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Research Article

Methodological Issues in Estimating Size of Key Affected Population: Illustrations with data from South Asia

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Abstract

An accurate estimate of the number of KAPs (Key Affected Population) in a country is vital for the monitoring and evaluation of the HIV prevention programme and services and also in the projection of the burden of disease. One of the major constraints in the mapping method of size estimation is that the population to be mapped includes only those who come to mapped locations during the mapping period. It is imperative as some members of KAPs visit hotspots infrequently, and there is turnover in the population; there are also chances of duplication in their estimates. This paper deals with the mapping based size estimation of KAPs and development of correction factors that enhance the accuracy in size estimates of KAPs. These correction factors and adjustments are illustrated with behavioural data from Bangladesh (2015-16), Bhutan (2012-13), Nepal (2011-12), and India (2009-10) collected as part of mapping and size estimation exercises, conducted using the time location cluster sampling.

Applications of all the four correction factors have resulted in a substantial increase in the estimated number of KAPs. The estimated number of MSMs (Men who have Sex with Men) in Bhutan has experienced the maximum increase (80%) due to application of correction factors followed by FSWs (Female Sex Workers) in Nepal (46%) and IDUs (Intravenous Drug Users) in Bangladesh (02%). These illustrations clearly reveal that application of correction factors are useful tools to enhance the accuracy in the size estimates of KAPs, which are often used as the denominator in computing output, outcome and impact indicators adopted for monitoring and evaluation of HIV prevention programmes and interventions. The application of validation in India, Nepal, and Bangladesh portrays that the implicit mechanism of validation with the mapping and size estimation exercise provides a gold standard to assess the effectiveness of the method with the condition that the time gap between the original mapping and size estimation and validation should not be more than 30 days.

Introduction

The size estimation of KAP in an area or in a country is vital for the planning and implementation of HIV intervention programmes and equally useful for estimating and projecting the burden of HIV and co-morbidities in the country or region. Moreover, it has also been recognised as a critical piece of information for advocacy efforts that may influence there source allocation decisions that have an impact on the epidemic potential. Epidemic potential refers to the likelihood of new HIV infections occurring among population groups in different geographic locations. The epidemic potential is heavily influenced by the size of key populations at-risk for HIV (Singh et al., 2011). The UNAIDS and WHO (2010) guidelines on estimating the size of populations most-at-risk to HIV (UNAIDS and WHO, 2011) also emphasise the uses of size estimates for monitoring and evaluation

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of the HIV prevention programme and services, especially in terms of understanding the HIV epidemic patterns; planning prevention, care and treatment programmes, improving the quality of HIV programme evaluations and policy advocacy.

It is worth mentioning that a precise estimate of the size of KAP is essential to persuade policy makers, programme personnel and donors to increase their commitment to deal with HIV as a public health problem. In fact, it may be easier for potential funders to neglect at-risk populations if data are unavailable, or if the basis of the estimates is not clear, or if inconsistencies between estimates are not explained. Evidence of the need for prevention, care and treatment programmes is more compelling, when proper estimates of the sizes of KAPs are available. Further, with the existing epidemiological transition in developing countries, resources for HIV prevention and risk reduction are on a downward trend, and one needs to demonstrate value for money while investing in interventions. National programmes and international donors expect measurable progress towards set targets. Tracking efficiencies and effectiveness through programme monitoring and evaluations also require robust estimations of the size of KAP to precisely measure the reach and coverage of the on-going interventions.

The existing literature suggests a number of different types of methods for size estimation of KAP. One of the repeatedly used methods for the estimation of the size of KAP is the Network Scale-Up Method (NSUM). This is a population-based survey method with the general concept that individual social network is representative of the whole population along with the assumption that given a large sample size, the distribution of subpopulation in the general population is similar to its distribution in the average social network of representative survey participants. One of the major limitations of this method is that there is no direct interaction with KAP members during the survey. The NSUM also does not require the people engaged in risky behaviour to reveal their status to the investigators. The implicit mechanism of the NSUM may affect the accuracy of the information collected from the social network. This method allows one to generalise the model to account for variation in people’s propensity to know people in particular subgroups (barrier effects), such as their tendency to know people like themselves, as well as their lack of awareness or reluctance to acknowledge their contacts’ group memberships (transmission bias). The NSUM estimates also suffer from recall bias, in which respondents tend to underestimate the number of members of larger groups that they know, and conversely for smaller groups as well (Guo et al., 2013; Sulaberidze et al., 2016; Yu et al., 2014 & Maltiel et al., 2015).

