Sampling Males Who Inject Drugs in Haiphong, Vietnam: Comparison of Time-Location and Respondent-Driven Sampling Methods

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ABSTRACT *Accurate measurements of HIV prevalence and associated risk factors among hidden and high-risk groups are vital for program planning and implementation. However, only two sampling methods are purported to provide representative estimates for populations without sampling frames: time-location sampling (TLS) and respondent-driven sampling (RDS). Each method is subject to potential biases and questionable reliability. In this paper, we evaluate surveys designed to estimate HIV prevalence and associated risk factors among people who inject drugs (PWID) sampled through TLS versus RDS. In 2012, males aged ≥ 16 years who reported injecting drugs in the previous month and living in Haiphong, Vietnam, were sampled using TLS or RDS. Data from each survey were analyzed to compare HIV prevalence, related risk factors, socio-demographic characteristics, refusal estimates, and time and expenditures for field implementation. TLS ($n=432$) and RDS ($n=415$) produced similarly high estimates for HIV prevalence. Significantly lower proportions of PWID sampled through RDS received methadone treatment or met an outreach worker. Refusal estimates were lower for TLS than for RDS. Total expenditures per sample collected and number of person-days of staff effort were higher for TLS than for RDS. Both survey methods were successful in recruiting a diverse sample of PWID in Haiphong. In Vietnam, surveys of PWID are conducted throughout the country; although the refusal estimate was calculated to be much higher for RDS than TLS, RDS in Haiphong appeared to sample PWID with less exposure to services and required fewer financial and staff resources compared with TLS.*

KEYWORDS *People who inject drugs, HIV/AIDS, Respondent-driven sampling, Time-location sampling, Bio-behavioral surveillance*

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INTRODUCTION

Many countries conduct routine bio-behavioral HIV surveillance surveys among key populations at higher risk for HIV infection, including people who inject drugs (PWID), to monitor epidemic trends, assess the impact of interventions, and inform resource allocation for prevention, care, and treatment services. Accessing key populations for programmatic and surveillance purposes can be difficult because their risk behaviors are often stigmatized and illegal; this complicates recruitment of participants who might prefer to remain “hidden.”¹ Two widely used approaches to sample hidden, high-risk populations for surveillance are time-location sampling (TLS) and respondent-driven sampling (RDS).² TLS seeks to approximate probability-based sampling by mapping the universe of physical venues where the target population (e.g., PWID) congregates, randomly selecting the day, time, and location of these primary sampling units for recruitment, and systematically selecting participants from randomly selected time-venue units. Inference is limited to individuals who attend venues and may not represent populations that do not congregate at such defined venues.^{3,4} RDS is a modified “link-tracing recruitment” method with a limited number of recruits per enrollee that uses information about recruitment patterns (e.g., who recruited whom) and participants’ social network sizes to account for biases normally found in peer recruitment methods.^{5,6} Special software applies the network referral pattern and reported individual network size to produce population estimates and standard errors.⁷ Both methodologies have strengths and limitations related to implementation, analysis, and interpretation and have been widely implemented for HIV surveillance in Vietnam and elsewhere.⁴

Rigorous evaluation and comparison of these surveillance methodologies in various contexts and populations are necessary to determine the most accurate and appropriate approach for HIV surveillance among high-risk populations in specific settings. Comparisons of TLS and RDS to date have been based on analyzing RDS samples stratified by variables of interest (e.g., venue-going and non-venue-going)^{8,9}, applying different recruitment methods during different time periods^{10,11}, or have been limited by small sample sizes and unweighted analysis.¹² Direct comparison of TLS and RDS has been conducted among MSM and transgender persons in Latin America^{13,14} and among female sex workers in China¹⁵ to profile the differences in populations reached via TLS and RDS and to compare operational characteristics such as expenditures and time required for field implementation. To date, there have been no studies published that directly compare RDS and TLS among PWID.

