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Update for Sampling Most-at-Risk and Hidden Populations for HIV Biological and Behavioral Surveillance

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ABSTRACT

Two meetings, the first one in 2004 in Addis Ababa, Ethiopia, and the second in 2009 in Bangkok, Thailand, on “New Strategies for HIV/AIDS Surveillance in Resource-Constrained Countries” were held through collaborative efforts of UNAIDS, WHO, CDC-GAP and USAID. These meetings gathered technical staff from around the world, to share new strategies, advances and challenges in HIV biological and behavioral surveillance implementation in resource-constrained countries. The first meeting included discussions on recently developed sampling methods to improve data collected from HIV high-risk populations: time location sampling (TLS) and respondent driven sampling (RDS). With the widening use of the TLS and RDS methodologies over time, there have been important technical advances and ongoing methodological challenges not yet formally disseminated. This paper presents some of the key findings of the second meeting and highlights the status of these sampling methods, including challenges and recommendations, of using TLS and RDS with most-at-risk populations for HIV biological and behavioral surveillance.

Keywords

Respondent driven sampling, Time location sampling, most-at-risk populations, HIV, behavioral surveillance
INTRODUCTION

Accurately measuring the prevalence of HIV, other infections, and behaviors over time in most-at-risk populations (MARPs) through biological and behavioral surveillance surveys (BBSS) is essential to planning and implementing cost effective, targeted prevention, intervention and treatment programs [1, 2, 3, 4]. In low-level and concentrated epidemics, sub-populations that are considered most-at-risk for acquiring and transmitting HIV and other infections include injecting drug users (IDUs), males who have sex with males (MSM), and female sex workers (FSWs) [5]. Given that these populations practice stigmatized and/or illegal behaviors, they are often hidden and unwilling to participate in research efforts to measure their infection status and risks.

In January 2004, the first "New Strategies for HIV/AIDS Surveillance in Resource-Constrained Countries" meeting was held in Addis Ababa, Ethiopia1. Presentations and discussions from this meeting led to the rapid dissemination of new surveillance methods and an increase in the quality and quantity of data available to national and international programs. The meeting discussed the emergence of recently developed sampling methods to improve data collected from MARPs. Two of the most promising methods discussed for sampling trends of HIV prevalence and behavioral risk factors of hard-to-reach populations were time location sampling (TLS) and respondent driven sampling (RDS).

Since that meeting, over three dozen studies using TLS and 150 studies using RDS have been conducted among MARPs globally [6-20]. Despite increased use of these methods in recent

1 This meeting was a collaborative effort of the Joint United Nations Programme on HIV/AIDS (UNAIDS), the World Health Organization (WHO), the Centers for Disease Control and Prevention’s (CDC) Global AIDS Program (GAP), and the United States Agency for International Development (USAID).
years, there have been both important new methodological advances, and persistent challenges – neither which has been formally reviewed. The Second Global HIV/AIDS Surveillance Meeting was held in March 2009 in Bangkok, Thailand to share updated advances and limitations in surveillance implementation since the 2004 meeting. This paper presents some of the findings from the second meeting and provides an update to Magnani et al, to highlight the current status, including challenges and recommendations, of using TLS and RDS methodologies with MARPs for HIV BBSS [21].

OVERVIEW: TIME-LOCATION SAMPLING

TLS, also known as Venue-Day-Time Sampling or time-space sampling, came into use to sample hard-to-reach populations, primarily MSM, in the late 1980s-early 1990s [22]. The method draws from targeted and cluster sampling techniques; it is most useful for gathering data from MARPs who congregate and are accessible at public locations (or venues) that can be listed in a sampling frame [20, 23-26].

Briefly, the method entails identifying days and times when the target population congregates at specific locations (i.e., brothels, city blocks, bars, etc.), constructing a sampling frame of time and location units, randomly selecting and visiting time and location units (the primary sampling units), and systematically intercepting and collecting information from consenting members of the target population [24, 25, 27]. The number of group members at each location provides a sampling weight that can be used \textit{a priori}, to draw a self-weighting sample, or \textit{post priori}, in analysis. Data collection may take place at the venue, if space permits, or in a mobile site near the location, such as a van, or by making appointments for potential participants to come to a designated study site.
The major contribution of TLS over other cluster sampling methods is the ability to account for the fact that populations of interest are not statically associated with a particular location and often move between multiple locations during the course of a single day. As such, TLS allows researchers to construct a sample with known properties, make statistical inference to the larger population of location visitors, and theorize about the introduction of biases that may limit generalization of results to the target population [23]. TLS has been used extensively for routine BBSS among visible MARPs that are concentrated in specific geographical areas that may ‘float’ among locations.