Another method of estimating the size of populations at risk for HIV, though used in a limited number of studies, is the multiplier method. The multiplier method relies on data from two sources - institution and population based. It is highly dependent on the quality of the existing data. It can be used with any two population based surveys that intersect, as long as the size of one group is relatively well known. However, the two sources of data must be independent i.e., the probability of being included in the survey should be identical for everybody regardless of their inclusion in the list. Similarly, everyone on the list should be a member of the population being estimated and this population should also be captured randomly in the survey. The first data source (multiplier) need not be random but should be specific to the group being estimated. The two populations for the data sources are equivalent in this method and must have an aligned time period. (UNAIDS and WHO, 2011) In this method, we use a population sample to obtain a multiplier. It is mathematically simple but the greatest difficulty in using the multiplier method is the lack of correspondence between the two data sources. Another, critical issue in using the multiplier method successfully is the need to have clear and consistent definitions between different data sources.

According to UNAIDS 2010, another widely used method for size estimation is the capture-recapture method. It is a method to conduct a capture and tag everyone before releasing them and then to conduct recapture and calculate the proportion of those who were already tagged. The population is considered closed in this method. “In other words, the population available to be captured in the second sampling (i.e., recapture) includes exactly the same set of individuals as it did for the first”. There is no in or out migration .Individual identifiers are collected in both the samples and matched for checking the proportion of common appearances of participants in both the rounds. Notwithstanding the appealing mathematical simplicity, the method seems to suffer highly from its practical inability to adhere to the basic assumption of having a closed population with no migration between two rounds of capture and recapture (Abdul-Quader et al., 2014; Saidel et al., 2010; Sulaberidze et al., 2016 & UNAIDS and WHO, 2003). Moreover, the populations captured in the second sample need to be independent of the sample in the first and each person in the population should have an equal chance of being included in the sample. To avoid violation of these assumptions, often the time between two samples is shortened and unusual days are avoided when conducting the capture and recapture exercise.

The UNAIDS/WHO Surveillance Working Group has published two sets of guidelines for population size estimation in 2003 and 2010. Broadly, the methods described in these guidelines address two different types of size estimates. First direct local-level estimates based on primary or secondary data collection, using mapping or survey-based methods, covering a circumscribed area; these estimates are useful for local level planning and target setting. These also serve as the basis for geographic prioritisation and national level estimates of People Living with HIV/AIDS (PLHA). Second, indirect national-level estimates, derived through extrapolation of direct estimates, typically available in only a subset of locations, these estimates are useful for national level modelling, advocacy and high-level prioritisation (UNAIDS and WHO, 2003, 2011). One of the major constraints of the mapping method of size estimation is that the population that is “mappable” includes only those who come to the mapped locations during the mapping period (i.e., those who are “currently” active). However, the desired population size estimates need to cover a time-frame of one year. Because of this, the numbers obtained in the exercise (i.e., currently active and mappable) are to be adjusted to account for the following facts:

- **a.** Some members of the KAP do not visit hotspots frequently enough to be captured during the period of observation (usually three days at each hotspot).
- **b.** There is turnover in the population. For example, the mean number of years that a woman works in the sex profession might be around two to three years. Similarly, the average number of years that a person is an active IDU might be five to ten years, etc. This implies that each year there will be some "new" members added to the key population, while some others will drop out. Therefore, though such people will be active only for a part of the year they also need to be counted.
- **c.** Members of KAPs may visit multiple hotspots and, therefore, may be counted more than once (i.e., duplicates).
- **d.** Some KAP members never visit hotspots.

In view of the need for the above four adjustments to enhance the validity and reliability of the estimates, it is essential to collect through behavioural data, additional information required for making such adjustments during the mapping exercise. It is against this backdrop that this paper deals with the development of correction factors and validation techniques to enhance accuracy in the size estimation of KAP estimated through mapping of hotspots and size estimation from data collected from India (2009-10), Nepal (2011-12), Bhutan (2012-13) and Bangladesh (2015-16).

Data and Methodology

A precise estimate of the number of KAPs is an important pre-requisite to assess the effectiveness of HIV prevention programmes. This section details out the methods employed in determining the size of KAPs. It also presents the need for each of the above four adjustments with the underlying assumptions and concept of validation, the data required to make the adjustments and the method for applying the change. For making all the adjustments, behavioural data have been used from three countries in South Asia namely, Nepal, Bhutan and Bangladesh. Behavioural data were collected as part of the mapping and size estimation exercise conducted using the time location cluster sampling. The behavioural data were collected from the individual member of KAPs available at the soliciting or cruising hotspots. Respondents were selected from various hotspots by visiting each hotspot on three consecutive days at different points of time in such a way that it may constitute one typical day.