Haiphong, the third largest city in Vietnam (population 1.8 million), is an important port and industrial city. An estimated 7200 PWID reside in Haiphong. Using RDS, HIV prevalence among PWID in Haiphong was estimated at 65.8 % in 2006 and 48.0 % in 2009.¹⁶ Since 2005, availability of HIV/AIDS prevention, care, and treatment services has increased through significant investments by the Vietnam Ministry of Health, the President’s Emergency Plan for HIV/AIDS Relief, and the Global Fund for HIV/AIDS, TB, and Malaria. Haiphong has also made considerable progress in expanding its methadone maintenance therapy (MMT) program; >2500 PWID received MMT as of 2012.¹⁷ Because of the historically high prevalence of HIV and the investment in responding to HIV/AIDS in the country, evaluating surveillance techniques to identify the most appropriate and valid approach for HIV surveillance among PWID in Haiphong and other metropolitan areas with sizeable PWID populations is justified.

Two independent cross-sectional surveys were conducted among male PWID in Haiphong City, Vietnam, using TLS from October to November 2011 and RDS from February to March 2012 to measure HIV prevalence and associated risk behaviours and to compare key aspects of each surveillance methodology. Specifically, we sought to evaluate differences in characteristics of the population reached, biases in each of the sampling methods, response and refusal estimates, geographic coverage, and time and expenditures for field implementation.

METHODS

Sampling

Two cross-sectional surveys were conducted among males aged ≥ 16 years who reported injecting drugs in the previous month and lived or worked in Haiphong. The sample size was calculated for each survey using a baseline HIV prevalence of 45 %, with 80 % power, 95 % confidence to measure a 15 % change over time between survey rounds, and a design effect of 1.5. The final sample sizes calculated were 400 PWID for each survey. The protocols for these surveys were reviewed and approved by the US Centers for Disease Control and Prevention, FHI 360 (formerly Family Health International), and the Vietnamese Ministry of Health and National Institute of Hygiene and Epidemiology.

RDS METHODS

Before data collection commenced, formative assessments were conducted to (1) assess the networks and potential bottlenecks (isolated sub-populations of PWID), (2) screen and identify initial recruitment subjects (i.e., “seeds”), (3) determine appropriate compensation levels, and (4) identify and respond to logistical challenges.

RDS recruitment began with three seeds selected based on having large social network sizes of eligible PWID and diverse ages, duration of injection drug use, residential geography in the city, employment status and income. Eligible PWID with a valid coupon could enroll in the fixed interview site allocated for the survey. Upon completion of the survey requirements (i.e., eligibility screening, informed verbal consent, face-to-face interview, and biological testing), each seed and subsequent participant received two coupons to use for recruiting eligible peers in their social network. Participants could return to the survey site for a second visit to receive their secondary compensation for recruiting their peers. To facilitate confidentiality, participants' coupons, questionnaires, specimens, and test results were identified using a unique study identification number; no personal identifying information was collected. An electronic coupon manager system was used to monitor who recruited whom, coupon distribution and redemption, and compensation distribution.

TLS METHODS

TLS was conducted by generating a sampling frame comprising venues where PWID congregate (i.e., inject, hang-out, purchase, and sell drugs) and the specific times of day and days of the week during which they are most often found at these venues.³ Venues in Haiphong were identified by reviewing, verifying, and updating existing

mapping data from previous mapping exercises; Through field visits, the times and days when PWID frequented these venues were identified, and the number of PWID congregating at venues during these times and days were enumerated. In addition to the process of defining venues, formative assessment consisted of determining compensation levels and identifying and responding to logistical challenges. One hundred and thirty-six venues and gathering points were identified, some of which were combined if they were found to have small numbers of PWID or were close together. Venues were combined into clusters of approximately ten individuals, and 43 clusters were randomly selected using probability proportional to size. All PWID found at recruitment sites were approached, screened, and provided an invitation coupon to visit one of four fixed sites to enroll in the survey. When there were more PWID than the enumerated size, participants were randomly selected; when few PWID were present, all PWID appearing at the venue within 2 h were selected. If there were still not enough PWID in the sample after 2 h, interviewers returned to the venue on another day.