OVERVIEW: RESPONDENT DRIVEN SAMPLING

RDS uses a chain referral methodology to collect data from MARPs that are socially networked. Briefly, RDS begins with a set of initial participants (seeds) selected from the target population. Seeds who complete the survey are provided with a set number of coupons used to recruit peers from their social network. Seeds’ recruits redeem the coupon to enroll in the survey and receive their own recruitment coupons. Seeds’ recruits make up the first wave and the sample expands from wave to wave to form a recruitment chain. Recruitment ends when the calculated sample size is reached. In addition to the social incentive of peer pressure, RDS often relies on monetary or ‘gift’ incentives for participating in the survey and for peer recruitment [28].

RDS includes both field and analytical procedures which account for certain known biases found in most chain referral methods [28, 29]. Data are analyzed with mathematical modeling of the recruitment process (social network ties of recruits-recruiters) to generate relative inclusion probabilities [30]. In addition, each participant’s degree (social network size) is collected to account for overrepresentation of those with larger degrees (ability to recruit more persons). When all methodological and theoretical requirements are fulfilled, RDS yields estimates of
population parameters upon which inferences can be made about characteristics and behaviors of
the sampled population [28-30]. The widespread popularity of RDS has resulted in the
occasional ignoring of rigorous adherence to implementation and analysis requirements resulting
in studies claiming to use RDS when in fact they are chain referral samples [12].

ONGOING CHALLENGES: TLS

Challenges associated with TLS fall into three categories. One is whether results from the
sampled population can be extrapolated to the larger population, e.g., do MSM who frequent
dance clubs and bars adequately reflect the entire at-risk MSM population? The second issue
revolves around non-response. How does one account for non-participation at locations, e.g.,
when owners forbid recruitment on their property or for public locations where it is impractical
or illegal to recruit participants? A major question is whether non-response is differential in
settings when people are out on the street or in clubs, hustling or working, when they are
approached to participate in a survey and accept an HIV test. The third issue is analytical. Is the
underlying enumeration, on which the weights are based, sufficiently accurate? Are important
clustering factors associated with the relative frequencies with which people attend a given
location or multiple locations accounted for in the analysis?

There are numerous challenges to the implementation of TLS as well. Poor enumeration
efforts, which rely on identifying suitable locations and counting eligible population members,
create systematic bias. Some locations may be missed, particularly sites that are exceptionally
discrete, while others may not have sufficient numbers of eligible group members.

A potentially important source of bias occurs when a significant proportion of sub-group
members do not frequent public locations. In this situation, implementers must decide if the
public proportion of the population is appreciably representative enough of the group being
studied. In the United States National HIV Behavioral Surveillance System, data were available to suggest that a large majority of MSM (84%) in four cities attended at least one type of location in the sampling frame in the previous year [31]. Similar data are rare in low and middle income settings.

Recruitment locations for MARPs typically include clubs and bars, cruising sites, street corners or brothels, and a variety of other sites. Venue owners may refuse access to surveyors. In some cases, to enhance recruitment efficiency, a limited number of large events like Gay Pride are included as locations in violation of TLS assumptions because of the difficulty with obtaining a site-based denominator [31].

TLS uses a two-stage random cluster sampling technique whereby clusters consist of time frames and locations. These clusters imply that data should be analyzed as a complex sample. However, this kind of analysis is rarely reported. In addition, it has been suggested that TLS data should be explored for clustering by location and differential probabilities that persons who frequent sampled sites may be recruited [32]. The collection of additional data on frequency of site visits can be onerous and required analysis is complex. However, absent the necessary adjustments with such data, incorrect conclusions can be inferred from TLS data. Facilitating collection of minimum requirements for such analysis is an area for further research.

Logistically, TLS relies on public recruitment events that have the potential to jeopardize staff safety, as well as to draw an unwelcome spotlight to the target population. Further, the changing nature of locations, resulting from economics or law enforcement actions, can jeopardize consistent recruitment.
TLS RECOMMENDATIONS

TLS implementers should consider a number of steps to mitigate potential challenges. One, conducting careful and extensive pre-surveillance assessments, involving location mapping and qualitative research, are important to minimize biases [33, 34]. It is essential that this preliminary step be conducted despite expense and time constraints. This step should include both explorations of means to encourage participation of venue owners and better elicitation of attendance frequency.