Adjusting for the frequency at which members of KAP visit a hotspot

For different categories of KAPs i.e.,FSWs, MSM, and IDUs, the level of activity at a hotspot may vary widely on different days of the week. At the same time, some KAP members may visit hotspots more frequently than others. If they visit hotspots less often than the period of observation (i.e., if they do not come at least once in a 3-day period), then there is a probability that they were not present at the hotspot during the period of data collection. That is why, the frequency adjustment is based on the assumption that KAPs who visit a hotspot infrequently follow a random pattern in their visits over a period. If there is a strong pattern associated with visiting the hotspot some weeks but not others, then this adjustment may be applied incorrectly. For example, if clients of FSWs receive their salaries once a month or once every two weeks, and if they are more likely to engage in paid sex on a payday, then the number of FSWs estimated during a payday week will be different from that estimated during a non-payday week. For a similar reason, the overall pattern of seasonality (e.g. tourist season in some areas for FSWs or MSM) is not addressed by this adjustment.

The following formula of frequency adjustment is meant to adjust for that potential undercount:

$$S1=\sum_i{\sum_p{C_ixP_{i,p}xf_p}}$$

Where

S_1 = Adjusted total size

Ci = Estimated number of KAPs at the i^{th} hotspot (during the 3-day period when the hotspot is mapped)

$P_{i,p}$ is the proportion of people in facility i that are the frequency group p

$f_{p,}$=KAPs visiting the hotspot with frequency f_p which are derived from behavioural data collected as part of the mapping and size estimation exercise, i.e., f_p=1, for those who are visiting the hotspot daily; f_p=2.5 for those who are visiting the hotspot 2-3 days a week and f_p=7 for those who are visiting the hotspot once a week

Adjusting for duplication in number of KAPs

Some KAP members may visit more than one hotspot in a day or in a week. If key informants (KIs) estimate the number of KAP members coming to a hotspot, they might include those KAP members who have already been estimated by KIs at other hotspots. This adjustment accounts for people who visit multiple hotspots at least once a week. It also assumes that people visit all hotspots with the same frequency. For this adjustment, the data requirement for each hotspot is the number or proportion of KAP members at that hotspot, who also visit another hotspot. The proportions of KAPs operating from multiple hotspots are obtained through Participatory Rapid Appraisal (PRA) technique (Emmanuel et al., 2010) applied in each of the hotspots with a group of primary as well as secondary stakeholders, using specifically designed tools. The adjustment of duplication follows the assumption that this adjustment only accounts for KAP members who may visit multiple hotspots. It cannot appropriately adjust for the same KAP members visiting several hotspots and who will be "double counted" at every hotspot. This adjustment accounts for people who visit hotspots frequently, for example, at least once a week. It also assumes that KAPs visit multiple hotspots with the same frequency.

The formula developed for the adjustment of duplication is as under:

$$S_2 = S_1 - ½ (\Sigma di)$$

where:

S_2 = Adjusted total size

S_1 = Estimated number of KAPs at all hotspots (within the week prior to mapping) di = Estimated number of current KAPs at hotspot (within the week prior to mapping) who visited other hotspots this week

Adjusting for the turnover rate (i.e. people entering and exiting over the course of the year)

At any given point of time, the size of KAP comprises of a mixture of people who have just started, those who have been practicing the behaviour for a while, and those who may stop the behaviour in the near future. To estimate the overall number (for example in a year's time), the current number mapped must be "converted" to an overall number by accounting for the turnover. The basic data requirement for this adjustment is the average duration of risk activity for each group or sub-group of the KAP (e.g. duration of sex work, duration of injection drug use and duration of having multiple male anal sex partners). It should be noted at this point that the duration of risk activity is distinct from the frequency of practicing the activity. For example, a street-based sex worker may, on an average, engage in transactional sex for10 years. This indicates that the duration of being involved in FSW activity is 10 years. Such a sex worker may entertain clients almost every day, or just a few times a week, or possibly only a few days a month during that 10-year period. This indicates the frequency of practicing the activity.

It is worthwhile to mention that the data for estimating the average duration of risk activity should be captured for different groups and sub-groups. For example, if street-based sex workers, on an average, sell sex for a longer period than home-based or establishment-based sex workers, then this information should be captured separately, and the adjustment must be made by the type of sex worker. A rough average at the district or regional level may be sufficient for this adjustment, rather than having to make the calculation separately for each hotspot or even for each sub-district level. In the case of Nepal, Bhutan and Bangladesh this information was obtained from behavioural data collected from the individual members of the KAP population. However, it is also possible to measure this information using PRA of the hotspot. That is why, the adjustment of turnover is based on the assumption that, the number of people who are entering and exiting the population is relatively constant, and there is no seasonality effect in exiting. For example, the individuals who are going to stop the behaviour do not all stop at the end of the year. The group of people who enter the population is similar in composition to the individuals who leave the population, that is, the people leaving are replaced by other individuals who enter the community.

