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Population Size Estimation of Men Who Have Sex with Men in Ho Chi Minh City and Nghe An Using Social App Multiplier Method

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Abstract This study aims to estimate the number of men who have sex with men (MSM) in Ho Chi Minh City (HCMC) and Nghe An province, Viet Nam, using a novel method of population size estimation, and to assess the feasibility of the method in implementation. An innovative approach to population size estimation grounded on the principles of the multiplier method, and using social app technology and internet-based surveys was undertaken among MSM in two regions of Viet Nam in 2015. Enumeration of active users of popular social apps for MSM in Viet Nam was conducted over 4 weeks. Subsequently, an independent online survey was done using respondent driven sampling. We also conducted interviews with key informants in Nghe An and HCMC on their experience and perceptions of this method and other methods of size estimation. The population of MSM in Nghe An province was estimated to be 1765 [90% CI 1251–3150]. The population of MSM in HCMC was estimated to be 37,238 [90% CI 24,146–81,422]. These estimates correspond to 0.17% of the adult male population in Nghe An province [90% CI 0.12–0.30], and 1.35% of the adult male population in HCMC [90% CI 0.87–2.95]. Our size estimates of the MSM population (1.35% [90% CI 0.87%–2.95%] of the adult male population in HCMC) fall within current standard practice of estimating 1–3% of adult male population in big cities. Our size estimates of the MSM population (0.17% [90% CI 0.12–0.30] of the adult male population in Nghe An province) are lower than the current standard practice of estimating 0.5–1.5% of adult male population in rural provinces. These estimates can provide valuable information for sub-national level HIV prevention program planning and evaluation. Furthermore, we believe that our results help to improve application of this population size estimation method in other regions of Viet Nam.

Keywords Viet Nam · Size estimation · Most at-risk populations · HIV AIDS · HIV surveillance · Social network · RDS

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Background

Men who have sex with men (MSM) are a key group at risk of HIV in Viet Nam. Unprotected anal sex is the main route of transmission among MSM. HIV sentinel surveillance data from MSM in 2014 in eight provinces found an average HIV prevalence of 6.7%, with prevalence rates highest in major urban areas (up to 16% in Hanoi and Ho Chi Minh City) [1, 2]. Estimates and projections of new infections based on behavioural and biomarker surveys and using the AIDS (or Asian) Epidemic Model [3] show that MSM are the only key population in Viet Nam among which annual new infections have continued to increase in the past 20 years [4].

Despite the alarming estimates of the epidemic and despite the ambitious targets set to control the epidemic

in the MSM community in Viet Nam, information on the size of this key population in Viet Nam and their access to/use of services is limited. The true magnitude of the epidemic will only become clear with better data that provide information on trends as well as geographic distribution. Meanwhile, stigma and discrimination, as well as financial cost, pose a challenge to data collection to better gauge the population size and their needs.

Size estimates of populations affected by HIV/AIDS help policy makers and program administrators understand the scope of the HIV epidemic and help plan appropriate interventions, and allocate sufficient resources. Population size estimates can be used as denominators in calculating program coverage and producing national estimates and projections of the HIV epidemic in Viet Nam. The size estimates data also help the national and provincial level authorities, and other stakeholders for disease control purposes, specifically for program coverage planning and assessments.

A number of direct and indirect methods exist for estimation of population sizes, with varying degrees of rigour [5–7]. Some popular methods are census, enumeration, network scale-up, capture-recapture, and unique object or service multiplier.

Some of these methods have been attempted in Viet Nam with varying results [8]. A 2009 study, using capture-recapture methodology with respondent driven sampling (RDS) in Ha Noi found 9763 MSM in the 18 to 39 age group, equivalent to 1.4% of the male population in this age bracket [9]. Several methods of size estimation among MSM in Ho Chi Minh City resulted in varying population sizes: 1817 [1523–2111] using multiplier method, 9505 [8658–10,352] using a two-way capture-recapture, 11,123 [9399–12,061] using a three-way capture-recapture, and [2172–3485] using mapping [10]. An indirect estimation using HIV Estimates and Projection Package produced a higher figure at 40,172 MSM in Ho Chi Minh City. The National Institute of Hygiene and Epidemiology estimates there are between 161,000 and 482,000 MSM in Viet Nam [8] and the Vietnam Authority of HIV/AIDS Control estimates the MSM population ranges from 191,000 to 573,000 [11]. A number of limitations of these studies have been acknowledged. Some of them include the use of a particular sampling strategy such as time-location sampling method, which fails to account for the non-location-based MSM who meet other MSM on social apps and websites.