Two, develop and use efficient methods to collect attendance frequencies for participants. Three, document those sites with blocked access and collect sufficient information about the types of individuals missed to help explain any pursuant non-response bias [35]. Four, sufficient cluster size data should be collected to permit correct complex sampling analyses and, five, such analytic methods should be used and reported. This precludes the use of special events in most cases because of the violation of underlying assumptions. There may be circumstances where recruitment efficiency outweighs maintenance of statistical assumptions. These decisions should be carefully considered and the ramifications described in subsequent reports. Six, full consideration of attendance frequency is recommended. This will require statistical assistance in most cases but a determination of the potential effects should be attempted and described. Finally, seven, strong staff safety protocols must be implemented.
Table 1. Current Challenges and Recommendations in using Time Location Sampling

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representativeness of populations found at accessible locations</td>
<td>High quality formative research to understand the larger population and the accessible population</td>
</tr>
<tr>
<td>Difficult to record non-response</td>
<td>Create rapid, accessible and meaningful individual and venue non-response instruments</td>
</tr>
<tr>
<td>Lack of appropriate analyses based on cluster sampling</td>
<td>Retain a statistician, use correct analyses</td>
</tr>
<tr>
<td>Weighting for analysis may not be accurate</td>
<td>Take steps to assure quality of cluster size determinations</td>
</tr>
<tr>
<td>Systematic bias if locations are missed</td>
<td>Assess potential for missed locations and minimize these. Account for potential biases in reporting</td>
</tr>
<tr>
<td>Bias if certain populations sub-groups do not attend locations</td>
<td>Assess potential for missed sub-populations and minimize these. Account for potential biases in reporting</td>
</tr>
<tr>
<td>Venue owners may block access</td>
<td>Document those sites with blocked access and collect as much information as possible about the types of individuals missed</td>
</tr>
<tr>
<td>Safety issues</td>
<td>Develop and implement protocols to maintain the safety of staff in the field and include security personnel on interview team if needed</td>
</tr>
</tbody>
</table>

**ONGOING CHALLENGES: RDS**

Challenges with RDS include assessing non-response bias; assumptions of random recruitment within personal networks; attaining equilibrium within sample sizes and timeframes; selecting seeds to maximize equilibrium attainment; appropriate incentives to maximize participation and minimize repeats; and managing multiple data collection sites, staffing and participant verification [12, 21, 36, 37].

An important challenge cited in Magnani et al. that still exists today is that RDS, similar to many sampling methods, has no method to fully track refusal rates and the potential impact of
non-response bias. Non-response bias can arise if individuals are brought into the respondent pool through persuasive efforts, (i.e., incentives, peer pressure), when the characteristics of those who agree to be interviewed may be markedly different from those who decline. Such coercion is not easily measured in RDS or other sampling methods.

The assumption of random recruitment among important subgroups within a social network has not been formally tested. There are three levels for assessing random recruitment among subgroups: 1) random coupon distribution (participants distribute their coupons randomly among different subgroups within their social network); 2) coupon acceptance (those approached accept coupons randomly); and, 3) coupon redemption (those who accept a coupon enroll in the study randomly). Non-random coupon distribution occurs when seeds are homogenous on an important variable, (e.g., MSM seeds identified through an active MSM organization) and therefore recruit from among their own subgroup, (e.g., “out” MSM) without reaching into other important subgroups (hidden MSM). Non-random coupon acceptance occurs when one subgroup, (e.g., out-of-treatment IDUs) is more reluctant to accept a coupon compared to another group (e.g., in-treatment IDUs). Non-random coupon redemption occurred when MSM who did not want HIV/STI testing accepted coupons from their peers with no intent to use them [38].

