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ORIGINAL PAPER

Estimating the Population Size of Males Who Inject Drugs in Myanmar: Methods for Obtaining Township and National Estimates

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Abstract
Estimating the sizes of key populations at risk for HIV is crucial for HIV prevention and treatment. We provide findings of population size estimates (PSE) of males who inject drugs (MWID) in Myanmar, provide an intuitive method for countries to extrapolate subnational estimates into national estimates and provide guidance on how to maximize the utility of current PSE techniques. We used unique object and service multipliers, and successive sampling PSE in conjunction with a respondent driven sampling survey of MWID in ten Myanmar townships in 2014. Township estimates were assessed at a stakeholder meeting for biases and coded into ranges of high, medium and low MWID prevalence areas. Using the sampled townships as benchmarks for a range of MWID proportion estimates, national level MWID size estimates were derived by multiplying the adult male population for all townships with their corresponding proportion estimates. Final PSE ranged from high (4.12%), medium (1.02%) and low (0.11%), with the final agreed national point estimate of 83,000 MWID. Using estimates from survey data, this can translate into actual numbers of MWID living with HIV and practicing risky injecting and sexual behaviors. Although PSE are vital for monitoring HIV epidemics, no guidance exists for interpreting results of different PSE techniques or for extrapolating these results into national estimates. Assessing bias and gaining consensus on township level estimates and deriving ranges of MWID PSE throughout the country using stakeholder input is intuitive and accessible to countries.

Keywords People who inject drugs · Myanmar · Population size estimation · Respondent driven sampling · Multiplers

Background

Estimating the sizes of key populations at highest risk for HIV is crucial for sustaining an effective HIV public health response [1, 2]. Knowing how many key population members exist in a country is essential for accurately measuring the burden of disease and service coverage, and for guiding resource allocation and advocacy for programs to prevent new HIV infections and provide treatment for people living with HIV. Over the past several years, efforts have focused on improving techniques to measure the population sizes of key populations, including men who have sex with men, female sex workers and people who inject drugs (PWID), with support from technical agencies and donors who rely on size estimations to guide and evaluate investments.

Estimating the size of populations that are stigmatized and may practice illegal behaviors is challenging, mostly because there are no places or lists from which members can be counted. Existing population size estimation (PSE) techniques have unmeasurable biases resulting in over or underestimations. In addition, most surveys of key populations are conducted in urban areas which are purposively selected because they have the highest HIV risk potential, they are areas where key populations are more likely to reside or work and because there are often organizations working with the population which can provide staffing and support during data collection. Therefore, most size estimations represent areas that are likely to result in high size estimates of key populations. Apart from mapping and census approaches, which are costly and time consuming, especially in large countries, many PSE methods are easily added into already planned surveys of key

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populations using probability-based sampling methods. With the expansion of biological and behavioral surveillance surveys using respondent driven sampling (RDS) methods, countries are increasingly incorporating PSE techniques [3–9].

RDS is effective for sampling networked populations that have no sampling frames and that are difficult to recruit into surveys [10–12]. RDS recruitment begins with a convenience sample of population members ("seeds") who use a fixed number of coupons to recruit members of their social network. The objective is to manage peer-to-peer recruitment whereby the generation of long recruitment chains results in a final sample that is independent of the initial convenience sample of seeds. The longer the recruitment chains the more representative the sample. Data collected with RDS methods are adjusted based on each participant's social network size (e.g., the number of people they know who fulfill the survey eligibility) and similarities in characteristics of persons who associate with each other [11].