The lack of consensus on the MSM population sizes in different provinces of Viet Nam has resulted in a compromised result. For national HIV and AIDS estimations, MSM population size estimations are simplified to three scenarios of low, medium and high estimates for large cities and rural provinces, ranging from 1 to 3% and 0.5 to 1.5%, respectively.

Service multiplier method is one of the most commonly used population size estimation methods because it is relatively straightforward and utilizes simple calculations [12]. The method uses data from two overlapping sources to estimate population size. The first set of data comes from a service that the target population uses, and number of subscribers to the service are known, such as the number of people who inject drugs tested for HIV at voluntary counselling and testing sites. The second set of data comes from a survey of the target population, where members are asked about their contact with the service. The number of subscribers to the service is then multiplied by the inverse proportion of the sample population that report using the service. There are three theoretical assumptions about the data sources in the multiplier method [6]. Firstly, it is important that the two sources of data be independent. The first source must be specific to the population group being estimated, and the second source must be random and representative of the whole population of MSM being estimated. The second data source must encompass the first data source, and any substantial in and out migration may invalidate this condition. Secondly, the two sources of data must define the populations the same way. Thirdly, the two data sources must have aligned time periods, age range and geographic areas.

With over 18 million active smartphone users in Viet Nam [13, 14], new opportunities are afforded for surveys and estimation using mobile app and social networks. Moreover, as gay men are more likely to use social media and for longer periods [15–17] some of the biases and costs of location-based service multiplier method can be overcome with the use of mobile technologies [18]. In this study, we examine the use of a simple, innovative, and low-cost method to estimate the size of MSM population in Ho Chi Minh City and Nghe An province, Viet Nam. This is the first use of such a method in Viet Nam, grounded on the principles of the multiplier method, and using social app technology and internet-based surveys.

Method

The method we used to estimate the size of the MSM population in Ho Chi Minh City and Nghe An was

similar to the service multiplier method [6]. In the formative phase of the study, a review of popularity of various social media (mobile social apps and online websites) in Viet Nam was conducted by creating accounts on the social media and counting the active users there. This information was supplemented by interviews with key informants from within the MSM community to find out which social media are popular with the MSM community in Viet Nam to meet new partners. Once the specific social media were identified, the study team members revisited them to examine their characteristics and to determine the feasibility of their use in the multiplier method.

A schedule of best times and days to find active users online was developed to approximate the count of all active users of the selected social media during a 1-month period of time. Based on the schedule developed, unduplicated count of active online users from two social apps was retrieved by directly counting active users on the social apps. After 1 month of enumerating unique user profiles, we arrived at the approximate count for the number of individuals presumed to be active users of the social app in each region of study, in 1 month.

After completing the enumeration, an online survey was conducted among the MSM population in Ho Chi Minh City and Nghe An province to find out about their use of the identified social media, as well as the size of their social network. The online survey participants were selected through a RDS technique [19]. The RDS began with the selection of "seed" individuals introduced by a local non-governmental organization, Provincial AIDS Committee, and those who are known members of the MSM community. Each seed was instructed to recruit two other MSM from their social circle, who in turn were enrolled (if eligible) and instructed to refer two other MSM and so on. Between six and eight seeds were to be introduced initially and additional seeds were to be introduced later depending on progress in referrals and rate of reaching the required sample size. Coupons were used to link who refers whom through the use of unique codes. Coupons used a four- or six-digit alphanumeric code and were shared with the participants upon successful completion of the online survey questionnaire. Recruitment progressed until both the sample size was met and equilibrium (i.e., stability with respect to composition of the sample) was achieved.

Sample sizes of the surveys were gauged to provide a reasonable precision around an estimate of the proportion of participants using the social apps. For this study, we used a 90% confidence interval. In addition to meeting the sample size, RDS required recruitment chains long enough for the sample estimator of key variables to stabilize, thereby reaching equilibrium [20, 21]. Equilibrium indicates that the purposive selection of seeds has not biased the final sample. It is measured by the proportions of key variables that remain stable, within 2% of the sample proportion [22]. In this study, the key variables designated to assess equilibrium were sexual preference, relationship of the referrer to the respondent, sex in the last 12 months with a man, and the usage of social apps. Convergence plots were made for each key variable.