In RDS the number of waves required for equilibrium is simulated for each variable using a Markov chain model that calculates the sample composition of each wave based on that of the prior wave. To be conservative, the simulation begins with 100% of the sample in one category state. The assumption is that after numerous waves, the sample composition stabilizes and becomes independent of the non-randomly selected seeds [29]. Often this is interpreted as an indication that the sample has a sufficient number of waves to justify analysis. Another interpretation is that only the waves after reaching equilibrium are unbiased by the seeds [37],
suggesting that only those participants in the waves beyond equilibrium are suitable for analysis. Yet another interpretation is that for studies in which the majority of recruits originate from one seed that analysis should occur only on the longest chain [39]. Recent analyses using actual and simulated data have found that the gain from analyzing only data obtained after reaching equilibrium was not worth the loss due to reductions in sample size resulting from throwing out earlier waves [36, 40]. Retaining earlier waves may contribute to bias based on its distance from the equilibrium point; however, discarding these data in smaller populations may induce bias because early respondents are effectively excluded from the study.

A sub-optimal selection of seeds can induce bias as well as increase the estimator variance more than originally reported [28, 29]. Current research indicates that attempts to diversify seeds have led to having too many seeds with too few waves to reach diverse sub-populations, especially in highly clustered populations [40, 41]. A sub-optimal diversification of seed characteristics may overlook important but not previously identified cleavages within social networks. In one example, IDU seeds were selected by outreach workers from an HIV testing organization based on age, gender, years of injecting and type of drug used [42]. The network of HIV (+) IDUs in this city was highly clustered and all seeds were HIV (+). Although recruitment chains were long (at least 9 waves), recruitment did not reach beyond the network of HIV (+) IDUs thereby biasing the final HIV estimates.

The use of incentives in RDS requires ascertaining its perceived value by the participant for the level of effort expended in having to participate in the study. This balance varies depending on the target population and should be considered while also recognizing the distinct difference of RDS to other types of sampling methods, namely the harnessing of peer pressure to increase participation by offering respondents a reward for recruiting their peers. To earn maximum
compensation participants must ensure that their recruits participate. Although attempts to re-enroll in surveys have been estimated to be minimal [43], survey planning must take into account that incentives that are too large will encourage repeat participants, (i.e., duplication).

The use of multiple sites to collect RDS data is usually a response to inaccessibility of the target population to a single site due to traffic or the size of the city. Managing multiple data collection sites to prevent participants from enrolling more than once and to ensure sample network cross over should be performed/considered carefully. A key assumption of RDS is that the sample population form one complete social [28, 29] network and that having multiple recruitment sites will result in having a separate sample (social network) for each site if social networks do not cross over among sites.

A final challenge to using RDS is how to ensure that participants who present to a survey with a valid coupon are actually members of the population being sampled. Although current IDUs can often be identified by asking them to show staff their injection stigmata, verifying whether MSM or FSWs are actually members of these respective populations is more difficult and can lead to measurement bias if not controlled. On the other hand, telling someone that they cannot enroll in the survey because staff believe they are not a member of the sampled population, when in reality they are, can lead to resentment from participants and others in the community and, in some cases, threats against staff.

**RDS RECOMMENDATIONS**

Although not all of the challenges mentioned above have solutions, there are several recommendations that can assist in reducing bias and increasing the success of RDS studies. To provide some understanding about the individuals who do not respond to a RDS survey, most surveys now incorporate a brief follow-up interview to collect data (data collected when
participants redeem their secondary incentive) about persons to whom participants tried to give a recruitment coupon and reasons for not accepting a coupon [44]. Reasons for non-acceptance are identified for each person whom the participant reports refused to accept the coupon. Although this does not cover the entire extent of potential non-response biases, it helps explain some bias and, perhaps, identify key groups missing from the sample.

Efforts to test random recruitment among sub-groups have had mixed results [19, 29 45] and require more development. Testing this assumption involves comparing the recruited population to the reported composition of participants’ subgroups with respect to visible attributes, such as gender or race [45]. However, non-random recruitment, if it occurs, will not necessarily bias the RDS estimator as long as recruitment is not correlated with any variable important for estimation [46].

Because of the numerous RDS studies conducted over the past few years, there have been a sufficient number of datasets available to assess the attainment of equilibrium within sample sizes and timeframes. During analyses of datasets from more than 20 RDS studies conducted around the world, equilibrium was reached on key variables such as HIV status, age and education between 2 and 6 waves, and in very few cases in as much as 9 waves (first author, personal experience). Best practice is to ensure very long recruitment chains (ideally >9 waves) and pay careful attention to the number, degree and diversity of selected seeds. In addition, conducting formative research in advance of an RDS study is vital to selecting seeds that will be as representative of the target populations as possible [40, 47] to ensure faster attainment of equilibrium.