Data Collection

Data and specimen collection processes at the study sites were the same for participants recruited through RDS and TLS. Eligible PWID who provided informed verbal consent were interviewed face-to-face using a structured questionnaire to measure socio-demographic characteristics, risk behaviors, and program access. Participants who completed the interview were asked to provide blood samples for HIV testing. All participants were remunerated 150,000 VND (7.5USD) upon study completion. RDS participants could return to the interview site for a second visit to receive 50,000 VND for each peer whom they recruited and who enrolled in and completed the survey.

HIV Testing and Results

Rapid HIV testing was conducted at the survey sites based on national guidelines. Venous blood was screened for HIV infection by using Determine (Abbot, Japan) and confirmed by using EIA-Green HIV ½ (Bio-Rad, US) and Murex ½ (Murex Biotech, UK). Participants were directed to the HIV testing and counseling center at the Provincial AIDS Center in Haiphong for further HIV testing and to receive their test results and, if necessary, referral for further management and care.

Data Analysis for Estimates

For RDS, estimates and 95 % confidence intervals (CI) were calculated with RDS Analyst version 9.0 (www.hpmrg.org) using the successive sampling estimator⁷ with a mid-range PWID population estimate of 7000.¹⁶ For TLS, all estimates were calculated using STATA version 12 with weights using the inverse proportion of the product of the probability of the venue (i.e., cluster) being selected, the probability of the individual participants being selected at each venue, and by the frequency of appearing at a venue.¹⁸ Variance in the TLS sample was adjusted for the complex survey design.

Measuring Bias in the RDS Sample

Biases for RDS were assessed by calculating convergence, homophily, reciprocal relationships, and consistency in reported network sizes over time. Convergence was assessed for each variable by comparing the wave at which the sample statistic stabilized in relation to the final sample statistic (within 2 %). Convergence should

occur well in advance of the maximum number of recruitment waves in the sample for each variable analyzed. If the sample estimate remains consistent in advance of the maximum number of waves, the final sample is said to be unbiased by the initial participants. Recruitment homophily was measured by the ratio of like-with-like ties in the recruitment chains, and population homophily was measured by the ratio of like-with-like social ties in the network. Population homophily should hover around 1 for a defined characteristic if recruitment is random. Extreme (>4) homophily could indicate nonrandom recruitment and bottlenecks (unconnected subpopulations) in the recruitment or the network and could result in biased estimates. Reciprocal recruitment was measured by asking recruits about their relationship with the person who recruited them and asking recruiters who showed up to the second visit about their relationship with the person(s) they recruited. Recruitment of strangers is a violation of reciprocal relationships, and strangers were not allowed to enroll in the survey.

Accurately measuring social network sizes is essential for producing unbiased estimates. Several questions were asked to measure each participant's social network, including the following: "How many men do you know, who also know you, who are 16 years or older, injected drugs in the past 1 month, reside in Haiphong and whom you have seen in the past 2 weeks?" To assess the accuracy of the responses to the social network size question, the same questions were asked at two different points by the same interviewer: during the survey first visit (i.e., enrollment) and again during the second visit (i.e., to collect secondary compensation). Consistent responses at the two time points suggest reliability of the network size responses.

Measuring Differences in TLS and RDS

Estimates Differences in adjusted means and estimates between the TLS and RDS surveys were calculated using unpooled Z-tests with differences between the two estimates divided by the square root of the sum of their variances. *P* values of ≤ 0.05 were considered statistically significant.

Geographic Coverage Geographic coverage was based on where each participant reported living within Haiphong City. These points were graphed onto a map of Haiphong city using ArcGIS v.10.1.