The recruited MSM were vetted for eligibility to participate in the survey. The eligibility criteria for inclusion were being male, being at least 18 years old, having had anal or oral sex with another man in the past 12 months, and residing in one of the areas chosen for the study for the past 3 months. Those found eligible were invited to participate in a survey questionnaire. The questionnaire obtained from each participant their year of birth, city and district of residence in the past 3 months, last use of relevant social app, number of peers who they personally know by name and who they have seen during the past 3 months, and a unique coupon code.

The questions were presented in Vietnamese. The online survey software, limesurvey (www.limesurvey.org), was used to design, develop, and conduct the questionnaire. Participants received reimbursements for lost time and income in completion of the survey. Since interviews took no more than 5 min, reimbursements were valued at no more than 40,000 VND ($2.00 USD) for completing the questionnaire. Secondary incentives were given for each successfully recruited peer. The incentives were in the form of a mobile telephone recharge.

The information collected in the survey questionnaire was entered into RDS Analyst version 0.51 [23]. The RDS adjusted proportion of respondents who answered "yes" to having used the social app in the past month, together with the 90% confidence interval, was estimated by the population frequency estimates module of RDS Analyst. The Gile's Sequential Sample option was selected in RDS Analyst for weights in the analysis, with a seed population

size of 2000, 500 bootstraps, and 1000 simulations per iteration. The MSM population size (N) was calculated for Ho Chi Minh City and Nghe An province using the formula:

$$N = \frac{n}{p}$$

where n is the enumerated number of MSM found active on the social media during the 1 month of enumeration. And p is the proportion of respondents who answered "yes" to having used the social app in the previous month. The 90% confidence interval of the MSM population size was calculated by substituting p in the above formula with the upper and lower bound estimated proportions calculated by RDS Analyst.

Qualitative in-depth interviews were conducted with 16 key informants before and during the data collection portion of the size estimation study to explore preferences for social apps, issues related to the piloted size estimation method, and feasibility of the method compared to other methods of size estimation. The key informants for the interviews included health program managers representing the provincial AIDS program, technical experts involved in surveillance, and individuals from the community of people at risk of HIV in Viet Nam. The interviews followed an informal format, as the research team has existing relationships with the majority of key informants and as such the interviews were similar to a "conversation with a purpose" than a more formal interview situation. An interview guide with open-ended questions aided the focus of the interviews. There was flexibility in the interview guide to offer space for key informants to raise other issues which they might consider to be pertinent. Interviews lasted from 30 to 90 min. All interviews were conducted in person and audio recorded with the key informants' consent and were transcribed verbatim. The transcripts were translated to English by the interviewers.

Results

Selection of Social Apps

We screened different mobile apps and social websites popular with MSM in Viet Nam. Websites such as Plun.Asia, Taoxanh.net, and Only Lads, as well as Facebook groups, were identified as potential data sources for the first capture. Among mobile social networking apps Jack'D, Grindr, Hornet, Growlr, Planet Romeo, Scrub and Blued were identified by the key informants. With regard to websites, membership numbers were very large at the time of the study: The Gioi Trai Dep Facebook group—33,000 members; Vietnamese Boys—25,000 members; Cong Dong LGBT thanh pho Ho Chi Minh—15,000 members; Taoxanh.net forum—78,056 members; Plun.Asia—47,880 registered members.

However, these websites faced three limitations that the social apps could overcome for the purpose of the size estimation study. Firstly, website accounts are often linked to individual members through their email address. A member, however, may have more than one email and therefore multiple accounts on the social website. However, by design, mobile devices allow only one installation of a social app per device, and instances of a user having two smartphones and using both actively is very rare. Secondly, it is not always possible to know or to confirm the exact location of a member of a social website. Even if the member publicly shares this information, it cannot be confirmed. Meanwhile, social apps make use of the mobile device's geolocation service, which allows users to locate other men within close proximity. This information also allows the researchers to count the users within a geographical boundary, like Ho Chi Minh City or Nghe An province, from the interface of the social app. Thirdly, social websites often do not distinguish between active and non-active members. Websites that do display active users online may overestimate the number of active users, because members must log out of their account in order to be considered non-active. And many people forget to log out, which can make the population estimations inaccurate. Mobile social apps show the users who are active within a certain amount of time. For example, Jack'D social app shows all users who have logged in in the past 3 days, which allows for a better estimation of active users.

