Further exploring the public health implications of the network scale-up method: Cross-sectional Survey Study

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Submitted to: JMIR Public Health and Surveillance
on: April 22, 2023

Table of Contents

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Abstract

Background: The network scale-up method (NSUM) was recommended by the United Nations Programme on Human Immunodeficiency Virus (HIV)/Acquired Immunodeficiency Syndrome and the World Health Organization to estimate the sizes of the populations at high risk of HIV infection in 2010; however, we found that the NSUM also revealed underlying population characteristics of female sex workers (FSWs) in addition to being used to estimate the size of the FSWs population.

Objective: We aimed to conduct a further exploration of the public health implications of the NSUM by using NSUM to estimate population size, popularity rate, and information transmission rate among people who inject drugs (PWID).

Methods: A stratified two-stage cluster survey of the general population and a respondent-driven sampling (RDS) survey of PWID were conducted in the urban district of Taiyuan, China in 2021.

Results: The estimated size of the PWID population in Taiyuan was 1,244 (95% CI: 1,011-1,477), corresponding to 0.044% (95% CI: 0.036%-0.052%) of the adult population aged 15-64 years. The estimated popularity ratio of the PWID population was 0.535 (95% CI: 0.512-0.558), and the estimated information transmission rate was 0.879 (95% CI: 0.867-0.892).

Conclusions: The NSUM revealed that the PWID population have smaller sized personal social networks while concealing their drug use, and these underlying population characteristics are extremely useful for planning appropriate service delivery approaches with the fewest barriers for the PWID population to access HIV prevention services.

(JMIR Preprints 22/04/2023:48289)
DOI: https://doi.org/10.2196/preprints.48289

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Further exploring the public health implications of the network scale-up method: Cross-sectional Survey Study

Abstract

Background: The decline in the number of new HIV infections among adults has slowed down, gradually becoming the biggest obstacle to achieving the 2030 target. Thus, a political declaration to ensure that 90% of people at high risk of HIV infection can access comprehensive prevention services was proposed by the United Nations General Assembly. Therefore, obtaining an accurate estimated size of the high-risk populations is required as a prior condition to plan and implement HIV prevention services. The network scale-up method (NSUM) was recommended by the United Nations Programme on Human Immunodeficiency Virus (HIV)/Acquired Immunodeficiency Syndrome and the World Health Organization to estimate the sizes of the populations at high risk of HIV infection; however, we found that the NSUM also revealed underlying population characteristics of female sex workers (FSWs) in addition to being used to estimate the size of the FSWs population. Such information on underlying population characteristics is very useful in improving the planning and implementation of HIV prevention services [10]. Especially for people who inject drugs (PWID) population, in addition to stigma and discrimination, criminalization further hinders access to HIV prevention services for PWID population.

Objectives: We aimed to conduct a further exploration of the public health implications of the NSUM by using NSUM to estimate population size, popularity rate, and information transmission rate among PWID population.

***Methods*:** A stratified two-stage cluster survey of the general population and a respondent-driven sampling (RDS) survey of PWID population were conducted in the urban district of Taiyuan, China in 2021.

***Results*:** The estimated size of the PWID population in Taiyuan was 1,241.9 (95% CI: 1,009.2-1,474.9), corresponding to 4.4×10^{-2}% (95% CI: 3.6×10^{-2}%-5.2×10^{-2}%) of the adult population aged 15-64 years. The estimated popularity ratio of the PWID population was 53.6% (95% CI: 47.2%-60.1%), and the estimated information transmission rate was 87.9% (95% CI: 86.5%-89.3%).

***Conclusions*:** In addition to being used to estimate the size of the PWID population, the NSUM

revealed that the PWID population have smaller sized personal social networks while concealing their drug use, and these underlying population characteristics are extremely useful for planning appropriate service delivery approaches with the fewest barriers for the PWID population to access HIV prevention services. Therefore, more cost-effectiveness brings new public health implications for NSUM, which makes it even more promising for its application.

Key words: network scale-up method; public health implications; people who inject drugs