Currently, there are several types of PSE techniques that are commonly used in conjunction with surveys using RDS: unique object multiplier, service multiplier and successive sampling population size estimations (SS-PSE) [3–6, 8, 13]. Briefly, multiplier methods use two overlapping data sources specific to the population being estimated, one being proportions from a survey using a probability based sampling method (i.e., RDS) and the other being a count of unique *objects* distributed to the survey population just prior to the survey (unique object multiplier method) and/or a count of survey population members accessing a *service* (e.g., drug treatment, HIV testing, etc.) during a specific time frame prior to the survey [3, 6]. To illustrate, if 1000 key chains are distributed to PWID 1 week prior to a planned survey and the survey representing PWID in the same area finds an adjusted estimation of 10% reporting that they received the object, then the total number of PWID would be 10,000. However, unique object multipliers are highly dependent on the correct distribution and recall of objects and the service multiplier is highly dependent on the availability and quality of data collected for other programming purposes (e.g., PWID accessing HIV testing). The SS-PSE is based on a Bayesian framework which uses previous knowledge and educated approximations of population sizes [4, 9, 14]. Information about population sizes (priors) are leveraged to calculate the uncertainty about unknown quantities (e.g., the estimated population size, the posterior). The SS-PSE incorporates data on each participant's social network size (gathered during any standard RDS survey) and the order in which they were sampled. In Bayesian statistics, information about unknowns is expressed through probability distributions over their possible values resulting in a distribution of means, medians, and probability intervals, rather than point estimates and confidence intervals [15].

With the global scale-up of HIV prevention and care services and the expansion of data collection among key populations using RDS [1], the components for estimating population sizes with multipliers and the SS-PSE are available throughout the world. Unfortunately, there is neither guidance on how to interpret varying results of PSEs produced by using different techniques, nor how to extrapolate those estimates to derive national estimates. In this paper, we provide findings of multiple PSEs incorporated into Biological and Behavioural Surveillance Surveys among males who inject drugs (MWID) in ten Myanmar townships in 2014. We also provide an intuitive method for countries to extrapolate local level estimates to derive national level estimates and discuss the challenges and provide guidance on how to maximize the utility of current PSE techniques. Finally, we present estimates of HIV prevalence and risk behaviors to describe how national population sizes can produce useful nationwide counts. The objectives of this paper are to increase awareness and to provide techniques which countries can easily use with their existing capacity to improve future HIV surveillance surveys that use RDS and PSE methods.

Methods

Survey

The survey was preceded by a pre-assessment which helped determine MWID network properties, acceptability of RDS approaches and appropriate implementation strategies. MWID were defined as males, 15 years or older, who injected drugs for non-medical purposes in the past month and had lived in the survey area for at least 1 year. Although both males and females were eligible, the primary analysis of results is focused on only male respondents due to females demonstrating unusual network properties (i.e., having high heterophily [not recruiting other females] or not recruiting anyone resulting in their being end nodes on a chain). Ultimately females comprised only 0.4–8% of the total survey sample across the ten sites.

The surveys included the essential RDS methodological requirements: Recruitment initiation with a diverse set of seeds identified through local contacts and well connected to and trusted by the target population; the use of a quota of recruitment coupons per participant; incentives for participation and peer recruitment; collection of each participants' social network size and recruitment ties; and, facilitation of long recruitment chains and consequent attainment of convergence for key variables of interest [16]. The sample size of 392 for each township was calculated based on the proportion of MWID that shared needles at last injection being 50%, confidence interval width set at + or − 7% and a design effect of 2. The survey was implemented by Myanmar's National AIDS Program and received approval from the Myanmar Ministry of Health.

Population Size

Unique objects, comprising multicolored plastic bracelets printed with the phrase "Getting to Zero", were distributed by NGO outreach workers to MWID in their service area approximately 2 weeks before the survey started. The unique object was designed to be memorable and not of any value to dissuade recipients from selling or giving them away. Staff distributing the bracelets were instructed to give only one unique object to each recipient and to tell the recipient not to forget having received the object. During the survey, each participant was asked whether they received the object in the week during which they were distributed.

The service multiplier was assessed during the survey by asking participants whether they accessed HIV testing or drop-in-centers at a township specific non-governmental organization (NGO) or received treatment at a township specific methadone maintenance therapy (MMT) center between November 2013 and January 2014. The respective services were asked to provide the exact non-duplicate count of MWID who accessed their services in the same period.