Based on these findings, mobile social apps were more suitable for this population size estimation study. In consultation with a group of key informants from within the MSM community, Jack'D and Grindr social apps were found to be more popular than others. On revisiting Grindr, and conducting a pilot count of users in September of 2015, we found very few users in Nghe An, but a sufficient number in Ho Chi Minh City. The interface of the Jack'D social app requires manual review of all users to find active ones and to record their

profile attributes. With the limited resources of this study, it would not have been feasible to manually review and record all active users on Jack'D in all of Ho Chi Minh City. In a pilot count of one district of Ho Chi Minh City in October 2015, 400 Jack'D users were found, which indicated that several thousand users should be expected in the entire city. It was therefore considered more feasible to count Jack'D users in only one district of Ho Chi Minh City, and to count Grindr users in the entire city.

Enumeration of Active Social App Users

Two social apps, Grindr and Jack'D, were used to estimate the MSM population size in Ho Chi Minh City and Nghe An province, respectively. Jack'D was also used in one district of Ho Chi Minh City. Review of the profiles on Jack'D in Nghe An Province found 474 active users during a 1-month period, after duplicates were removed. The age of the users ranged from 18 to 55, with a median age of 24. The profile attributes of username, age, height, weight, and approximate location of login into Jack'D were used to uniquely identify users of the social app, and to remove duplicates during the enumeration. Review of profiles on Grindr in Ho Chi Minh City found 8818 active users during a 1-month period, after duplicates were removed. The age of the users ranged from 18 to 58, with a median age of 25. A profile identification number generated by Grindr for each user was used to uniquely identify users of the social app, and to remove duplicates during the enumeration. A separate count was done in district 4 of Ho Chi Minh City for Jack'D users, in order to compare results between the two different apps, and also to measure variations between the overall density of MSM population in the city and in a central district. The choice of district 4 over other central districts (i.e. 1, 2, 3 or 5) was due to feasibility, to allow for manual counting of users on the app over several weeks. Review of the profiles on Jack'D in district 4 of Ho Chi Minh City found 1124 active users during the same month, after duplicates were removed. The age of the users on Jack'D in district 4 of Ho Chi Minh City ranged from 18 to 51, with a median age of 25.

Estimation of MSM Population Size

The total number of valid respondents to the RDS survey in Nghe An province and Ho Chi Minh City were 100 and 81, respectively. The age of respondents from Nghe An ranged from 18 to 44 with a median age of 27. The respondents represented 14 districts of Nghe An. The age of respondents from Ho Chi Minh City ranged from 18 to 41 with a median age of 22. The respondents came from 21 different districts of Ho Chi Minh City. Convergence plots indicate that most key variables stabilize long before recruitment ended (Figs. 1 and 2). However, in Nghe An the social app usage plot and the sexual preference plot did not reach convergence long before recruitment ended.

The adjusted proportion of respondents to the RDS survey in Nghe An province who reported having used the Jack'D social app in the past month was 0.269, for an estimated 1765 MSM population size [90% CI 1251–3150]. The adjusted proportion of respondents to the RDS survey in Ho Chi Minh City who reported having used the Grindr social app in the past month was 0.237, for an estimated 37,238 MSM population size [90% CI 24,146–81,422]. The adjusted proportion of respondents to the RDS survey in district 4 of Ho Chi Minh City who reported having used the Jack'D social app in the past month was 0.288, for an estimated 3904 MSM population size [90% CI 2910–5830].

Some data checks were used to validate the RDS survey data. These included questions required for inclusion in the survey, "trap" questions about use of non-existing social apps, relationship of the respondent to the person who referred them to the survey, and the duration of time it took the respondent to complete the survey. Two scenarios were then created which removed some respondents based on these validation criteria. The first scenario excluded respondents who answer the questionnaire in less than 1 min. The second scenario excluded respondents who do not meet the inclusion criteria (i.e. has not had sex with another man during the past 12 months), do not know the person giving them the referral coupon, or give a positive answer to the "trap" question (i.e. Have you used the mobile application "Lumba"?). The population size estimates based on these scenarios can be found in Tables 1, 2 and 3.