Introduction

In the past fifteen years, the successful scale-up of antiretroviral therapy has effectively controlled the number of acquired immune deficiency syndrome (AIDS)-related deaths. Furthermore, continued efforts to eliminate mother-to-child transmission of human immunodeficiency virus (HIV) have led to a significant decline in the number of new HIV infections among children each year. Therefore, global progress against HIV and AIDS has made it possible to end the epidemic by 2030 [1]. However, the decline in the number of new HIV infections among adults has slowed down, gradually becoming the biggest obstacle to achieving the 2030 target [1]. Between 2010 and 2022, new HIV infections declined by 35% in the 15–49-year-old population globally, but only by 11% among people at high risk of HIV infection [2,3]. Discrimination, stigma and criminalization hinder access to availability of services for people at high risk of HIV infection [2]. Thus, a political declaration to ensure that 90% of people at high risk of HIV infection can access comprehensive prevention services was proposed by the United Nations General Assembly in 2016 [1]. Therefore, obtaining an accurate estimated size of the high-risk population is required as a prior condition to plan and implement HIV prevention services [4,5]. As the latest estimation method of the size of the high-risk population recommended by the Joint United Nations Programme on HIV/AIDS (UNAIDS) and the World Health Organization (WHO) in 2010, the network scale-up method (NSUM) is more cost-effective method compared to all of the previous size estimation methods because it produces size estimates for multiple high-risk populations using a single survey [4,6]. For example, the sizes of the populations of female sex workers (FSWs), people who inject drugs (PWID), and men who have sex with men (MSM) could be estimated through a single NSUM survey.

The NSUM was first proposed by Bernard, Killworth, Johnsen, and Robinson in 1991 and uses social network information of the general population to estimate the sizes of populations at high risk of HIV infection [7]. In 2011, Salganik *et al.* used the popularity ratio and information transmission rate to adjust for the barrier effects and transmission error that existed in the NSUM [8,9]. In 2018, we found that these two coefficients revealed underlying population characteristics of FSWs in

addition to being used to adjust the estimate the size of the FSWs population [10]. Populations at high risk of HIV infection are considered hidden or hard-to-reach populations because of their stigmatized nature; therefore, such information on underlying population characteristics is very useful in improving the planning and implementation of HIV prevention services [10]. Especially for PWID population, the overwhelming majority of countries (143 countries) criminalized the use or possession of small amounts of drugs [11]. Thus, in addition to stigma and discrimination, criminalization further hinders access to HIV prevention services for PWID population. As a result, global coverage of HIV prevention services is extremely low, with less than 1% of PWID living in settings with sufficient, combined and high-coverage services [11]. This resulted in 38.1% of PWID not knowing their HIV status [12], thus the risk of acquiring HIV infection for PWID was 35 times higher than for people who do not inject drugs [13]. Globally, HIV infection rates have declined across all age groups, while HIV infection rates in PWID have been rising [14].

The prevalence of injecting drug use varied greatly both between and within countries [15]. Globally, almost half of PWID lives in China, Russia, and the United States [14]. In China, PWID are concentrated in seven provinces (Yunnan, Xinjiang, Guangxi, Guangdong, Guizhou, Sichuan, and Hunan). Taiyuan, the capital of Shanxi Province, is not from a province with a high prevalence of injecting drug use, but it represents the situation in most cities in China [16]. Thus, the present study aimed to conduct a further exploration of the public health implications of the NSUM by using NSUM to estimate population size, popularity rate, and information transmission rate of PWID population in the urban district of Taiyuan, China in 2021.

Methods

The network scale-up method

FSWs, PWID and MSM are high-risk populations, members of the general population and live in the social network of the general population. Therefore, the average proportion of high-risk populations in the personal social network of the general population also reflects the proportion of the high-risk population in the general population in the region. Thus, the basic formula of the NSUM is $e_1/t = m_1/c$, where e_1 is the estimated size of the high-risk populations in the region, t is the latest annual average population in the region, m_1 is the reported average number of high-risk population members in the personal social network of each respondent from the general population, and c is the reported average number of members in the personal social network of each respondent from the general population [6,17,18]. Membership in a personal social network was defined using the following statement: ‘They know you and you know them by name or by sight, they live in this region, and you have had some contact with them in the past 12 months’ [18]. The average size of the personal social networks of the general population (c) can be calculated by another formula $e_0/t = m_0/c$, where e_0 is

the sum of a list of specific populations, for which the actual size of the population is known by researchers (McCormick *et al*. verified that recall bias can be minimized through the approach of using given last names, with each accounting for 0.1–0.2% of the urban population in a region, as a known population to estimate the average size of the personal social networks) [19]; *t* is the latest annual average population in the region; and m_0 is the average size of the reported specific populations in the personal social network of each respondent from the general population [20,21].

However, there are two situations that are considered that affect NSUM estimates. First, the average size of the personal social networks of the high-risk populations may be smaller because of their hidden nature; therefore, their probability of becoming members of the personal social networks of the general population may be reduced. These barrier effects could cause the NSUM to underestimate the size of high-risk populations. Second, the members in the personal social network of the high-risk populations may be unaware that these people engage in high-risk behaviours [4,8,9,22]. This transmission error could also cause underestimation. In 2011, Salganik *et al*. proposed the popularity ratio and information transmission rate to adjust for barrier effects and transmission error, respectively [8,9]. The popularity ratio is the ratio of the average size of the personal social network of the high-risk population to the average personal social network size of the general population. The information transmission rate is the ratio of the average number of members in the personal social network of the high-risk population who are aware that these people engage in high-risk behaviours to the average size of the personal social network of the high-risk population. Finally, the NSUM estimate (e_1) is divided by the popularity ratio and information transmission rate to adjust for barrier effects and transmission error, respectively.