The adjustment of turnover is based on the period for which the estimate is required (e.g. one year) using the following formula:

$$S_3 = S_2 + [T \times (S_2/D)],$$

where:

S_3 = Adjusted total size of KAP over time T

S_2= Estimated number of current KAPs at all hotspot(within the week prior to mapping)

T = Period of interest for the estimate (e.g. one year)

D = Average duration of being a KAP (e.g. three years)

It is worthwhile to mention that the T and D should be in the same units i.e., if one is expressed in years, the other should be expressed in years as well. If one is expressed in months, the other should be expressed in months as well.

Adjusting for "Hidden" Population

This adjustment is conducted in order to account for the fact that a certain proportion of KAPs who are currently engaged in high-risk behaviour may not visit mappable hotspots, or may visit them less than once a week. However, they should be counted in the overall KAP due to their role in establishing the epidemic potential and enhancing the disease burden in any country. This type of adjustment would best be made if there were a way to survey broader groups of KAPs and to assess the percentage of those who visit mappable hotspots (e.g. the proportion of MSM who visit public cruising hotspots, rather than only meeting sex partners at private house parties or via the internet).Sound evidence from published literature about the proportion of different categories of KAPs who are not coming to any mappable hotspot is required. In fact, with the changing scenario of sex workers and IDUs, the modalities of getting clients has also been changing and hence this estimate should be derived with the involvement of key stakeholders in the country.

Formula for hidden population adjustment

The total number of KAPs in a district is inflated by the inverse of the proportion of the population estimated to visit mappable hotspots as follows:

$$S_4 = S_3/P,$$

where:

S_4 = Adjusted total size

S_3= Sum of estimated number of current KAPs at all hotspots (during the week prior to mapping)

P = Estimated proportion of KAPs who visit mappable hotspots

Validation Exercise

To ensure the reliability of size estimates of KAPs derived from broad mapping of locations and hotspots using the segmentation approach, the validation of the estimates is a crucial step before extrapolating it from the local to the national level. It is worth mentioning that any deviance in the number of hotspots or estimated number of KAPs operating from different hotspots may arise due to a number of structural, contextual and environmental factors as well as their simultaneous functioning from multiple hotspots, which may influence the KAPs' mobility from one area of operation to another. Hence, validation plays an important role in the size estimation of KAPs and in introducing necessary modifications if considerable differences are found in the indicators. The validation exercise is conducted to ascertain the accuracy of the estimates obtained from the field mapping exercise and to provide reliable and credible estimates through some core statistical indicators discussed in this section. If values of the core statistical indicators are less than its statistical acceptability, it reflects a partial coverage and hence needs to be updated. Otherwise, the estimates may be refined using various correction factors and extrapolated to produce local to national estimates. The validation methodology includes the following two main approaches.

***Modified Capture-Recapture Approach*:** Owing to the time lag between completion of the original mapping of KAPs across different districts/epidemic regions and the initiation of the validation exercise, which in the case of Nepal ranged from a minimum of one week to a maximum of four weeks, the validation team adopted a modified capture-recapture method and classified all the hotspots into the following three categories:

- Hotspots recorded by mapping teams and could be traced by the validation team (+/+) were classified as matched hotspots;
- Hotspots recorded by mapping teams but could not be traced by the validation team (+/-) were classified as missed hotspots; and
- Hotspots not recorded by mapping teams but could be found by the validation team after using the segmentation approach were classified as new hotspots (-/+).

Application of indices/tests: The data on the estimated number of KAPs of various typologies and their hotspots, gathered by the mapping and validation teams at two points of time was assessed for completeness and effectiveness by applying the following three indices/tests to arrive at the following validation findings:

Estimated number of hotspots expected to be missed by the mapping and validation teams: The estimation of some hotspots that might have been missed by both the teams may be vital for the overall planning and implementation of HIV prevention practices on one hand and for the availability of essential services for different KAPs on the other. This number can be estimated by applying Chandrashekar-Demming's method (NACO, 2009 & Scott, 1973), developed to match events recorded under two independent systems for collecting information under the dual record system. This method is applied under the assumption that the probability of missing a hotspot by the mapping team is independent of the probability of missing a hotspot by the validation team. The formula is as follows:

$$n = \frac{n_1 * n_2}{C}, \text{ where}$$

n_1 is the number of hotspots recorded only by the mapping team in a geographical area, which was not found by the validation team (+/-),

n_2 is the number of hotspots recorded only by the validation team in the same geographical area after a gap of one to four weeks, which was not recorded by the mapping team (-/+), and

C is the number of hotspots recorded by mapping as well as validation teams (+/+).