With an average population in Ho Chi Minh City in 2015 of 8,224,900 [24], a male to female sex ratio of 92.2% [25], and assuming an adult population of 70% [26], Ho Chi Minh City has an estimated adult male population of 2,761,900. The estimated MSM population is then 1.35% of the adult male population in Ho Chi Minh City [90% CI 0.87–2.95]. With an average population in Nghe An province in 2015 of 3,063,800,

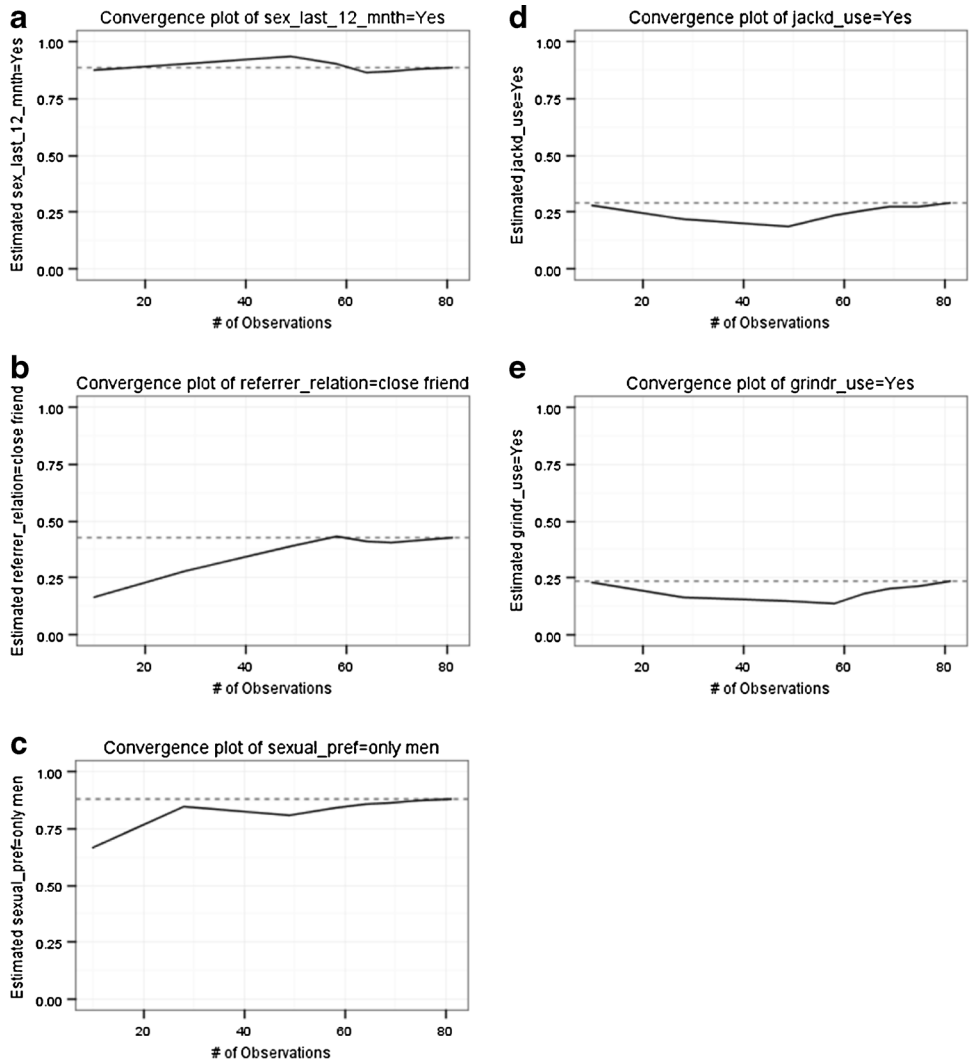

Fig. 1 Five convergence plot from RDS survey of MSM in Ho Chi Minh City; The dashed line shows the estimate based on the complete sample. **a** Proportion of male respondents who have had sex with a man in the last 12 months. **b** Proportion of respondents who were referred to the survey by a close friend. **c** Proportion of respondents who prefer sex with men only. **d** Proportion of respondents who used the Jack'D social app in the past 2 weeks. **e** Proportion of respondents who used the Grindr social app in the past 2 weeks