Multiplier methods rely on several assumptions, including that no individual be counted more than once in each multiplier (non-duplicated data) and that the two data sources be independent of each other (i.e., inclusion in one source not being related to inclusion in the other). Multipliers also require that the sampling methodology be probabilistic, adhering to methodological and statistical probability features. For RDS this includes that participants accurately report their social network size, measured as the number of people they know who know them, who are 15 years or older, injected drugs for non-medical purposes in the past month and whom they have seen in the previous 2 weeks. It also requires that implementation included the collection of data about who recruited whom, that variables were assessed to reach convergence, and that the estimates were adjusted for differential network sizes [11, 17].

To derive the SS-PSE, prior estimates about MWID's most reasonably likely, lowest and highest population sizes were collected from NGOs that work with the population, the Ministry of Health and other stakeholders for each of the 10 townships. These parameters were used to model population sizes and the medians and modes were used for the final estimates.

Analysis

Once data are collected, the calculation of multiplier estimates is straightforward. The numerator is the count of persons who received an object (the number reported to have been distributed and accepted by an eligible person prior to the survey) or accessed a service (the number of eligible persons the service reports to have accessed the service during a specific time period). The denominator is the RDS weighted proportion provided through the RDS survey (the proportion who affirm that they received an object and/or the proportion who affirm that they accessed the service). The mathematical formula is $N = M/P$, where N is the estimated population size, P is the RDS weighted proportion and M is the total number of those who reported receiving an object or accessing the service. Estimates were calculated in RDS Analyst using the successive sampling estimator [12].

The SS-PSE was calculated in RDS Analyst using visibility imputation, [18] which imputes network sizes using information about participants' actual number of recruits, enrollment date, and the total sample size. The SS-PSE uses information about the sequential nature of data collection assuming that reported degrees decrease over time, reflecting a depletion of the population [18, 19]. Final estimates of population sizes of male MWID are extrapolated from the actual population of Myanmar comprising 17,352,484 males over the age of 15 years [20]. Estimates of HIV prevalence and risk behaviors from the 10 townships are weighted by differential network sizes and then weighted by township population size estimations to derive an aggregate average estimate.

Gaining Consensus for the Township PSE

Consensus on township estimates was obtained during a workshop of national and international experts on PSE and RDS methods and issues concerning MWID. Participants included officials from the Ministry of Health, township medical officers, HIV monitoring and evaluation staff and researchers, NGO and civil society representatives, and specialists and consultants from UNAIDS, WHO and UNODC. Participants were divided into four groups with the task of reviewing the size estimations for two or three townships based on an example table presented in Table 1.

Each group was asked to gain consensus on the final township size estimations by assessing biases inherent in each of the methods (Table 2) based on knowledge about the methods, local context and possible issues faced during survey implementation. For the multiplier methods, potential overestimations of population sizes will occur if the denominator (i.e., estimate of those who reported having attended a service or received an object) is underestimated and potential underestimations will occur if the denominator is overestimated. Likewise, if the denominator data are accurate and the numerator is overestimated, then there will be an overestimation of the population size and vice versa. For the SS-PSE, the direction of the bias is difficult to ascertain

Table 1 Example population size estimation (PSE) techniques, estimates, confidence bounds and proportions of the adult male population from Bamaw township in Myanmar, 2014

Method	PSE	95% CI	Percent of adult male population
Object multiplier	737	521, 954	1.57
Methadone service multiplier	719	580, 861	1.54
HIV test service multiplier	633	340, 927	1.35
Drop in center service multiplier	799	693, 906	1.71
SS-PSE (mode)	424	337, 4094	0.91
SS-PSE (median)	424	–	0.91
NGO ranges	1100	900, 1400	2.34

given that so many factors are involved in modeling the final estimates and that many of the biases may arise from an inadequate implementation of the RDS method. Especially relevant factors to assess related to the sampling method include the sample fraction size (this method performs best if the sample fraction is above 10%), challenges during data collection (e.g., did the sampling stop during recruitment because of police raids, festivals or holidays thereby changing the composition of the sample), exclusion of important sub-groups, whether the social network size question was asked correctly by interviewers and responded to correctly by survey participants [12, 17, 19, 21]. It is equally important to evaluate the accuracy of prior estimates provided by NGOs and those familiar with MWID. NGOs may have a difficult time thinking of a size estimate beyond the total number population members registered in their programs. Prior estimates from NGOs may be overestimates given that their funding is contingent on the number of population members they service. Alternatively, given that coverage is important in meeting the 90–90–90 targets [22], NGO staff may want to underestimate the number of population members if service and HIV treatment coverage are low.