Refusal Estimates Refusal estimates in TLS were assessed by summing the number of eligible persons who refused invitation coupons at a venue and the number who accepted an invitation coupon at a venue but did not participate and then dividing by the number of eligible persons who were approached at a venue. The following formula was used:

$$\text{Refusal estimate} = \left(\sum m_i + \sum n_i \right) / \sum t_i$$

where

- m_i : # eligible people who refused invitation coupons at a cluster (i.e., venue)
- n_i : # eligible people who accepted invitation coupons at a cluster *i* but did not participate
- t_i : # eligible approached at a cluster *i*

For RDS, refusal estimates could be impacted through one of the three following scenarios: participants not passing a coupon to peers, and peers not accepting or not

redeeming a coupon. Refusal estimates were assessed by asking participants who returned for a secondary compensation the following questions: (1) “How many people did you try to give a coupon to?” and (2) “Among those, how many accepted a coupon?”

Field Implementation Expenditure Estimations We applied an ingredients-based costing methodology, in which direct field implementation expenditures and logistics (recruitment, compensation, staffing, and other expenditures; not including protocol and materials development) for each study were estimated from expenditure records. Staffing costs in person-days and per participant during recruitment and data collection were also estimated from expenditure records.

RESULTS

RDS and TLS Recruitment

The RDS survey took 6 weeks, resulting in 415 participants recruited from three seeds, with a maximum of 12 recruitment waves. Bias in the RDS sample was measured for all variables in Table 1. Convergence was attained for all variables before the fifth wave, indicating minimal seed dependence for the final sample. Recruitment and population homophily were low or not present (<1.1), indicating random recruitment within recruitment chains and the social networks. Relationships between recruits and recruiters were reciprocal: 0.3 % of participants reported that their recruiter was a stranger, 85 % of recruits reported seeing their recruiter at least every week, and 97.1 % of recruiters reported knowing their recruit for at least 1 year. Among those participants who presented for a second visit ($N=192$), reported network sizes did not differ significantly between the first and second visit.

The TLS survey, including mapping, took 10 weeks, resulting in the identification of 136 PWID hotspots at which 1065 PWID were enumerated. Among the 43 clusters selected with probability proportional to size, ten participants were recruited from 12 clusters, <10 participants were recruited from 13 clusters, and >10 participants were recruited from 18 clusters.

Several estimates derived from the RDS and TLS samples differed significantly (Table 1). PWID sampled with RDS compared with those sampled with TLS were older (mean age, 37 vs. 34.8 years, $p=0.02$), injected more frequently (2.8 vs. 2.6 times per day, $p=0.01$), and had fewer sex partners in the past year (mean, 0.9 vs. 1.3 partners, $p=0.01$); mean income and mean number of years injecting drugs did not differ significantly between the two samples. PWID sampled with RDS compared with those sampled with TLS were less likely to inject at home (12 vs. 24 %, $p=0.01$), and more likely to inject on railway tracks (86 vs. 66 %, $p=0.02$); the estimates of the proportion of PWID who were employed, injected in public places or shared needles in the past 6 months, did not differ significantly. Estimates did not differ significantly for having had sex or using condoms with a regular or commercial partner in the past year.

A significantly lower proportion of PWID sampled using RDS compared with those sampled through TLS reported receiving methadone (2 vs. 16 %, $p=0.00$) and meeting with an outreach worker (15 vs. 27 %, $p=0.04$) in the past year. There were no significant differences found between the two survey methods for the proportion of PWID who had received clean needles, had an HIV test in the past year or who were HIV seropositive.

TABLE 1 Demographics, behaviors, service utilization, and HIV prevalence among PWID, Hai Phong, Vietnam, 2011–2012