Field survey

The NSUM was applied to estimate the population size, popularity rate, and information transmission rate of PWID in the urban district of Taiyuan, China. Taiyuan is the capital city of Shanxi Province in northern China and has a population of 4.5 million. The field survey consisted of two parts, including a stratified two-stage cluster survey of the general population to obtain e_1 and a respondent-driven sampling (RDS) survey of the PWID population to obtain the popularity ratio and information transmission rate. RDS is a standard method recommended by the WHO to obtain representative samples of people at high risk of HIV infection [23-25]. All surveys were conducted between May 2021 and October 2021.

Stratified two-stage cluster survey of the general population

A stratified two-stage cluster survey of the general population was conducted in respondents' workplaces. According to the sample size required for stratified two-stage cluster sampling, the sample size of the general population survey was 1600 respondents [26]. In the first stage, 36 primary units (institutions, organizations, and companies) from all 20 industries (agriculture, manufacturing, electricity, construction, transportation, information transmission, retail, accommodations and catering, finance, real estate, business services, and others) were selected with the probability of selection proportional to the industry size from the sampling frame. In the second stage, 83 second-stage units (departments) were selected from the primary units chosen in the first stage. Finally, 1679 third-stage units (individual respondents) from the departments chosen in the second stage were interviewed in their workplaces. In addition, 68 unemployed respondents were interviewed at their former workplaces or communities. All respondents were required to be at least 18 years old.

In the survey, respondents were asked the following: 1) the numbers of members with specific last names in their personal social network whose last names are on a given list of last names, with each last name accounting for 0.1-0.2% of the population of Taiyuan (48 last names were used in our survey); and 2) number of PWID members in their personal social network. PWID are defined as people aged 15 years or older who had injected drugs (ie, illicit, nonprescribed, or illegal substances) at least once in the past 12 months [27]. Because question 2 is sensitive, an unrelated question randomized response technique (RRT) was used to eliminate response bias [28]. Before the interview, respondents were randomly divided into two groups. The respondents of the first group randomly received question 2 (number of PWID members in their personal social network) or an unrelated question (average hours online per week), with the ratio of the two questions being 8:2. The ratio of the two questions for the second group is 2:8. Because only each responder knows which question is answered, their privacy is protected, and question 2 is more likely to be answered truthfully. After the interview, the mean and variance of the respondent's answer to question 2 can be calculated by the formulas [28],

$$\mu = \frac{(1 - P_2) \times \mu_1 - (1 - P_1) \times \mu_2}{P_1 - P_2}$$

where μ_1 is the mean of responses from the first group, μ_2 is the mean of responses from the second group, P_1 is the proportion of sensitive questions in the first group, P_2 is the proportion of unrelated questions in the second group.

RDS survey of PWID

The RDS survey of PWID began with two seeds. According to sentinel surveillance data of drug

users in Taiyuan, the proportion of heroin and methamphetamine for injection is more than 90%, thus one heroin user and one methamphetamine user were used as two seeds. As the survey was conducted during the coronavirus disease 2019 (COVID-19) pandemic, PWID respondents were interviewed at COVID-19 nucleic acid amplification testing sites. First, the screeners checked whether the respondents met all of the following criteria: (1) people who had injected in the past 12 months, (2) living in the urban district of Taiyuan, and (3) aged 18 years or older. Second, PWID respondents were asked the following: (1) numbers of members with specific last names in their personal social network whose last names are on a given list of 48 last names, with each last name accounting for 0.1-0.2% of the population of Taiyuan; and (2) numbers of members with specific last names in their personal social network who are aware of their drug use. Third, each respondent received three coupons to recruit peers. After eight waves, a total of 302 PWID were interviewed to estimate the popularity ratio and information transmission rate. Due to RDS, the bootstrap method (10,000 resamples) was applied to calculate the 95% confidence intervals (CIs) for the popularity ratio and information transmission rate [29-31].

Ethical Considerations

The study was approved by the Medical Ethics Committee of Shanxi Medical University (reference number: 2018001). The study was conducted anonymously to protect the privacy of respondents. We received a waiver of the informed consent requirement for all respondents because no personally identifiable data was collected in the survey. All respondents were compensated for the time they spent participating in the survey. In addition, unemployed respondents and PWID respondents received transportation subsidies.