Each group presented their findings of biases to all workshop participants in a plenary session. They explained whether they found and eliminated unreasonably high or

Table 2 Potential biases in the multipliers and their impact for each of the PSE methods

Sources of bias and their potential impact		
Resulting in potential overestimations (potential underestimation in the denominator [P])	Resulting in potential underestimations (potential overestimation in the denominator [P])	Unknown direction of bias
Service multiplier		
Respondents who accessed the service but responded in the survey that they did NOT access the service in the pre-defined time period, hence were underestimated in denominator Duplicate records were included in the service monitoring counts of individuals accessing specific services in the pre-defined time period	Respondents who did NOT access the service responded in the survey that they did access the service in a pre-defined time period, hence were overestimated in denominator Those more likely to receive an HIV-related service, and thus more likely to be sampled in the survey (non-independence between the two data sources)-this occurs when surveys are conducted at or close to the referenced service Survey participants/seeds more likely to access the service formed a large social network (non-independence between the two data sources)	Questions in the survey were not asked or understood or were responded to incorrectly by survey participants Important sub-groups missed in the sample (e.g., when a more hidden sub-group, less likely to use a service or be included in the survey, was missed-this could result in an overestimation) Problems during data collection (perhaps making the findings invalid overall) Areas of service delivery and PSE do not overlap or are not defined clearly enough
Unique object multiplier		
Inaccurate over count of the number of unique objects distributed and/or accepted Respondents who did receive a unique object but responded in the survey that they did NOT receive it, thus were not included in denominator Unique objects only distributed in geographical areas covered by programs (i.e., those more likely to be in the program) Multiple unique objects given to the same person	Inaccurate undercount of the number of unique objects distributed Respondents who did NOT receive a unique object but responded in the survey that they did receive it Those more likely to receive a unique object were also more likely to be sampled in the survey (non-independence between the two data sources)-this occurs when objects are distributed to those more likely to enroll in the survey (i.e., those in the geographical areas close to the interview site) Survey participants/seeds more likely to receive a unique object formed a large social network (non-independence between the two data sources)	Questions in the survey were not asked or understood or were responded to incorrectly by survey participants Important sub-groups missed in the sample (e.g., when a more hidden sub-group, less likely to receive a unique object, was missed-this could result in an overestimation) Problems during data collection (perhaps making the findings invalid overall)

low estimates and how they reached consensus on the most reasonable estimate for a specific township. Ultimately, all workshop participants provided feedback and agreed on the final most reasonable estimates.

Mapping High, Medium and Low PWID Prevalence Areas

Participants then formed groups to color code areas on a map of Myanmar where MWID prevalence was likely to be high, medium or low. Decision making criteria included presence or proximity with drug producing and refinement areas, drug trafficking routes, border and urban areas, mining areas with high rates of male laborers, areas affected by migration, transportation routes and ports. Groups used their personal knowledge and experience as well as online maps and secondary information sources. Again, the final maps were presented to all participants for feedback and consensus and one final map was agreed upon (Fig. 1). In addition, annual progress reports presenting the numbers of MWID reached each year in each of the sampled townships, reports on drug trafficking and drug related crime, and reports from NGOs on drug use and harm reduction issues were reviewed to validate final PSE proportions for high, medium and low prevalence of MWID. The final proportions were then plugged into all 330 townships in Myanmar based on their location in the maps and multiplied by the population size of males aged 15 and older derived from the 2014 Census. Final size estimations of all townships were then added up to derive a national population size estimate for MWID.