Characteristics	RDS (N=415)			TLS (N=432)			P value
	Mean	95 % CI	SD	Mean	95 % CI	SD	
Age	37.0	36.1, 37.8	9.0	34.8	33.7, 35.9	8.0	0.02
Income (in million VND)	4.5	4.3, 4.7	2.1	4.8	4.4, 5.2	2.8	0.19
Injecting duration (year)	7.3	6.7, 7.8	5.5	7.7	6.9, 8.6	4.9	0.44
Injecting frequency/day	2.8	2.7, 2.9	0.8	2.6	2.5, 2.7	0.9	0.01
Number of sex partner in past month	0.9	0.7, 1.1	1.8	1.3	1.1, 1.5	2.0	0.01
Unemployed	%	95 % CI	SD	%	95 % CI	SD	P value
Injecting locations	27.2	21.9, 32.4	44.6	19.5	13.8, 25.2	39.7	0.29
Home	11.8	7.7, 15.9	32.3	23.5	18.2, 28.7	42.4	0.01
Railway tracks	85.6	81.6, 89.6	35.1	66.2	52.5, 79.9	47.4	0.02
Public places	2.5	0.7, 4.2	15.3	5.6	2.8, 8.5	23.7	0.07
Shared needle in past six months	4.1	0.7, 7.5	19.6	3.7	1.5, 5.9	18.8	0.77
Sex with regular partner in past year	37.3	30.8, 43.6	48.8	47.4	40.8, 56.8	50.0	0.29
Used condom with regular partner in past year	29.1	19.2, 38.9	45.7	41.7	33.3, 50.0	49.4	0.30
Sex with commercial partner in past year	14.8	10.1, 19.5	35.6	18.2	13.8, 22.6	38.6	0.78
Used condom with commercial partner in past year	71.2	50.3, 91.3	45.9	91.0	83.4, 98.7	28.7	0.37
Received needles in past year	20.3	15.1, 25.2	40.3	28.5	19.5, 37.5	45.2	0.49
Received methadone treatment in past year	1.6	0.0, 3.1	12.4	16.1	9.4, 22.9	36.8	0.00
Met with outreach worker in past year	15.2	11.2, 19.2	8.0	26.8	19.8, 33.8	43.3	0.04
Had HIV test and received test results in past year	21.8	16.4, 27.1	41.4	30.7	24.5, 36.9	46.2	0.21
HIV prevalence	38.8	32.1, 45.7	48.9	43.5	36.7, 50.2	49.6	0.82

Geographic Coverage Figure 1 provides a visual description of the geographic dispersion based on each participant's reported area of residence in Haiphong City. The RDS interview site was located at one central location, whereas the TLS interview sites were located in four separate locations. Most participants in TLS (66.7 %) and RDS (85.4 %) were clustered in the central districts of the city (Hong Bang, Le Chan, Ngo Quyen, Thuy Nguyen).

Refusal Estimates Of 604 PWID approached in the TLS survey, 560 received an invitation coupon. Forty-four PWID (7.3 %) refused to accept a coupon and 128 who received a coupon did not redeem it, resulting in an enrollment refusal estimate of 28.5 % [(128+44)/604].

For the RDS survey, of the 415 PWID who enrolled, 30 did not receive a recruitment coupon and therefore were not eligible to recruit. Among the 385 eligible to recruit others*, 192 returned for the second visit and reported that they approached 782 PWID†; of these, 351 of 380 who accepted coupons successfully enrolled in the survey and 431 did not. This could indicate that 2.23 PWID (782/351) were approached for each successful recruit. There were 41 who successfully recruited 61 PWID for the survey but did not come back for second visit and did not provide follow-up recruitment information. Assuming that those PWID ($n=41$) had no refusals, this would result in 843 (782+61+0) approaches and a refusal estimate of 54.3 % [$1-(385/843)$].

Field Implementation and Logistics Expenditure Estimations Table 2 provides information about the field implementation and logistics expenditures. Overall, the total field implementation expenditures for RDS were US \$12,250 or US \$29.40 per participant sampled, and for TLS was \$17,200 USD or \$40 USD per participant sampled. Table 3 provides the staffing time required for recruitment and data collection. For RDS, 236 total person-days, or 0.57 person-days per participant, were required; for TLS, 495 total person-days, or 1.15 person-days per participant, were required.