I. **Positive Predictivity (PP)**: If one assumes that the quality of the validation exercise is of gold standard both regarding completeness and effectiveness, then the positive predictivity of the mapping exercise indicates that the hotspots identified as hotspots by the mapping team are true hotspots. This essentially calculates the proportion of hotspots that are counted by both the mapping and validation teams to the total hotspots counted by the mapping teams. It is calculated as follows:

$$PP = \frac{C}{C + n_1}$$

Where C denotes the number of matched hotspots (+/+), and n_1 denotes the number of missed hotspots, that is, those that were recorded by mapping agencies (-/+) but not recorded by the validation teams in a particular location.

II. **Adjusted Sensitivity:** The proportion of hotspots that are counted by both the mapping and validation teams to the total number of hotspots counted by the validation teams is the adjusted sensitivity. In other words, it indicates the proportion of ‘true’ hotspots identified by the mapping team in a given geographical area. Adjusted sensitivity of the mapping of KAPs (S) in a particular location is computed as follows:

$$S = \frac{C}{C + n_2}$$

Where C denotes the number of matched hotspots (+/+), and n_2 denotes the number of new hotspots, that is, those that were not recorded by mapping agencies (-/+) but recorded by the validation teams in a particular location. Given the variation in the number of KAPs in the common (+/+) and new (-/+) hotspots, this study has used an indicator modified sensitivity by weighting the number of hotspots by the mean size of KAPs. The adjusted sensitivity is defined as follows:

$$Adjusted\ S = \frac{C\overline{\overline{x}}_1}{C\overline{\overline{x}}_1 + n_2\overline{\overline{x}}_2},$$

Where C is the number of matched hotspots (+/+) in a given district/epidemic region for a particular category of KAPs, n_2 is the number of new hotspots (-/+) mapped by the validation team,

$\overline{\overline{x}}_1$ is the weighted average of the number of KAPs of all typologies in a district/epidemic region, and

$\overline{\overline{x}}_2$ is the weighted average of KAPs in all new hotspots recorded by the validation team.

$\overline{\overline{x}}_1$ is computed by assigning the number of KAPs in a particular typology (w_1, w_2, …w_n) as weights to mean numbers of KAPs of various typologies, that is, $\overline{x}_{11}, \overline{x}_{12} \ldots \overline{x}_{1n},$

$$\text{Thus, } \bar{\bar{x}}_1 = \frac{w_1 \bar{x}_{11} + w_{12} \bar{x}_{12} + \ldots + w_n \bar{x}_{1n}}{w_1 + w_2 + \ldots + w_n},$$

Where $w_1 + w_2 + \ldots + w_n = n_1$ or n_2 as per the case. The process of the computation of $\bar{\bar{x}}_2$ is the same as the computational process of $\bar{\bar{x}}_1$ explained above.

Operational Strategies

The first stage of validation is as election of location/hotspots where the validation exercise would be conducted. Ten percent of the locations are selected for this purpose by using the Probability Proportional to Size (PPS) sampling method. PPS sampling is a sample selection method in which the probability of selection for a sampling unit (i.e., location) is directly proportional to the size of locations/hotspots. Larger hotspots have better probability of being sampled in the selected ten percent of locations. (Jenness et al., 2011) Care should be taken to ensure the selection of at least 10 percent of the hotspots of each included KAP typology (i.e. 10% each of FSW, MSM and IDU hotspots) in each location, and wherever not possible, a minimum of one hotspot in each category should be selected. Subsequently, the same process should be repeated, which was followed by the mapping team adopting the segmentation of each location/ hotspot into smaller operational areas, and comprehensive assessment of KAP sizes in each operational area, using free listing techniques.

Results

Results of frequency adjustment presented in Table 1 for the data collected from Kathmandu (Nepal), Thimpu (Bhutan) and Dhaka (Bangladesh) have produced a substantial increase in the estimated size of MSM in Thimpu, Bhutan (37%) followed by FSWs in Kathmandu, Nepal (12%). However, there is no increase in the estimates of people who are injecting drugs in Dhaka, Bangladesh as nearly all of them reported visiting the hotspots on a daily basis. The adjustment for duplication among FSWs, MSM and IDUs is evident from Table 2. This adjustment results in a decline in the number of estimated KAPs, which has increased after the first adjustment. Table 2 reveals that the MSM in Bhutan has the maximum prevalence of duplication (33%) followed by IDUs in Bangladesh (26%) and FSWs in Nepal (11%). As a result, the number of FSWs in Kathmandu (Nepal) declines from 5019 to 4743, the number of MSM in Thimpu (Bhutan) declines from 201 to 168 and number of IDUs in Dhaka (Bangladesh) declines from 3435 to 2992. Therefore, this adjustment is extremely important for designing HIV prevention programmes and providing essential services to the desired people.