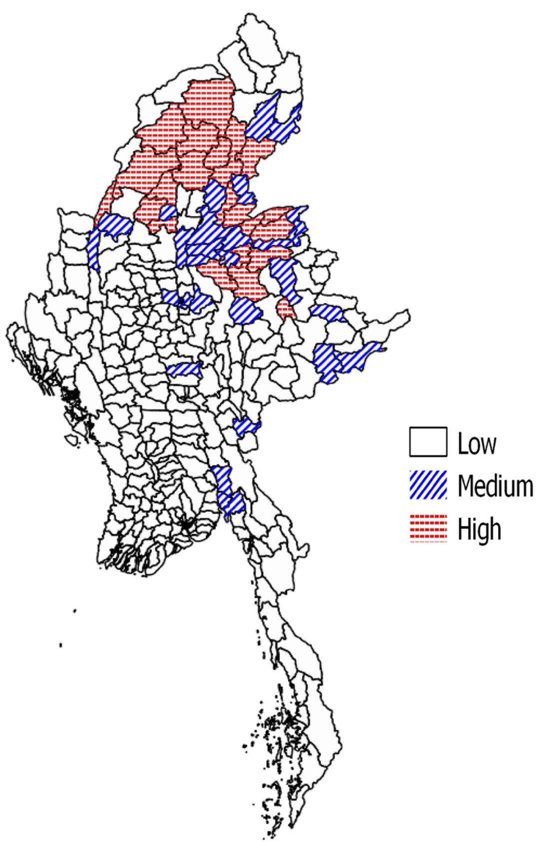

Fig. 1 Map of Myanmar with low, median and high MWID prevalence areas

Results

The final mapped areas of high, medium and low prevalence areas of MWID are shown in Fig 1. The highest concentration of PWID are in the Northern regions, mostly in the states of Kachin and Shan and the region of Sagaing. Consensus PSEs for each of the 10 sampled townships and the final consensus are shown in Fig. 2. Mandalay, with a total population of roughly 1.2 million, was estimated to have the highest number of MWID. As in many surveys, the townships for the Myanmar surveys were selected non-randomly based on their potential to have the highest HIV risk potential, the most MWID and because there were organizations already working with the population to help with data collection. Because of these factors, seven of the 10 townships with PWID population size results were considered to represent a high number of MWID. Two townships, Kalay and Mandalay, were considered to represent a medium number of MWID. Yangon, the capital city, was considered to represent a low number of MWID because of strict law enforcement, the high cost of drugs and its distance from drug production and refinement areas which are mostly concentrated in remote and border areas of the country. These factors were validated by representatives of UNODC and NGOs.

Using the consensus estimates as benchmarks, the following proportions for high, medium and low MWID prevalence areas resulted at 4.12, 1.02 and 0.11%, respectively.

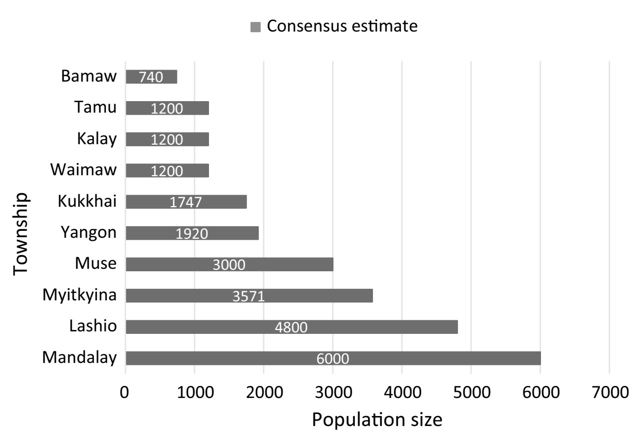

Fig. 2 Consensus population size estimations by township

Corresponding lower bounds were derived using 2.60, 0.75 and 0.08% and upper bounds were derived using 5.79, 1.32 and 0.14%. The final national PSE of MWID in Myanmar in 2014 was estimated to be 83,314, with 95% confidence of between 55,948 and 113,021. This final PSE could provide some important additional benchmarks related to HIV prevalence and risk factors. Using estimates adjusted for network [23] and population size (Table 1) for each township, 29.2% (approximately 24,300 MWID nationwide) were HIV sero-positive, 20.8% (~17,300 MWID nationwide) reported having had an HIV test in the past year and receiving their results, 13.2% (~11,000 MWID nationwide) reported using previously used needles or syringes the last time they injected and 11.2% (~9,300 MWID nationwide) reported ever being on methadone treatment.