Although the most effective incentive to maximize participation is unknown, the majority of studies have used cash incentives, followed by cash equivalents, (e.g., grocery vouchers, gift
certificates), small goods with minimal monetary value, and condoms or lubricants [13]. A handful of studies have used no incentive [13]. Beyond incentives, many studies offer additional services, such as free HIV and STI testing and counseling or clinical examinations which may facilitate recruitment more than monetary incentives, especially for marginalized respondents without access to health care [12]. Appropriate incentives should be determined through formative research and an assessment of the economic value of goods in each setting.

Currently, several studies have introduced the following question to understand motivation for participating: ‘Why did you accept a coupon to participate in this survey?’ For instance, in a study of MSM in Dhaka, Bangladesh, the majority of respondents (57.9%) responded that their primary reason for accepting a coupon was to receive the ‘clinical consultation and blood test’; only 28.5% stated ‘receiving money’ as their primary reason for accepting [48].

In addition, the incentive offered should not be so large that it will encourage repeat participants, (i.e. duplication). Attempts to re-enroll in surveys has been estimated to be minimal [43]; however techniques to minimize re-enrolments include using a computer program to record and search participants’ biometric measurements [43, 49], having program staff rotate between sites to decrease the likelihood of participants visiting multiple sites [12, 49], and, explaining to participants that if they give their coupon to someone found to be ineligible due to prior participation, they will not get their recruitment incentive for that person.

To avoid repeated enrollment by population members due to having multiple data collection sites within a city is best addressed by examining the reason behind having more than one recruitment sites, (i.e., the need to reach populations across a large, sprawling city; cities with poor transportation). First, recruitment sites should not be so close together that population members can easily travel from one site to the other. Second, the incentive should not be so high
that the time and cost needed to travel between sites are justified for participants to re-enroll. To manage data collection in and network cross-over among multiple sites, develop a communication protocol and ensure that site supervisors meet daily or, if there is one supervisor for multiple sites, that he/she visit each site daily to review management forms.

Finally, verification of respondents’ membership in the target population is best addressed by well-trained staff with extensive experience working with the population. In some cases, hiring actual members of the sample population is useful. Finally, hiring and training a ‘screener’, whose only job is to verify eligibility and enroll participants, will reduce chances that ineligible individuals are enrolled [44].
Table 2. Current Challenges and Recommendations in using Respondent Driven Sampling

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Recommendations</th>
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<tr>
<td>Popularity of RDS has resulted in ignoring rigorous adherence to</td>
<td>Review and understand relevant materials on conducting RDS; use the RDS manual</td>
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<td>implementation and analysis requirements</td>
<td>[44]; seek out others who have properly conducted RDS studies; obtain</td>
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<td></td>
<td>professional technical assistance; use a written protocol that has been</td>
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<td>reviewed by experts and assure adherence to the protocol</td>
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<tr>
<td>Difficult to assess non-response bias</td>
<td>Incorporate a brief follow-up interview to collect data about persons to whom</td>
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<td>participants tried to give a recruitment coupon and reasons for not accepting</td>
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<td>a coupon</td>
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<tr>
<td>Difficult to measure the assumptions of random recruitment within personal</td>
<td>Compare recruitment to the reported composition of participants’ sub-groups with</td>
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<td>networks</td>
<td>respect to visible attributes and then comparing these self reports to actual</td>
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<tr>
<td></td>
<td>recruitment patterns</td>
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<tr>
<td>Ensuring the attainment of equilibrium within sample sizes and timeframes</td>
<td>Ensure very long recruitment chains (ideally &gt;9 waves); pay careful attention</td>
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<td>to the number, degree and diversity of selected seeds</td>
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<tr>
<td>Selection of seeds to maximize equilibrium attainment</td>
<td>Conduct formative research in advance of a study to select seeds that are as</td>
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<td></td>
<td>representative of the target populations as possible</td>
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<tr>
<td>Determining the appropriate incentives to maximize participation</td>
<td>Conduct formative research in advance of a study to determine appropriate types</td>
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<td></td>
<td>of incentives; assess the economic value of goods in each setting; ask</td>
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<td>participants their motivation for participating in an RDS study to plan</td>
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<td></td>
<td>incentives for future studies; be creative.</td>
</tr>
<tr>
<td>Determining the appropriate incentives to minimize repeaters</td>
<td>Conduct formative research in advance of a study to determine appropriate types</td>
</tr>
<tr>
<td></td>
<td>of incentives; assess the economic value of goods in each setting; if</td>
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<td></td>
<td>available, use a computer program to record and search participants’ biometric</td>
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<td></td>
<td>measurements; explain to participants that if they give their coupon to</td>
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<tr>
<td></td>
<td>someone found to be ineligible due to prior participation, they will not get</td>
</tr>
<tr>
<td></td>
<td>their recruitment incentive for that person; be creative.</td>
</tr>
<tr>
<td>Managing multiple data collection sites and staffing</td>
<td>Assess the reasoning behind having multiple recruitment sites; hire staff with</td>
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<td>either personal</td>
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or work experience with the sample population; have designated staff roles with adequate training; develop a communication protocol to ensure cross over among sites and to coordinate data collection.