The adjustment of turnover is evident from Table 3 that the average duration of working as a KAP is the highest among IDUs in Bangladesh (8.93 years), followed by MSM in Bhutan (6.45 years) and the least among FSWs in Nepal (5.93 years). Even among the FSWs of different types, the average duration of working is the lowest among those operating from establishments like hotels, bars, massage parlours, etc. (4.71 years). However, FSWs operating from their homes have the maximum duration of engagement in the profession (7.07 years). As a result, the estimated number of KAPs after this adjustment increases from 4743 to 5143 in the case of FSWs in Nepal, from 168 to 181 in the case of MSMs in Bhutan and from 2992 to 3160 for IDUs in Bangladesh. Results presented in Table 4 show the adjustment for the hidden population using the proportion of KAPs not coming to any mappable hotspot using the Delphi method.

After this adjustment the number of FSWs in Kathmandu increases from 5143 to 7346, the number of MSM in Thimpu increases from 180 to 361 and number of IDUs in Dhaka increases from 3160 to 3511. Thus, adjustment of all the four correction factors has resulted in a substantial increase in the estimated size of KAPs among each of the three categories of KAPs. The estimated size of MSM in Bhutan has the maximum increase (80%) followed by FSWs in Nepal (46%) and IDUs in Bangladesh (02%). The estimated final size of KAPs may also be presented in interval estimates using the coefficient of range developed with the help of percent difference in the three sources of information about the size of KAPs i.e., PRA estimates, agreed upon estimates and observed and interacted during the hotspot visits by the research team.

Given the relatively larger number of hotspots for FSWs, MSM, and IDUs in the mapped districts in India, Nepal and Bangladesh, the validation exercise has also been proportionately conducted. Application of the Chandrasekhar- Deming's method yields a very few new hotspots and higher values of positive predictivity and adjusted sensitivity in all the three categories of KAPs, especially among IDUs and FSWs (Table 5), suggesting a comprehensive coverage of hotspots by the mapping teams.

Finding of the validation from Table 6 shows that a significantly large number of hotspots were missing resulting in the lower level of adjusted sensitivity in Maharashtra, India. Another important feature of validation in Nepal was the almost simultaneous execution of the validation exercise, with the maximum time lag of four weeks between mapping and validation. It is evident from the analysis that owing to the minimal time lag between the mapping and validation, it yielded highly accurate information in Nepal. In contrast, validation in India, which was conducted after a time lag of four to six months resulted in low Positive Predictivity and adjusted sensitivity (Table 6). The cut-off of 0.90 for Positive Predictivity and 0.80 for Adjusted Sensitivity has been considered following ROC curve to get a decision threshold. It is evident from Tables 6 and 7 that for all the three categories of KAPs, the value of adjusted sensitivity in Nepal is 0.96, 0.89 and 0.94 for FSWs, IDUs, and MSM respectively. The corresponding values in Bangladesh are 0.94, 0.99 and 1.00 for FSWs, IDUs, and MSM respectively, which are much higher than the expected satisfaction level of 0.80.

Discussion

Application of the above methods of adjustment to get precise estimates of KAP size using different correction factors in the countries of South Asia has resulted in increased national commitments to address the STI/HIV vulnerabilities of KAPs and developing suitable policy instruments. Illustrations of these methods with data collected from India, Nepal, Bhutan and Bangladesh and the emerging issues have been organised under two domains namely, different levels of adjustments in the KAP size and validation of the size estimates using modified capture-recapture methods.

Under the first domain, the frequency adjustment has been made on the estimated size of KAPs arrived by those observed and seen during three consecutive day visits to a hotspot after a broad mapping in the selected areas using the segmented approach with values of frequency of their visits to mappable hotspots derived from the behavioural data. Results of frequency adjustment have produced a substantial increase in the estimated size of MSM in Thimpu, Bhutan followed by FSWs in Kathmandu, and, Nepal, however, there is no increase in the estimates of people who are injecting drugsin Dhaka, Bangladesh as nearly all of them reported visiting the hotspots on a daily basis.

The adjustment of turnover has also been an important guiding principle for assessing the concentration of KAPs in any geographical area both regarding number and duration, which may have implications for designing a suitable response to the epidemic. The illustration from the adjustment of turnover reveals that application of correction factors is an effective tool to enhance the precision level of the KAP size estimates. These are often used as the denominator in developing output, outcome and impact indicators used for the monitoring and evaluation of HIV prevention programmes and interventions across the countries at different levels of HIV epidemic.

The inferences drawn from the results of turnover adjustment, necessitates validation of the generated hotspots, by making use of Chandrashekhar- Deming's method. The findings from the validation technique suggest a comprehensive coverage of hotspots by the mapping teams. This level of convergence has been possible primarily owing to the strategy of organising district-level consultations and including all stakeholders related directly or indirectly to the prevention of STI/HIV in KAPs and the general population through different welfare measures and programmes. In fact, the inclusion of NGO partners working in the district also enabled comprehensive listing of the KAP hotspots.