Discussion

These PSE methods are easily incorporated into already planned routine surveys, such as HIV surveys using RDS, by adding a few additional questions for the multipliers and by making use of data collected on personal network sizes and enrollment timing. The final estimation of the number of MWID in Myanmar on which there was consensus is 83,000, which in turn provided a more valid estimation of the number of MWID who are living with HIV, reported having an HIV test and receiving their results in the past year. Other indicators from the behavioral survey can be calculated to derive counts for improving program coverage and appropriate funding where it is most needed. In Myanmar, these national and township level size estimates are being utilised to determine the costs of HIV prevention, care and treatment and harm reduction throughout the country.

As with other PSE approaches it is always useful to start from the premise that estimating the size of a highly stigmatized, often criminalized and therefore hidden population, is a difficult task. Consequently, PSE results will never provide the 'truth' or a precise figure. No matter how sophisticated the method, each has weaknesses as well as strengths. There is no golden standard that works well in every context. Given that resources for HIV are becoming scarcer, adding additional questions to calculate PSEs to already planned surveys does not require additional funding. It is recommended to include as many PSE techniques and sources as possible as many of these methods are prone to biases. Ideally, the selection of sites for surveys that have the goal of producing national prevalence and PSEs should be carefully planned and somehow randomized.

Although the steps described above are imperfect, the assessment of bias pertaining to different PSE methods and data collection issues, the consensus among stakeholders, and the ability to visualize and assess the areas of high, medium and low population sizes of MWID in Myanmar, help ensure that these findings will be used. Consensus emerged as a critical factor that led to endorsement and publication and use of the PSEs. Furthermore, the steps involved do not include a complicated process and can be implemented by countries on their own, without too much involvement from outside consultants.

Each of these methods could be impacted if the sampling method, RDS, is not implemented and analyzed correctly, especially if the network sampled is not really the networked captured. For example, this may occur if the intention were to gather data from all MWID and only a sub-group of older MWID or of only the highest risk MWID were captured. This would change the population that the sample was intending to represent and require adjustments to both the PSE and prevalence estimate inferences. Indeed, this survey intended to capture female and male MWID, however few females enrolled. Although there is evidence of females who inject drugs in Myanmar and, although, a few were recruited into this survey, they were taken out of the final analysis. We determined that the higher levels of risk among females compared to males and the underlying network structure of females (as is found in many countries), resulting in high heterophily (i.e., females being only tied to males or no one rather than to other females), would result in unstable prevalence estimates [17] and PSEs. Some data from the National AIDS Program show that of the 18,104 persons who injected drugs and who attended drop-in centers in 2013, only 340 (2%) were female, and out of 21,227 persons who injected drugs reached by prevention outreach activities, only 939 (4%) were female [24].

This paper fills a needed gap to provide guidance on how to extrapolate township (or city, district, region, province) level data to derive national PSEs. Many countries have merely relied on using the mean of estimation techniques or the estimation from just one technique to represent the population size of an entire nation [2, 25]. If countries have unadjusted mean or single PSEs for more than one city, then these estimates are merely averaged to derive a national estimate [25]. The development of more advanced methods to derive national estimates from sub-national data may be forthcoming. However, methods that use more advanced statistical approaches should provide tools that can be easily used by country nationals. Nevertheless, all approaches to deriving national estimates from sub-national data should involve a consensus among a wide range of stakeholders and national experts to ensure that the result is nationally accepted and used.

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Compliance with Ethical Standards

Conflict of interest All authors declare no conflict of interest.

Ethicial Aproval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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