Results

Results of the stratified two-stage cluster survey in the general population

In the survey of the general population, despite the use of RRT, respondents who were still embarrassed during the survey were encouraged to submit unanswered answer sheets to ensure that they do not respond falsely. Finally, 6.3% (110/1747) of the respondents submitted unanswered answer sheets. Therefore, 93.7% (1637/1747) of respondents were successfully interviewed. The average size of the reported specific populations in the personal social network of each respondent (m_0) was 8.3 (95% CI: 6.2-10.3) (Figure 1). The sum of 48 specific populations of given last names (e_0= 302,251) and the annual average population in Taiyuan in 2021 (t= 4,531,429) were obtained before the survey; therefore, the estimated average size of the personal social networks of the general population (c) in

Taiyuan was 123.9 ([8.3×4,531,429]/ 302,251; 95% CI: 93.0-154.4). Furthermore, the reported average number of PWID population members in the personal social network of each respondent (m_1) was 1.6×10^{-2} (95% CI: 1.3×10^{-2}-1.9×10^{-2}); therefore, the initial NSUM estimate of the size of the PWID population (e_1) in Taiyuan was 585.1 ([1.6×10^{-2}/123.9] ×4,531,429; 95% CI: 475.5-694.9).

Results of the RDS survey of PWID

The average reported 48 specific populations of given last names in the personal social network of each PWID respondent was 4.4 (95% CI: 4.3-4.6) (adjusted estimate) (Figure 2); the average reported for each of the 48 specific populations of given last names strongly correlated with the actual proportion of the population size for each of the 48 last names (r=0.7, P<.01) (Figure 3); therefore, the estimated average size of the personal social networks of the PWID population in Taiyuan was 66.3 ([4.4×4,531,429]/ 302,251; 95% CI: 63.5-69.2), and the estimated popularity ratio of the PWID population in Taiyuan was 53.6% (66.3/123.9; 95% CI: 47.2%-60.1%). In addition, the average of reported numbers of members with 48 specific last names in the personal social network of the PWID respondents who are aware of their drug use was 3.9 (95% CI: 3.7-4.0) (adjusted estimate) (Figure 4); therefore, the estimated average number of members in the personal social network of the PWID population who are aware that these people engage in drug use was 58.5 ([3.9×4,531,429]/ 302,251; 95% CI: 55.5-60.0), and the estimated information transmission rate of the PWID population in Taiyuan was 87.9% (58.5/66.3; 95% CI: 86.5%-89.3%).

Results of the adjusted NSUM estimate

Finally, the adjusted NSUM estimate of the size of the PWID population in Taiyuan was 1,241.9 (585.1/[53.6%×87.9%]; 95% CI: 1,009.2-1,474.9), corresponding to 4.4×10^{-2}% (1,241.9/2,820,541; 95% CI: 3.6×10^{-2}%-5.2×10^{-2}%) of the adult population aged 15-64 years. In China, PWID are concentrated in seven provinces (Yunnan, Xinjiang, Guangxi, Guangdong, Guizhou, Sichuan, and Hunan) [16]. Therefore, the NSUM estimate of the population proportion of PWID (0.044%) in our study in Shanxi Province was below the national-level estimate (2.5×10^{-1}%, 95% CI: 1.9×10^{-1}%-3.1×10^{-1}%) obtained from a recent worldwide systematic review of the proportion of the population that is PWID in the adult population aged 15-64 years in 2008 [15].

Discussion

NSUM was recommended by UNAIDS and WHO to estimate the sizes of the populations at high risk of HIV infection. However, we found that the NSUM also revealed underlying population characteristics of PWID. In the current study, the average size of the personal social networks of the PWID population was only 53.6% of the average size of the personal social networks of the general population. Barrier effects thus reduced the opportunity for PWID to be members of the personal social networks of the general population by 46.4% because of the hidden nature of the PWID population, with its smaller average personal social network size. Additionally, 87.9% of the members of the personal social networks of the PWID population were aware of their drug use. Transmission error thus increased the possibility of PWID concealing their drug use from personal social networks by 12.1% because of the stigmatized nature of the PWID population. Therefore, the popularity ratio and the information transmission rate together revealed a characteristic of the PWID population: they have smaller sized personal social networks while concealing their drug use. A similar situation has occurred in the NSUM research, where the popularity rate and the information transmission rate were estimated. For example, the estimates of the popularity ratio and information transmission rate of PWID in Brazil in 2011 were 0.69 and 0.77, respectively; in 2013, the estimates for PWID in Iran were 0.69 and 0.54, respectively, and the estimates for FSWs were 0.77 and 0.45, respectively; and in 2018, the estimates for FSWs in China were 0.41 and 0.80, respectively [9,32,10].

