocacy for funding of prevention activities, surveillance research, and, possibly, care and intervention efforts. Fort example, the fact that sex workers represent a bulk of newly detected HIV+ cases will not necessarily motivate governmental institutions to invest in targeted interventions, especially if there is a political imperative to claim (at least, officially) that sex work is hardly existing in the country. However, a scientifically reliable estimation that there are between 10,000 and 15,000 sex workers nation wide, the funding is more likely. In addition, PSE will enable you to calculate resources needed for prevention and intervention, including, for example, the number of condoms to be distributed for free and the number of outreach workers to be educated and sent out to advocate behavioral change and anonymous HIV testing in the population.

Often there are competing targets for intervention and it is not clear which one should be prioritized. Let us assume that available data suggest HIV prevalence of 2% among female sex workers (FSWs) and of 4% among male sex workers (MSWs). Also, there is some evidence that MSWs may have a somewhat larger number of clients per week than FSWs. Although it seems that MSWs should be the priority research target, we still lack one crucial piece of information – how many FSWs and MSWs are there? An estimation showing that the size of FSW population is 4-5 times larger than the MSW population may lead to a different conclusion. Obviously, PSE is an important element in deciding how resources should be allocated and which targets should be prioritized.

Finally, suppose you are planning a bio-behavioral study among FSW in the city Z. Without a local estimate of the target population, how would you know if such study is feasible? What if the number of FSW in the town Z is too small for meaningful sampling?

◈ **Question A**

Please list all hidden populations in your country/region that are relevant for HIV surveillance. Next, try to sketch an operational definition for each of the populations of interest. What happens when you change a definition, let's say by shortening the time frame? Are your definitions focused on behaviors or identity (sense of belonging)? Why?

PSE methods: A brief overview

(1)   Survey, census, and enumeration method

Household or general population surveys provide a very robust way to measure the size of a vulnerable group. Arriving at a population size estimate is simple: the prevalence measured in the survey if generalized to the whole population (2% of MSM in the study = 2% of MSM in the general population). The strength of national probability surveys is that they provide an opportunity for triangulation with smaller-scale samples, regardless of their sampling approach. However, there are a number of potential limitations of this method. To be representative, national surveys need to apply high-quality sampling based upon a highly-accurate sampling frame and should have high response rate. Usually, national surveys do not include social groups such as prisoners, homeless people, migrant workers, those who are in hospitals and other treatment centers, and those who live in hotels. Furthermore, as at-risk populations usually constitute a tiny minority in the general population, they tend to get underrepresented (under-sampled) in national surveys. Importantly, members of a vulnerable population may be overrepresented among non-responders or, if they agree to participate, may not be willing to disclose their membership in a vulnerable population in fear of stigmatization or legal sanctions.

Unlike household surveys, census and enumeration methods actually count individuals of interest. Census requires visiting every place of interest (e.g. shooting galleries) and counting how many people inject drugs at each site. Obviously, this must be carried out in a brief period of time, as migration between sites may result in duplications. Enumeration is somewhat different. It begins with some kind of a sampling frame (e.g. list of all brothels in an area) and then proceeds with sampling a number of sites (maybe one fifth of those in the sampling frame) where members of the population of interest will be counted. The obtained number is then scaled up according the size and structure of the sampling frame. Clearly, census and enumeration methods will not work with "invisible" members of an at-risk population (those who do not work or gather in public or semi-public places).

(2)   Capture-recapture method

Capture-recapture (CRC) method has been used in a range of settings, from biology to epidemiology, to estimate the size of hard to reach populations. Esentially, the method requires two independent samples from the same population. The second study must include an indicator that would provide information whether an individual also participated in the first study. This overlap between the studies is used to arrive at the overall size according to the following formula:

$$N = \frac{MC}{R},$$

where

N = Estimate of total population size

M = Total number of individuals who participated in the first study

C = Total number of individuals who participated in the second study

R = Number of individuals who participated in both studies

Although simple and straightforward at first glance, CRC becomes more complex in the case of multiple recaptures. Declining popularity of the simple variant of CRC is due to frequent violations of the principle of independence between capture and recapture samples (lower class IDUs are, for example, more likely to end up in jail then IDUs from upper class; younger MSM are more likely to frequent gay bars and clubs then older MSM, etc.) and often encountered difficulties in identifying and/or verifying recaptures.

(3)   Multiplier method

Multiplier method is a potentially powerful and mathematically simple, easy to use, tool. Currently, it is probably the most popular PSE method. As in the case of CRC, it requires data from two independent but overlapping probability-based sources. The first source is often an institution or service-based dataset, while the other may be a behavioral surveillance survey. An estimate is produced by multiplying the number of individuals of an at-risk population who attended the institution or service X during a certain period of time by the inverse of the proportion of surveyed individuals belonging to the same population who reported that they attended this institution/service over the same period.