DISCUSSION

To our knowledge, this is the first study globally to directly compare TLS with RDS among PWID using two independent surveys conducted simultaneously within the same population. This comparison was undertaken because, up to now, it is unclear which of these sampling methods resulted in fewer identified biases, were more efficient, or produced significantly different findings. Our findings demonstrate that the two methods produced similar population estimates for HIV prevalence, a main outcome variable for HIV surveillance, and for income, injection duration, unemployment, injecting in public places, needle sharing, sex, and condom use with commercial and regular partners and receiving needles. However, we found several important and statistically significant differences related to socio-demographic characteristics, injection behaviors, and exposure to services. Of particular interest

*30 PWID participants were not provided with any recruitment coupons and therefore had no chances to recruit anyone.

†Those who returned for a secondary compensation were asked: "How many people did you try to give a coupon to?" and "Among those, how many accepted a coupon?"

Legend

TLS Recruitment (n)

- less than 10
- 10 to 25
- greater than 25

RDS study site

TLS study site

RDS Recruitment (n)

- les than 10
- 10 to 25
- greater than 25

FIG. 1 A visual description of the geographic dispersion based on each participant's reported area of residence in Haiphong City.

TABLE 2 Field implementation and logistics expenditures in US dollars for RDS and TLS among PWID, Hai Phong, Vietnam, 2011–012

	RDS (<i>n</i> =415)		TLS (<i>n</i> =432)	
	Total	Per participant	Total	Per participant
Recruitment ^a	1000	2.4	4800	11
Incentives	2050	5	2100	5
Staffing and other costs ^b	9200	22	10,300	24
Total	12,250	29.4	17,200	40

^aFor RDS, this includes payment for referrals, and for TLS, this includes cost for peer-educators, staff for mapping, and distribution of coupons at venues

^bFor both RDS and TLS, this includes survey team management, survey staff responsible for data collection including interviewers, lab technician, and data entry specialists. All surveys were conducted in existing health clinics for which there were no charges

was the finding of significantly lower percentages of PWID in the RDS sample who had received methadone, met an outreach worker, or had an HIV test and received results in the past year (and, although not significant, received needles) compared with the TLS sample. Similar differences were found in a comparison of targeted sampling (TS) to RDS among PWID in San Francisco, where RDS recruits were significantly less likely to report using methadone maintenance (6 vs. 19.2 %) and to have obtained syringes from a needle exchange program (81 vs. 95 %) compared to TS recruits.¹⁹ These findings indicate that RDS might reach a more hidden population that is less exposed to important services compared with TLS. Compared to TLS, a finding reported previously from other surveys found that RDS reaches more hidden segments of the population, including those who are less likely to access some services.^{20,13} RDS might provide an added benefit to these more hidden PWID by being their first point of contact with HIV testing and test results and useful services related to injection drug use and sexual risk. Reasons for why PWID are not accessing available harm reduction services should be obtained if conducting future rounds of RDS among PWID in Haiphong.

Because RDS was expected to capture more hidden populations, we had anticipated that PWID recruited through RDS might be more likely than those recruited through TLS to inject at home and less likely to inject in railway tracks or public places. In fact, we found the opposite. What these data do confirm is that most PWID sampled, regardless of the method of sampling, inject most commonly on railway tracks, a location well-known to PWID in Haiphong to inject, buy drugs,

TABLE 3 Staffing time (person-days) for RDS and TLS among PWID, Hai Phong, Vietnam, 2011–2012

	RDS (<i>n</i> =415)		TLS (<i>n</i> =432)	
	Total (person-day)	Per participant (person-day)	Total (person-day)	Per participant (person-day)
Recruitment ^a	1	0	242	0.56
Data collection ^b	236	0.57	253	0.59
Total	237	0.57	495	1.15

^aRecruitment is the period of time for which staff were involved in recruiting participants

^bData collection is the period during which PWID enrolled and went through all of the survey steps

and find partially filled syringes and discarded injecting paraphernalia.²¹ No significant difference was found for PWID who injected in public places. Twice as many PWID in the TLS sample reported injecting at home than in the RDS sample.

As reported previously, TLS recruited participants from a wider geographic area than did RDS.¹³ The RDS survey had only one recruitment site, whereas TLS had four recruitment sites which might have influenced enrollment and refusal estimates. To sample geographically dispersed participants through RDS, seeds who have and will recruit PWID in their network from multiple locations across the geographic eligibility parameters should be selected.²² A better selection of seeds, accounting for geographic differences in the city, as well as additional interview sites, might have resulted in wider sample coverage in the RDS survey.