However, such population characteristics present barriers to PWID populations accessing HIV prevention services. This may partly explain the fact that few countries have achieved adequate coverage of HIV prevention services [1]. As a result, progress in preventing the spread of HIV remains far too slow. It was estimated that the total number of new infections worldwide in 2019 was more than three times higher than the 500,000 milestone set for 2020 [33]. Therefore, UNAIDS recommended that the situation should be carefully evaluated before providing HIV prevention services to improve the programme’s effectiveness and sustainability [11]. In our study, the characteristics of the PWID population revealed by the NSUM indicated that peer-led services might be more effective than professional-led services in improving coverage of HIV prevention services. For example, the comprehensive package for HIV prevention could be delivered by peer outreach workers (i.e., individual members of the PWID population who are trained to deliver or support access to harm reduction services) rather than health facilities. Because of common experience, peer outreach workers are more likely to be trusted by the PWID population to give acceptable and appropriate HIV prevention services. Especially for HIV testing services, the PWID

population could conduct self-testing counseled by peer outreach workers. This strategy is both discreet and convenient while improving disruptions in HIV prevention services for the PWID population caused by COVID-19 pandemic because of health facilities repurposed to handle the influx of COVID-19 patients.

Conclusions

As the latest method for the estimation of the size of the high-risk population recommended by the UNAIDS and WHO, in addition to producing size estimates for the PWID population, the NSUM also revealed the social network characteristics of the PWID population. These underlying population characteristics are extremely useful for planning appropriate service delivery approaches with the fewest barriers for the PWID population to access HIV prevention services. Therefore, the NSUM could help to improve the coverage of HIV prevention services, effectively preventing new HIV infections. More cost-effectiveness brings new public health implications for NSUM, which makes it even more promising for its application.

limitations

In general, household surveys are recommended for surveys of the general population. We piloted a household survey in this study. Unfortunately, the response rate is less than 10% due to the COVID-19 lockdowns. Therefore, we conducted a survey of the general population in respondents' workplaces. According to the 2020 National Economic and Social Development Statistical Communiqué released on March 18, 2021, the unemployment rate in Taiyuan in 2020 was 3.2%, and thus 68 unemployed respondents were interviewed at their former workplaces or communities. Although we included respondents who were unemployed proportionally, there was still some possibility of selection bias. In addition, due to the sensitive questions included in the survey, general information about the respondents' characteristics (e.g., age, gender, etc.) was not collected in the survey. Therefore, we were unable to describe the general characteristics of the respondents in this study.

Acknowledgements

This study was funded by National Social Science Fund of China.

Data Availability

The data related to this study can be obtained upon reasonable request to the corresponding author.

Conflicts of Interest

None declared.

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Figure titles

Figure 1. Numbers of specific populations in the personal social network of each respondent from the general population in Taiyuan, China in 2021.

Figure 2. Numbers of specific populations in the personal social network of each PWID respondent in Taiyuan, China in 2021.

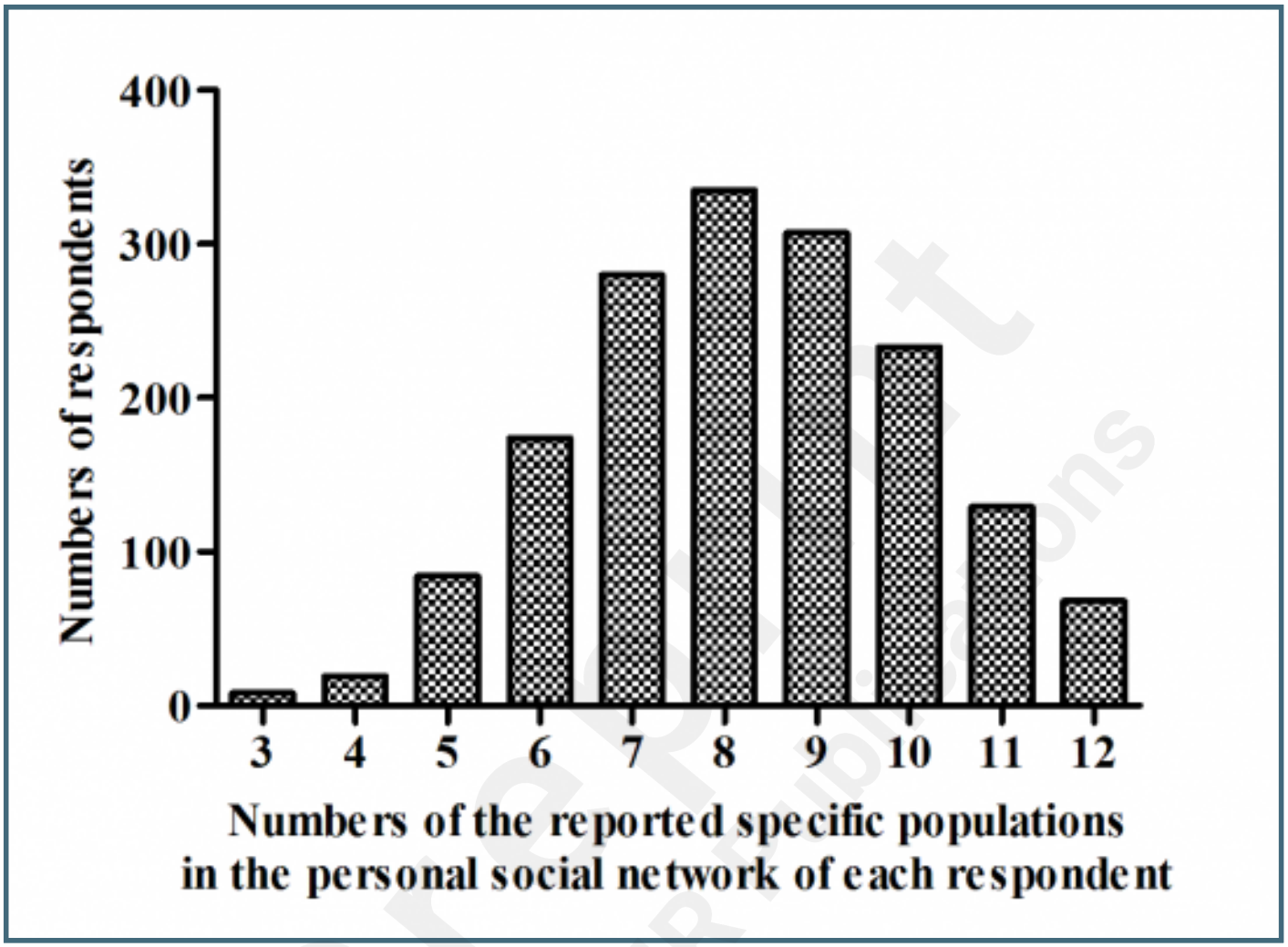
Figure 3. PWID respondents reported proportion compared to the actual proportion of the population size for each names in Taiyuan, China in 2021.