Clearly, multiplier method requires systematic record keeping by relevant institutions/services and the inclusion of appropriate indicators (questions) in all behavioral surveillance surveys. The method is based on the assumption that members of the target population have a non-zero probability of inclusion in both sources and that the time frame used must be the same in both datasets. The importance of a precise and consistent definition of the target population becomes obvious when thinking about members of the population who may not have access to certain services or those who may not be included in a survey that captures only "visible" parts of the population.

(4)   Network scale-up method (NSU)

The basic principle underlying NSU is that social networks are, on average, representative of the population. More precisely, the proportion of individuals from the (sub)population of interest known to "an average" participant in a nationally representative sample is equal to the proportion that this subpopulation forms in general population. The NSU approach thus relies on asking a random sample of individuals from the general population whether they know any members of the population of interest. It also requires information on the average personal network size (usually unknown) in the general population and the number of the total population (usually known). The NSU method is simple and does not require contact with the hidden population. Relevant indicators can be added to any nationally representative survey to produce PSE for different hard-to-reach populations at the same time. However, some difficulties are usually encountered when using NSU, particularly those related to reliable estimates of the average size of social networks, those caused by overlaps between two or more populations of interest, and those generated by non-random mixing or uneven distribution of hidden populations.

Steps in doing PSE

(A)   Defining the purpose

Different estimation techniques may fit different needs. The choice of PSE method(s) should be guided by previously defined purpose of the estimation process. For example, the goal of arriving at a national estimate of HIV infected FSW, which would be used to plan for outreach services, would hardly benefit from a capture-recapture exercise in the capital city. Likewise, planning a time-location study men who have sex with men (MSM) will not require carrying out a nation-wide sexual health study.

        Needless to say, both local and national PSE are needed as they address different needs and are used by different institutions. The first are used for planning prevention, intervention, and treatment programs, surveillance studies and evaluation at a local level. National PSE are required to determine national policy priorities and for overall planning, raising money, and allocation of resources. Often, local estimates of the size of at-risk populations can not be simply aggregated to produce a national estimate. Geographical spread of the members of a vulnerable population is almost never constant. There will be areas (cities, provinces) with high and those with low prevalence of, for example, injecting drug use (IDU), due to a number of cultural and social differences between the areas, migratory flows, drug trafficking routes, security issues in the neighboring regions, tourism, etc. Thus, arriving at national estimates usually requires careful

stratification between areas of high, medium and low presence of the members of an at-risk group. Separate estimates from key provinces are usually essential.

(B)   Defining target population

Sex work is not always easy to define. There are different types of sex workers (from street-operating SWs to high-class SWs who work in hotels or as escorts) and different types of sex work – some of which, for example, may not includes exchanging sex for money. Before starting the estimation process it is crucial to define the population of interest precisely. In a situation where multiple types of sex work exist, estimation may have to be carried out separately for each subpopulation.

(C)   Assessing access to a target population

Some estimation methods require contact with members of a target population and some do not. Obviously, an assessment of access to individuals from this at-risk population will precede any estimation efforts. The access may be possible through specialized (dedicated) institutions – such as community services, outreach programs, or correctional facilities – or at community entry points (places where the members of the target population gather).

(D)   Using available data

Estimation process utilizes all types of data: service based, site-based, and population based. Provided their quality is reasonable (e.g. probability methods were used to collect data), more data sources usually mean more precision and better estimates. Therefore, a systematic assessment of the quality of each data source – which would address sampling and data collection methods, potential biases, and other validity issues – is an imperative.

(E)   Applying appropriate PSE method(s)

Once the purpose of PSE and the population of interest are defined, appropriate estimation method(s) will be chosen based on the available data, feasibility of collecting additional information, and – least but not last – country-specific cultural and social context.

(F)   Bearing in mind ethical aspects

Especially when PSE requires contacts with member of a hard-to-reach population, ethical issues should be discussed extensively during the planning phase and systematically monitored during the execution phase. The golden standard of not doing harm to participants is also valid here. Estimation efforts should not be used to increase stigmatization or discrimination against certain social groups. Sometimes, the dissemination of new estimates may, in itself, mobilize the police force or be misused by some to advocate harsher measures against members of the population. This should be anticipated and dealt with in advance.

Summary

Particularly in the countries characterized by low-level or concentrated HIV epidemic, PSE is an essential tool for assessing the needs for adequate services and persuading decision-makers to plan, fund, and implement these services. In addition, PSE enables proper planning of surveillance and its evaluation. Here are some points to remember for estimating the size of at-risk populations:

- Whenever possible, use more than one PSE method (multiple method approach). Triangulation of obtained estimations may improve reliability and provide better estimates.
- All types of available data should be used for PSE, provided that the sources are carefully analyzed for biases and omissions, and carefully interpreted.
- Different estimation methods may be needed for different populations (bear in mind the importance of starting with a precise definition of the target population).
- Both local and national estimates are needed, but be cautious about simple aggregation.