The special feature of the validation exercise in the mapping and size estimation of KAPs in India, Nepal and Bangladesh was the application of standard protocols both by the mapping and validation teams. This process minimised the chance of any deviance owing to structural and operational factors. The importance of district consultations in broad mapping and following uniform protocols is further highlighted by the Indian experience, where the validation exercise for high-risk group (HRG) mapping and size estimation was conducted by the National AIDS Control Organization (NACO, 2009). A substantial proportion of missed hotspots were found in all the districts that were included in the validation in each of the 17 major states covered by the exercise (Singh et al., 2011). One of the important findings of the validation in India was the incomplete coverage of hotspots in the mapping exercise due to variability in the protocols.

An additional attribute of the validation exercise is the time lag between mapping and validation, which has a tremendous impact on the positive predictivity and sensitivity calculated using ROC curve. Variation in the adjusted sensitivity may be due to the increased number of hotspots reported during validation, and variation in the average number of KAPs in the hotspots. These figures of adjusted sensitivity affirm a high degree of convergence in the mapping and validation estimates of hotspots in Nepal and Bangladesh. In contrast, the adjusted sensitivity of validation estimates was found to be low in the case of India, which may be primarily due to increased mobility of KAPs and seasonal variations between the mapping and re-validation exercises. Thus, a minimum time lag between mapping and validation helps in obtaining reliable size estimates and establishing credible evidence for planning programs and services for KAPs.

Conclusions

The application of different levels of correction factors in the mapping method of size estimation of KAPs with illustrations using data from countries in South Asia clearly highlights its role and importance in enhancing the level of accuracy in the estimated size of KAPs. Thus, size estimates with the application of correction factors may increase the reliability of various indicators applied for monitoring and evaluation of HIV prevention programmes across the countries at different levels of HIV epidemic. It provides an opportunity to derive and use the estimated size of KAPs from an independent source other than programme coverage and hence outcome and impact indicators developed based on various programmes and interventions will have higher reliability than those developed with the programme data.

It also provides an opportunity to deviate from the sample surveys, which are based on a strong assumption that KAPs are randomly distributed in the population. The application of validation in India, Nepal, and Bangladesh portrays that the implicit mechanism of validation with the mapping and size estimation exercise provides a good practice for assessing the effectiveness of the method with the condition that the time lag between original mapping and size estimation and validation should not be more than 30 days apart.

Limitations of the Study

There are two major limitations of the method discussed in this paper to estimate the size of KAPs that we would like to specify here. First, while developing correction factors to adjust for undercounting as well as over counting (frequency as well as duplication), the proposed methodology assumes that the visiting pattern observed in the selected hotspot will remain by and large the same across the country. Secondly, adjustment for the proportion of KAPs not coming to any mappable hotspot (D) has been estimated either qualitatively using the Delphi method or from the secondary sources primarily from the published literature, which may not reflect the most recent situation as nature of these behaviours are continuously evolving over time.

List of abbreviations

KAP: Key Affected Population
MSM: Men who have Sex with Men
FSWs: Female Sex Workers
IDUs: Injecting Drug Users
PLHA: People living with HIV/AIDS

Declaration

Ethics approval and consent to participate

Ethical considerations were duly taken care of at the time of collecting primary data from all the countries namely, India, Nepal, Bhutan and Bangladesh. A comprehensively designed consent form with the provision of voluntary participation by explaining to them the possible harm and benefits of participating in the study, protection from harm, informed consent and privacy and confidentiality were canvassed before interviewing the subjects. In fact, key ethical considerations were emphasised during the different phases of the research process namely, planning and preparation, developing a research design, data collection and dissemination of results.

Availability of data and materials: The data which we have used in this paper are taken from the report of each particular country. The datasets analyzed during the current study are not publicly available due to its sensitive nature.

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Table 1: Adjustment for Frequency among FSWs, MSMs and IDUs

Indicators	FSWs (Kathmandu-Nepal, 2011-12)				MSMs (Thimpu-Bhutan, 2012-13)	IDUs (Dhaka-Bangladesh, 2015-16)
	Establishment Based (EB)	Home Based (HB)	Street Based (SB)	All		
PRA estimate	3146	64	809	4018	48	4203
Agreed upon estimate	3754	73	567	3435	93	3621
Observed & interacted(C)	3592	86	790	4476	146	3435
Frequency Adjustment						
P1	0.97	0.89	0.84	0.93	0.87	99.999
P2	0.03	0.10	0.16	0.07	0.09	0.001
P3	0.00	0.01	0.00	0.00	0.04	0.0001
S1	**3911.58**	**104.06**	**1008.01**	**5018.71**	**200.75**	**3435.00**