Figure 4. Numbers of members in the personal social network of the PWID respondents who are aware of PWID respondents' drug use in Taiyuan, China in 2021.

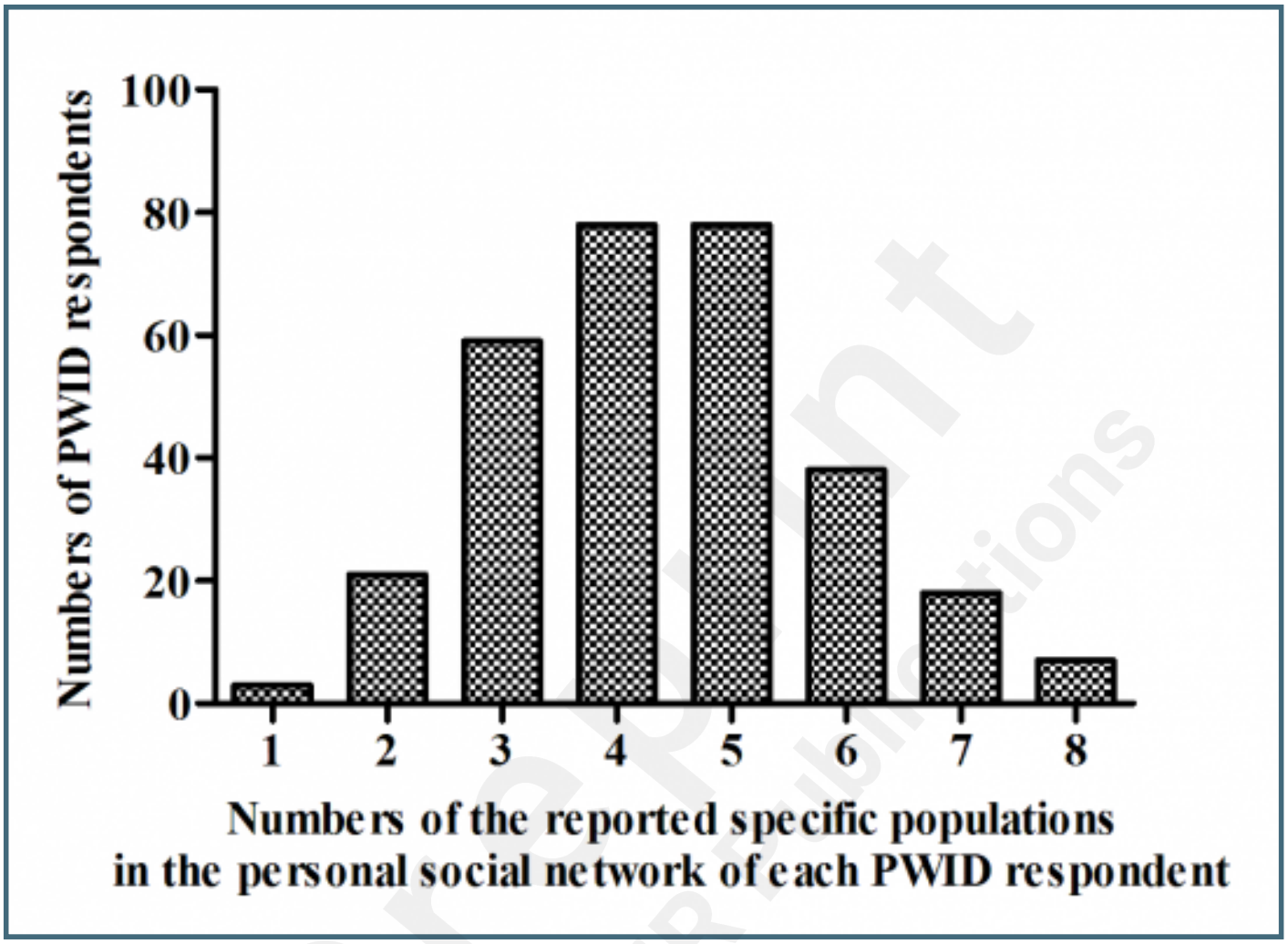