based on a 0.87% population growth rate over 2014 [25], a male to female sex ratio of 98.7%, and assuming an adult population of 70%, Nghe An province has an estimated adult male population of 1,065,300. The estimated MSM population is then 0.17% of the adult male population in Nghe An province [90% CI 0.12–0.30]. District 4 in Ho Chi Minh City had a population of 183,261 in 2011 [27]. Based on a population growth rate of 2.07% [25], a male to female sex ratio of 92.2% [25], and assuming an adult population of 70% [26], district 4 has an estimated adult male population of 66,800. The estimated MSM population is then 5.85% of the adult male population in district 4 [90% CI 4.36–8.73].

Interviews with key informants revealed that the advantages of the method were its low cost for producing valid result, and the ease of understanding of the method, requiring brief training and little guidance from experts. Some interviewees were also interested and excited about the novelty of the method itself, which they attributed to improved response rates to the RDS survey. One interviewee expressed that the method also

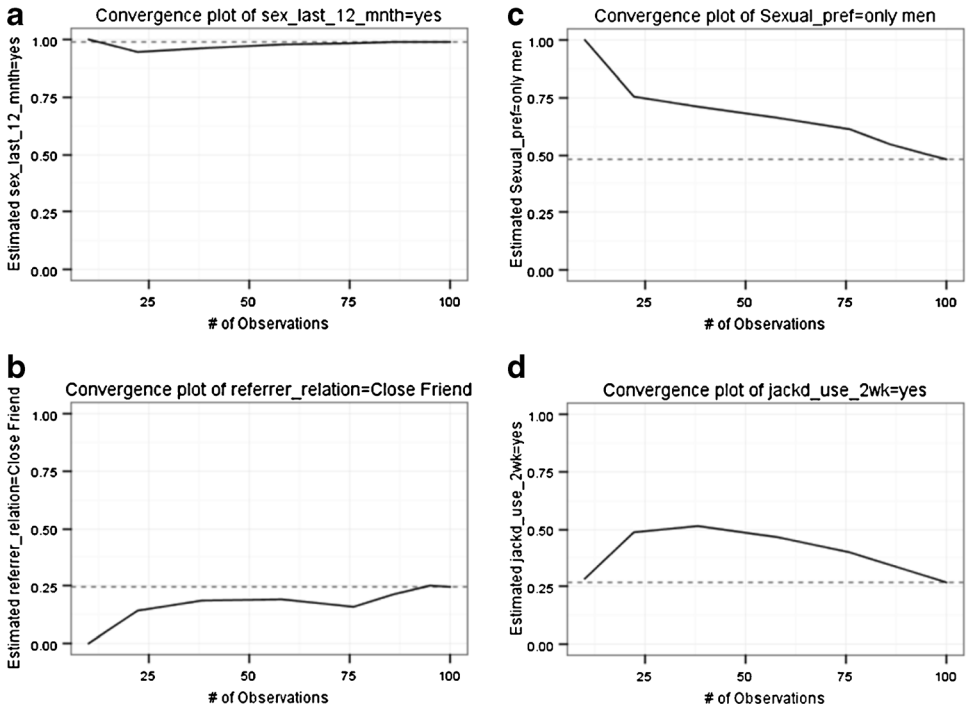

Fig. 2 Four convergence plot from RDS survey of MSM in Nghe An province. The dashed line shows the estimate based on the complete sample. **a** Proportion of male respondents who have had sex with a man in the last 12 months. **b** Proportion of respondents who were referred to the survey by a close friend. **c** Proportion of respondents who prefer sex with men only. **d** Proportion of respondents who used the Jack'D social app in the past 2 weeks

did not require MSM to come out, which facilitates reaching the network of MSM including hidden pockets of the group. After the surveys had run for some time, some interviewees expressed that they did not expect the method to work in the rural mountainous provinces of Viet Nam, nor in estimating the population size of other key populations at risk of HIV such as people who inject drugs or female sex workers.