| Verification of membership in the sampled group | Hire and train a ‘screener’ whose only job is to verify eligibility and enroll participants; Use current or former sample population members as screening staff; know the behaviors and develop screening questions to which only the sample population can accurately respond. |
CONCLUSION

This paper updates the current use and challenges associated with using TLS and RDS for measuring HIV prevalence and risk factors among MARPs. Each approach has advantages and disadvantages. Decisions about which approach to use require careful analysis of the geography, target population, and surveillance goals. However, sampling MARPs is a challenging task and currently TLS and RDS are the most reliable methods available.

The strength of RDS is externally valid (generalizable) data from hidden populations in urban areas. Reaching the non-visible sub-groups of MARPs is important to understanding the full impact of the HIV epidemic. The extent to which RDS is able to reach a portion of the population missed by TLS has been examined among FSWs in Vietnam [50], FSWs and MSM in Papua New Guinea [51] and MSM in the United States [52] using a subsample of an RDS sample to simulate TLS. All of these simulations found that the RDS sample recruited more hidden population members than did TLS and produced variation in estimators depending on the sampling method. In a comparison of TLS (2002) and RDS (2005) conducted in MSM in Brazil, RDS data were more diverse with respect to socio-economic status and closer to the area’s social class structure [53].

However, RDS relies on a theoretical foundation that is still debated. Many of the assumptions require further testing and refinement. Now that RDS has been utilized in several countries as the sampling method for routine surveillance, more evidence will arise to assess its level of accuracy in measuring HIV and risk behavior trends over time. An important consideration is prior use of a method for HIV surveillance in a country. Jettisoning a reasonably successful method for marginally improved data from a new method must be
weighed carefully. A newly introduced sampling method may require 2-3 rounds before it will provide valid trend data.

TLS may be a more appropriate method than RDS method to gather HIV BBSS data if the target population can be identified at visible, safely accessible locations. Furthermore, TLS may be superior if a population is not networked to permit sustained recruitment through RDS. A well-conducted TLS study can have the advantage of providing a measure of control of the sampling frame, resulting in knowable reliability when tracking trends, (i.e., trends are realistic and make sense, e.g., Nepal and Thailand). [54-56]

However, data collection using any TLS or RDS has a “forgiveness factor”; as long as the methodology used is consistently applied over time, the resulting trends in prevalence, both biological and behavioral, provide useful information because biases are assumed to be consistent over time.

The importance of conducting detailed pre-surveillance field assessments to properly plan TLS or RDS surveys is vital. Qualitative data are critical to well-designed sampling procedures, e.g., venue selection for TLS or seed selection for RDS, and the required spectrum of indicators and the correct phrasing of questions.

Some key RDS issues requiring more research include: 1) the impact of seed selection on the estimators, and how to best recognize social network cleavages and select appropriate seeds; 2) the impact of degree on the estimators, and how to improve degree measurement; 3) respondent behavior associated with coupon distribution, acceptance and redemption (whether this occurs randomly), 4) whether peer recruitment is random such that a respondent can be reached by any other respondent through a series of network ties (network forms a single component); and, 5) how to manage pre-equilibrium data.
The underlying assumptions of TLS are well-validated. However, a closer examination of frequencies of venue owner participation and its impact on weighting is warranted. Formal methods for documenting and considering the effects of venue participation refusals are needed. Additional research on analyses that include frequency of attendance at participating venues is critical to determine if inferences are valid.
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