Supplementary Files

Figures

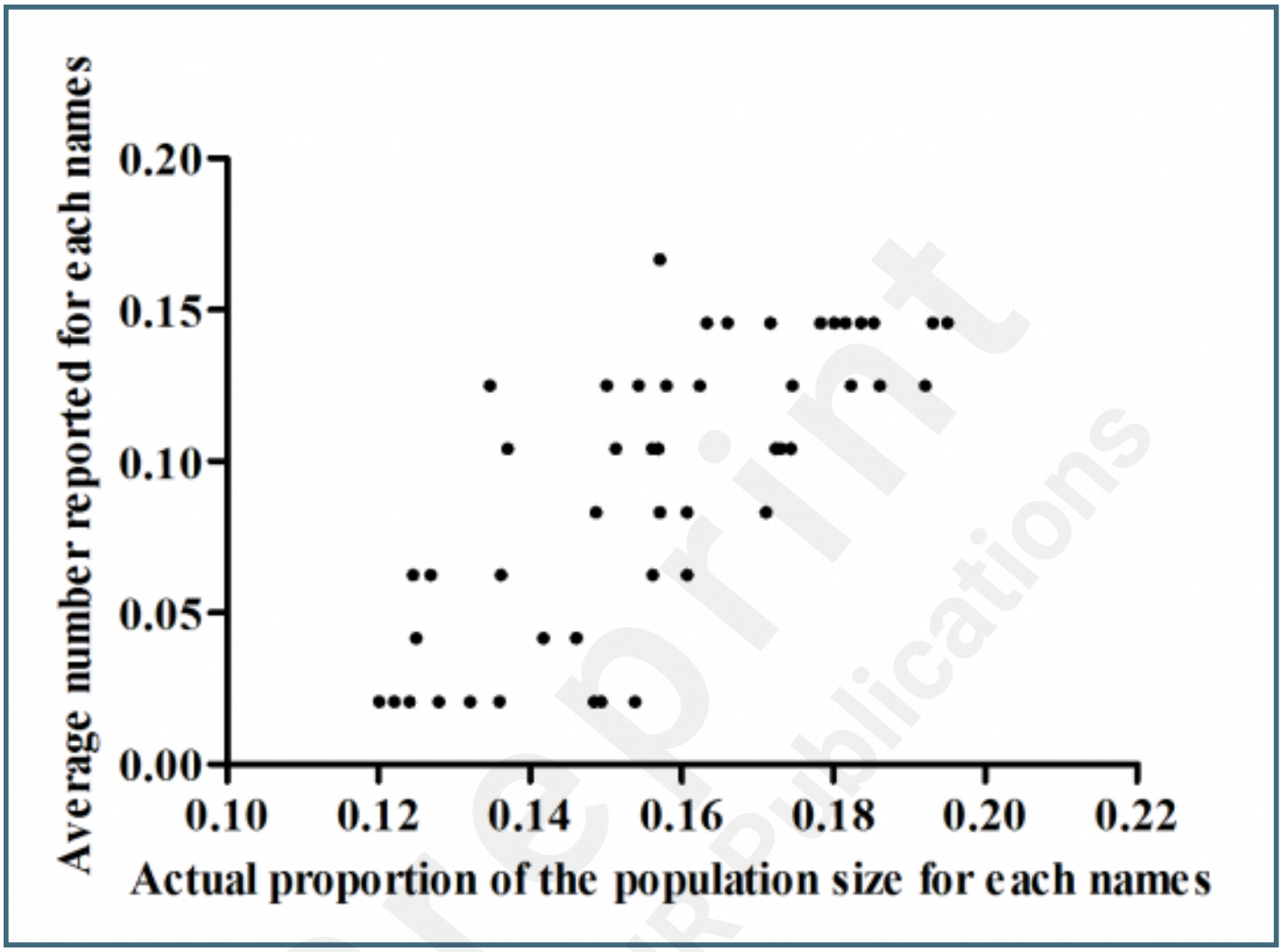
Numbers of specific populations in the personal social network of each respondent from the general population in Taiyuan, China in 2021.