Interviews with the key informants during the Nghe An size estimation activity also helped in making several important improvements to the online RDS survey of Ho Chi Minh City. Those interviews revealed that two questions on sexual behaviour may be sufficient to disqualify respondents, thus eliminating one sexual behaviour related question initially included in the pilot. Based on feedback in the interviews, referral coupon codes were reduced from six alphanumeric digits to just four digits, for easier memorization. Key informants interviewed during the Nghe An data collection phase advised that seeds selected should not be projects based or peer educator seeds. Community members interviewed also expressed a need to receive additional information about their community, once they complete the survey questionnaire, particularly for the young LGBT who have not come out, "to connect with the community and not feel alone." The look of the online survey was subsequently revised to make it more

Table 1 MSM population size estimate in Nghe An province in 2015 using social app multiplier method

	RDS survey respondents	Count of users on social app	Proportion using social app [90% CI]	Population estimate [90% CI]
Base Scenario	100	474	.269 [.151–.379]	1765 [1251–3150]
Scenario 1	96	474	.275 [.152–.388]	1727 [1220–3120]
Scenario 2	92	474	.273 [.147–.390]	1736 [1216–3216]

Table 2 MSM population size estimate in Ho Chi Minh City in 2015 using social app multiplier method

	RDS survey respondents	Count of users on social app	Proportion using social app [90% CI]	Population estimate [90% CI]
Base Scenario	81	8818	.237 [.108–.365]	37,238 [24,146–81,422]
Scenario 1	80	8818	.239 [.115–.363]	36,849 [24,272–76,479]
Scenario 2	72	8818	.202 [.103–.300]	43,740 [29,364–85,612]

recognizable as a community owned survey with LGBT flags, logos and weblinks of the community-based organizations involved in conducting the surveys.

Discussion

This study examines a feasible, innovative, and low-cost method to estimate the size of MSM population in Ho Chi Minh City and Nghe An province, Viet Nam. The MSM population as a proportion of the adult male population in Ho Chi Minh City as estimated by this method was 1.35% [90% CI 0.87–2.95] which is consistent with the current standard practice of estimating 1–3% of adult male population in big cities. The MSM population as a proportion of the adult male population in Nghe An province estimated by this method was 0.17% [90% CI 0.12–0.30], which is lower than the current standard practice of estimating 0.5–1.5% of adult male population in rural provinces. The MSM population as a proportion of the adult male population in district 4 of Ho Chi Minh City was 5.85% [90% CI 4.36–8.73]. This proportion is higher than the overall Ho Chi Minh City proportion of 1.35%, which indicates the possible variations of MSM population density in Ho Chi Minh City. This information can improve the efficiency of targeting interventions to locations where key at-risk populations reside.

The study found some cases of survey respondents possibly giving inaccurate or inattentive responses, as demonstrated by some positive answers to being a user of a non-existing social app "Lumba". Others provided answers to questions that could disqualify them, for example by stating that they did not know the person who gave them the coupon, which violates the preconditions of the RDS method. Getting some inaccurate or inattentive answers is common and expected in online surveys. The rate of such answers in this study ranged from 3.8 to 10.4% of all respondents in the two scenarios presented, which is consistent with research which suggests that 3–9% of respondents engage in highly inattentive responding [28].

The findings of this study illustrate the benefits and challenges of the online RDS method, in that the survey can progress very quickly, but the benefits of personal intuition and judgement of the interviewer to identify inaccurate or inattentive reporting are lost. Based on a review of literature, observations from the study, and key informant interviews, we have some recommendations to help monitor and improve the precision and validity of the online RDS methods. Firstly, time taken to respond to questions is important and should be tracked. Quick answers to certain questions, like the

Table 3 MSM population size estimate in district 4 of Ho Chi Minh City in 2015 using social app multiplier method

	RDS survey respondents	Count of users on social app	Proportion using social app [90% CI]	Population estimate [90% CI]
Base Scenario	81	1124	.288 [.193–.386]	3904 [2910–5830]
Scenario 1	80	1124	.296 [.192–.394]	3796 [2856–5866]
Scenario 2	72	1124	.261 [.164–.358]	4311 [3141–6862]

Notes: "Base Scenario" includes all respondents who completed the survey.

"Scenario 1" excluded respondents who answered the questionnaire in less than one minute

"Scenario 2" excluded respondents who did not meet the inclusion criteria (i.e. has not had sex with another man during the past 12 months), or did not know the person giving them the referral coupon, or gave a positive answer to the "trap" question (i.e. Have you used the mobile application "Lumba"?)

network size question, are likely to be inaccurate [20]. Secondly, consistency of responses can be checked with follow-up questions, including "trap" questions, and reverse wording of questions [29]. Thirdly, surveys can ask open-ended questions and examine the completeness and appropriateness of the responses [30].

