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Original Article

Estimating the Prevalence of People Injecting Drugs at Ages 18-45 in Shiraz, Iran: The Use of a Network Scale-Up Approach

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Abstract

Background and aims: Accurate estimation of populations at heightened risk for Human Immunodeficiency Virus (HIV) infection is essential for effective healthcare intervention planning and resource allocation. This study employed the network scale-up method to estimate the prevalence of People Who Inject Drugs (PWIDs) aged 18-45 in Shiraz, Iran.

Methods: A purposive sampling approach was used to recruit 768 individuals aged 18-45, who were interviewed using a self-administered questionnaire. The average social network size was estimated using 16 reference groups with known population frequencies. Post-correction factors were applied to adjust for transmission and relative network-size errors. Data were analyzed using SPSS version 25.

Results: The mean reported social network size was 203 individuals. The crude estimate of PWIDs in the target age group was 1,812, while the adjusted estimate was 4,857 (95% UI: 4,231-5,483). The prevalence of PWIDs was estimated at 561 (95% UI: 488-633) per 100,000 individuals, with the highest prevalence observed among those aged 35-39 years.

Conclusion: The estimated number of PWIDs significantly exceeds the current number of individuals receiving support from harm-reduction services. To effectively combat the spread of HIV, enhancing access to prevention and treatment services for this population is crucial.

Keywords: Prevalence, Risk groups, HIV infections, Social network analysis

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Introduction

Human Immunodeficiency Virus (HIV) infection in the Middle East and North Africa (MENA) region is primarily concentrated among subgroups engaged in high-risk behaviors, including people who inject drugs (PWIDs), female sex workers (FSWs) and their clients, and men who have sex with men (MSM).[1] These groups are classified as the most-at-risk populations (MARPs) for HIV.[2,3]

In countries such as Iran, which are experiencing a concentrated HIV epidemic, these subpopulations are integral to understanding the transmission dynamics of the virus within the broader community.[4,5] Accurate estimation of their population sizes is essential for effective intervention planning, resource allocation, infection prevalence assessment, disease burden prediction, service coverage monitoring, and program evaluation at both local and national levels.[2,6-8]

Given that the concentrated HIV epidemic in Iran is largely observed among PWIDs, reliable size estimates of this population are essential for informing national harm-reduction policies, optimizing resource allocation, and assessing progress toward the UNAIDS 95–95–95 goals.[7-9] Without precise data on the magnitude of the PWID population, the planning, implementation, and evaluation of evidence-based interventions remain significantly limited.[5,10,11]

However, due to the nature of their behaviors, as well as concerns about stigma, discrimination, and legal consequences, these populations often remain hidden in society and difficult to reach.[12,13] Consequently, obtaining accurate population size estimates poses major challenges for national HIV/AIDS surveillance systems.[2,5,14] Given that these groups constitute only a small proportion of the general population and are largely concealed, conventional sampling methods and direct estimation approaches are typically ineffective for estimating their sizes.[15-17]

In recent years, several methodologies—including enumeration, census, capture–recapture, and the network

scale-up (NSU) approach—have been developed to estimate the size of hidden or hard-to-reach populations, each with distinct strengths and limitations.[3,6,18] Among these, the NSU method has gained particular prominence due to its ability to estimate the sizes of multiple high-risk groups simultaneously without necessitating direct contact with their members.[16] By collecting information from the general population rather than recruiting individuals from high-risk groups, NSU provides a safer, less intrusive alternative to direct estimation techniques such as capture-recapture and multiplier methods.[5,19,20] However, despite its advantages, the NSU approach is susceptible to various forms of bias, most notably transmission error and relative network-size bias, which must be carefully addressed to enhance the accuracy and validity of resulting estimates.[5]

Despite notable advances in HIV prevention efforts in Iran, reliable estimation of the number of PWIDs remains a significant surveillance gap.[4,21] According to the latest national report (2020), the HIV prevalence among registered PWIDs is estimated at approximately 3.5%, highlighting the urgent need for accurate population size estimation to strengthen targeted interventions.[21] As PWIDs accounted for about 61.9% of HIV transmissions in Iran by 2018, primarily through needle sharing, precise size estimation is essential for evidence-based planning and evaluation of harm-reduction programs.[4] This study aimed to estimate the size of the PWID population aged 18–45 years in Shiraz using the NSU method, while addressing key sources of bias inherent to this approach. The findings are expected to enhance the precision of HIV surveillance data and support the development of more effective prevention strategies at both local and national levels.