Table 2: Adjustment for Duplication among FSWs, MSMs and IDUs (2009-2016)

Indicator	FSWs (Kathmandu-Nepal, 2011-12)				MSMs (Thimpu-Bhutan, 2012-13)	IDUs (Dhaka-Bangladesh, 2015-16)
	EB	HB	SB	All		
PRA estimate	3146	64	809	4018	48	4203
Agreed upon estimate	3754	73	567	3435	93	3621
Observed & interacted (C)	3592	86	790	4476	146	3435
S_1	3911.58	104.06	1008.01	5018.71	200.75	3435.00
Duplication Adjustment						
C_i	0.11	0.10	0.14	0.11	0.33	0.26
D_i	430.27	10.41	141.12	552.06	66.25	885.54
$\mathbf{S_2}$	3696.45	98.86	937.45	4742.68	167.63	2992.00

Table 3: Adjustment for Turnover among FSWs, MSMs and IDUs

Indicators	FSWs (Kathmandu-Nepal, 2011-12)				MSMs (Thimpu-Bhutan, 2012-13)	IDUs (Dhaka-Bangladesh, 2015-16)
	Establishment Based (EB)	Home Based (HB)	Street Based (SB)	All		
PRA estimate	3146	64	809	4018	48	4203
Agreed upon estimate	3754	73	567	3435	93	3621
Observed & interacted(C)	3592	86	790	4476	146	3435
S_1	3911.58	104.06	1008.01	5018.71	200.75	3435.00
S_2	3696.45	98.86	937.45	4742.68	167.63	2992.00
Turnover Adjustment						
T	1	1	1	1	1	1
D	4.71	7.07	6.64	5.93	6.45	8.93
S_3	4088.85	105.85	1008.04	5142.57	180.62	3160.00

Table 4: Adjustment for Hidden Population among FSWs, MSMs a n d IDUs

Indicator	FSW (Kathmandu-Nepal, 2011-12)				MSMs (Thimpu-Bhutan, 2012-13)	IDU (Dhaka-Bangladesh, 2015-16)
	EB	HB	SB	All		
PRA estimate	3146	64	809	4018	48	4203
Agreed upon estimate	3754	73	567	3435	93	3621
Observed & seen (S)	3592	86	790	4476	146	3435
S_1	3911.58	104.06	1008.01	5018.71	200.75	3435.00
S_2	3696.45	98.86	937.45	4742.68	167.63	2992.00
S_3	4088.85	105.85	1008.04	5142.57	180.62	3160.00
Hidden Population Adjustment						
P	0.7	0.7	0.7	0.7	0.5	0.9
S_4	5841.22	151.21	1440.06	7346.53	361.00	3511.00

Table 5: Revalidation Exercise Indicating the Effectiveness of Coverage of KAPs in Maharashtra, India 2009-10

KAPs Categories	**Matched Hotspots (+/+)**	**Missed Hotspots (+/-)**	**New Hotspots (-/+)**
FSWs	841	64	330
IDUs	57	54	306
MSM	25	43	132
Total	923	161	768
Statistical Indicators Revealing Effectiveness in the Coverage of KAPs in Maharashtra, India			
KAPs Categories	Estimated no. of missed hotspots	Positive Predictivity	Adjusted Sensitivity
FSWs	0.25	0.93	0.72
IDUs	2.90	0.51	0.16
MSMs	2.27	0.38	0.16

Table 6: Revalidation Exercise Indicating the Effectiveness of Coverage of KAPs in Kathmandu Nepal, 2011-12

KAPs Categories	Matched Hotspots (+/+)	Missed Hotspots (+/-)	New Hotspots (-/+)
FSWs	172	08	05
IDUs	66	06	08
MSMs	62	01	03
Total	300	15	16
Statistical Indicators Revealing Effectiveness in the Coverage of KAPs in Kathmandu, Nepal			
KAPs Categories	Estimated no. of missed hotspots	Positive Predictivity	Adjusted Sensitivity
FSWs	0.23	0.96	0.96
IDUs	0.73	0.96	0.89
MSMs	0.05	0.99	0.94

Table 7: Revalidation Exercise Indicating the Effectiveness of Coverage of KAPs in Dhaka, Bangladesh, 2015-16

KAPs Categories	Matched Hotspots (+/+)	Missed Hotspots (+/-)	New Hotspots (-/+)
FSWs	47	6	5
IDUs	47	3	1
MSMs	40	5	-
Total	134	14	6
Statistical Indicators Revealing Effectiveness in the Coverage of KAPs in Dhaka, Bangladesh			
KAPs Categories	Estimated no. of missed hotspots	Positive Predictivity	Adjusted Sensitivity
FSWs	0.6	0.89	0.94
IDUs	0.1	0.94	0.99
MSMs	0.0	0.89	1.00