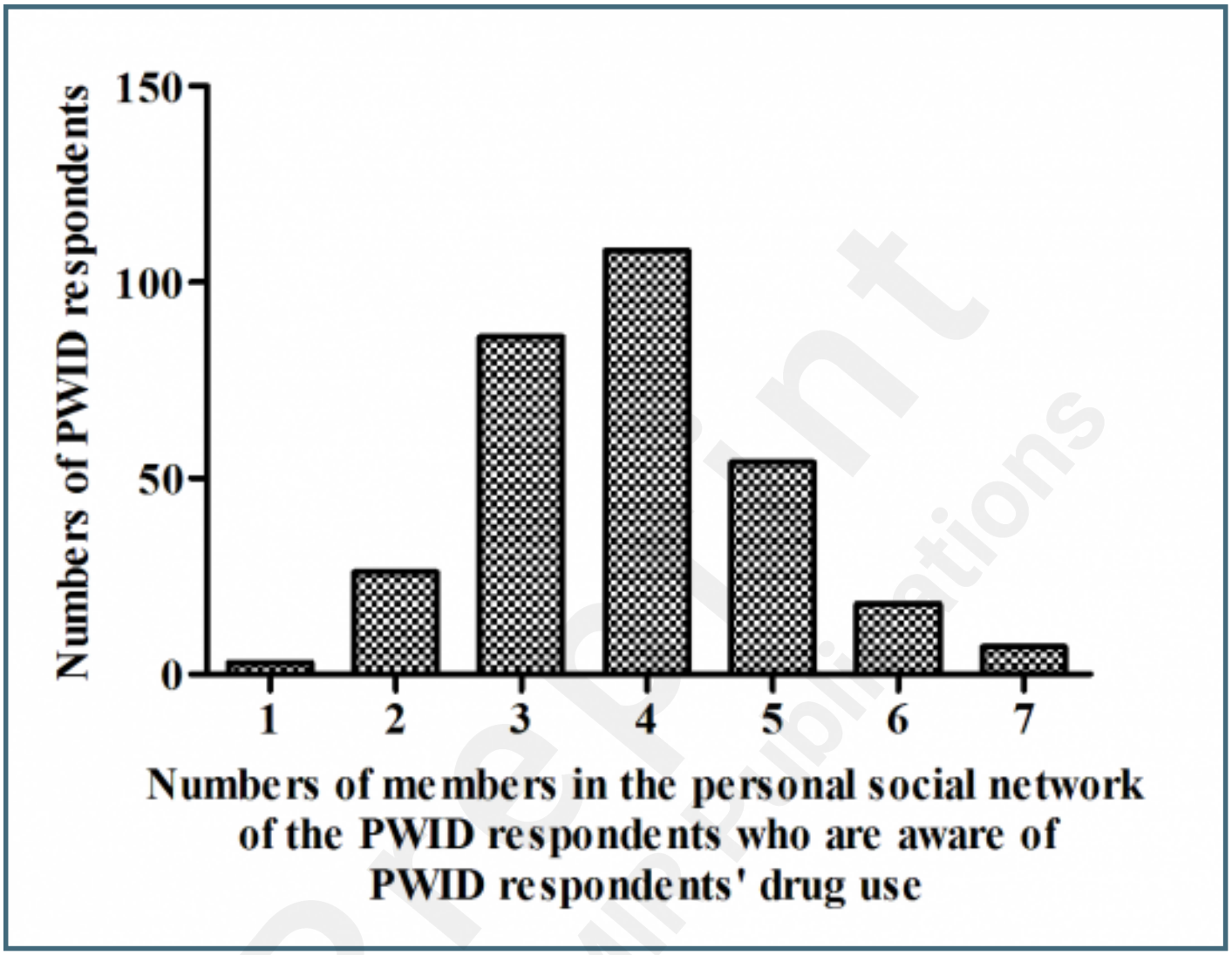
Numbers of specific populations in the personal social network of each PWID respondent in Taiyuan, China in 2021.



PWID respondents reported proportion compared to the actual proportion of the population size for each names in Taiyuan, China in 2021.



Numbers of members in the personal social network of the PWID respondents who are aware of PWID respondents' drug use in Taiyuan, China in 2021.



CONSORT (or other) checklists

STROBE_checklist_cross-sectional.
URL: http://asset.jmir.pub/assets/22ee73d4c0c68220efedbeebfaa534b5.pdf