Refusal estimates for enrollment were high for both sampling methods, but higher for RDS. Having only one recruitment site for the RDS survey compared with four for the TLS survey may have increased refusal estimates in RDS. However, refusal estimates for RDS may be overestimated because no data were collected from PWID who returned to the interview site for a second visit to determine whether PWID refused a coupon because they already had a coupon (and had not yet enrolled in the survey) or had already participated in the survey. This was tested by plotting the network sizes of PWID by wave which demonstrated a systematic decline, indicative of the depletion of the available pool of recruits.²³ In addition, there may be potential social desirability bias from participants self-reporting higher numbers of PWID than they had actually approached. Including questions about recruitment refusal and why PWID refused a coupon in future surveys would provide better refusal estimates among PWID and other hidden populations.²⁴

Staffing time and field implementation expenditures for conducting TLS were higher than for RDS. TLS requires pre-survey formative work to identify and enumerate sampling venues. In the RDS survey, only one person-day of staff time, compared to 242 person-days for TLS, was required for recruitment which consisted of identifying seeds. Comparison studies in three metropolitan areas in the US among PWID have found RDS to require less person-time per recruit than TS (4 vs. 1 h).²⁵ Another comparison from San Francisco reported that TS recruitment required 16 weeks, while RDS required 32 weeks although there is no measurement of the person-time needed.²⁰ In addition, qualitative feedback from studies found that the privacy, comfort, and security provided by defined RDS sites were preferable to field-based recruitment.^{25,26} The ability to recruit seeds quickly is most likely because of the large number of organizations in Haiphong that can easily identify appropriate and eligible seeds. In many surveys using RDS, especially for the first time, more formative research may be needed to identify seeds. Strategically selecting seeds that could have recruited across wider geographic areas in Haiphong would have required more time for training and recruiting.

In addition to the limitations mentioned above, other limitations should be noted. First, both TLS and RDS rely on adhering to numerous assumptions, some of which are difficult to reach in real-world settings. Based on measurements of convergence, homophily, network size consistency, and reciprocal recruitment, many of the RDS assumptions appear to have been met. The analysis of these data benefited from the most up-to-date and reportedly robust estimation procedures available for TLS and RDS. Secondly, given the hidden nature of PWID in Haiphong, knowing whether these findings represent the true population of PWID is difficult. RDS typically represents the network of the population, a proxy for the population, whereas TLS typically represents those who are more visible and who can be found at venues.

Nevertheless, RDS and TLS are the most suitable sampling methods that we have available to obtain critical data from hidden and stigmatized groups.^{1,2} A final limitation is that PWID were not provided their test results on site but, instead, were referred to the HIV testing and counseling center at the Provincial AIDS Center to be retested and receive their results. This is a missed opportunity for PWID to learn their test results, especially in light of the finding that only between 20 and 30 % of PWID had an HIV test and received their results in the past year.

In conclusion, each of these survey methods recruited a diverse and hard-to-reach sample of PWID in Haiphong. Although the refusal estimate (as was calculated in this paper) was found to be much higher for RDS than TLS, RDS in Haiphong required fewer staff resources and was less expensive overall. It is notable that lower proportions of PWID in the RDS survey, compared with TLS, reported exposure to MMT treatment, outreach, and HIV-related services. Findings and recommendations from this evaluation can also be used to inform other cities in Vietnam, and globally, about the most feasible sampling technique for PWID.

ACKNOWLEDGMENTS

The authors are indebted to the study participants and would like to thank the directors and research staff of the Haiphong Provincial AIDS Center and Haiphong Medical University. We also wish to thank the leader of the research group, Nguyen Thi Minh Ngoc, Haiphong Medical University for supporting this work."

Disclaimer. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the United States Centers for Disease Control and Prevention or the U.S. Agency for International Development (USAID).

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