The multiplier method is grounded in assumptions of independence of the two data source, consistent definition of the populations in the data sources, and alignment of data sources in terms of time frame and geographic coverage. We have attempted to fulfil these assumptions of the multiplier method to reduce potential bias in the results. Active users on the gay social apps are specific to the MSM group being estimated, so the assumption that the first data source is specific to the population group being estimated was fulfilled. Every person who had a social app and used it should have had Internet access to download the app, a smartphone to install that app, and an email address to register on the app. The app users could have used the same technologies to receive links to the survey from their friends, and load and complete the online survey. So the assumption that the RDS survey encompasses the app user group in the enumeration was very likely met. The short time period of data collection (4 weeks of counting users on social apps and 4 weeks of RDS survey), and no delay between the collection of data from the two sources, minimized the potential of substantial in or out migration during our study period. With high access to Internet and mobile devices, particularly by gay men in Viet Nam [15–17], any member of the MSM group would have had the opportunity to be recruited to the online survey, not just those who were counted on the social apps. This condition addressed the requirement that at least one source of data was representative of the whole population. The second and third theoretical assumptions of the multiplier method were addressed by limiting the included age groups, and matching period of time and geographic areas of the two sources of data.

Although access to the Internet is high among gay men in Viet Nam, it is not universal. A recruit without Internet access could have called a friend with Internet access to get help with answering the survey. However, we can assume that some referrers may have chosen to forward the survey only to their friends who they already knew have easy access to the Internet. Therefore, there may be some selection bias in which friends received the survey coupons. To address this bias of the social app multiplier method, future size estimations should make an off-line survey accessible, to allow respondents to appear in person to complete the survey, or to allow respondents to obtain a printed copy of the survey, fill it by hand, and send it back to the survey administrators.

In rural Nghe An province, access to Internet may be more limited than in urban Ho Chi Minh City. This may be one possible explanation for the lower than expected prevalence of MSM among adult male population in Nghe An, whereby the estimates are counting a subset of MSM who are well connected and socially and sexually active [31, 32]. Another possible explanation may be the stigmatization of "gay hook-up sites" by the MSM community, characterizing users of social apps as having a high sexual desire [33]. This stigmatization may be stronger in rural provinces than in urban cities, and the estimates using the social app multiplier method may then be a reflection of the higher risk population among the MSM community in rural provinces like Nghe An. The convergence plot of two of the four key variables, social app usage and sexual preference, did not reach equilibrium long before recruitment ended in Nghe An, which indicates a need for enrolment of additional participants. However, given that the other indicators converged, and that there were ample waves propagating from some of the seeds, it is likely that the bias from seed dependence is substantially diminished.

A limitation of the study is that not all users on the social apps could be counted, and a method of enumeration was utilized to count active users at different points of time when usage was expected to be high. With the Grindr app, users who have logged in remain active for an hour after they stop using the app, so over a 2-week period, and several different times per week, we expect to capture most active users. The Jack'D app shows users who have been online in the past 72 h, so a less frequent enumeration is required over a 2-week period to capture active users. Despite these controls for counting all active users, it is possible some users who logged in 48 h prior to the 2-week period were counted, and some users were missed who logged in on a window of time when our monitors were off.

The width of the confidence interval on the estimates may be narrow with an upper range that is nearly twice the point estimate and a lower range that

is nearly half of the point estimate. However, there are no reference intervals for the method used in this study. Earlier MSM population size estimations in Ho Chi Minh City using capture-recapture method obtained proportionally narrower confidence intervals, with simple random sampling [10].

Conclusions

This is the first population size estimation study among MSM in Ho Chi Minh City and Nghe An province in Viet Nam using the innovative method of social app multipliers. Our estimates are in line with the current limited estimates available on MSM in Ho Chi Minh City, and lower than the expected number of MSM in Nghe An province. This pilot study demonstrated that the social app multiplier method is feasible to implement in Viet Nam for MSM population. It provides a refined and tested RDS questionnaire for use in future size estimation studies, as well as a set of procedural recommendations to improve the implementation and validity of the estimates.

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