Materials and Methods

Sampling and Data Collection

This cross-sectional study aimed to estimate the size of the PWID population in Shiraz, the capital of Fars Province, using the NSU method. The target population included individuals aged 18-45 years who had resided in Shiraz for at least five years. According to the latest National Population and Housing Census conducted by the Statistical Center of Iran, Shiraz has a total population of 1,712,745, of whom 866,160 fall within this specified age range.

All individuals aged 18-45 years who had lived in Shiraz for at least the preceding five years were considered eligible for participation. In accordance with ethical research standards, only individuals who provided written informed consent were enrolled. Prior to obtaining consent, participants were informed that all collected data would remain anonymous and that participation was entirely voluntary.

Since obtaining a fully random sample from the entire population of Shiraz was not feasible due to its size and logistical constraints, a multistage sampling strategy was implemented to improve representativeness. First, the city was stratified into three socioeconomic tiers (low, middle, and high) to reflect the diversity of the 18-45-year-old population. Within each socioeconomic stratum, neighborhoods were defined as distinct clusters, and three neighborhoods were randomly selected from each stratum. Following the selection of neighborhoods, data were collected through convenience sampling, with trained interviewers administering the questionnaire during both morning and evening periods in the streets of the selected areas. In total, 768 eligible participants completed the self-administered questionnaire.

The study questionnaire comprised three sections: (1) demographic information, (2) items assessing the average size of respondents' social networks, and (3) questions estimating the frequency of PWIDs known to participants within the target population. The questionnaire is provided in the Supplementary Material. The social network section included questions regarding the number of acquaintances within each reference-name group. In contrast, the PWID section inquired whether respondents personally knew anyone who had injected drugs at least once in the past 12 months. To minimize recall bias, the questionnaire provided examples and clear definitions.

Network Scale-up Method

The NSU method is based on the assumption that the prevalence of a target group within an individual's active social network reflects its prevalence in the general population. To minimize under-reporting of sensitive behaviors, participants were asked about the high-risk behaviors of individuals within their social network. The primary NSU formula is as follows:

Formula (1): $\frac{m}{c} = \frac{e}{t}$

where m is the number of individuals known by the respondent within the intended group (e.g., PWIDs), c denotes the respondent's network size, e represents the size of the intended group, and t is the total population size. The average social network size is calculated using Formula (2):

Formula (2): $c_i = t * \frac{\sum_{j=1}^{L} m_{ij}}{\sum_{j=1}^{L} e_j}$

where j and i represent the respondent's group and the respondent, respectively.

In the current study, "active social network" refers to cases in which the respondent is familiar with the individual by name or sight, has personal or telephone contact, and can connect with them if needed.

Calculation and Validation of C

Reference groups were selected based on the availability of reliable national frequency data, cultural familiarity, and balanced gender representation. Sixteen first names (eight male and eight female) were chosen, each with

a prevalence range of 0.1% to 4%, while combined or gender-neutral names were intentionally excluded. The frequency of these names was obtained from the National Organization for Civil Registration.

Data from all selected names were used to calculate the adjustment factor (*C*), which was then applied to back-calculate the sizes of reference groups. Internal consistency was evaluated using iterative ratio testing of actual-to-estimated group sizes, excluding any reference groups with ratios outside the acceptable range (0.5-2). This process was repeated until all ratios met the criterion, and the final *C*-value was then used for estimating the size of the PWID population.

To validate the results, the Pearson correlation coefficient was computed between actual subgroup values (nominal subgroups or their remnants) and their corresponding estimated values.

Crude Estimation of the Size of People Who Inject Drugs

After determining the *C*-value, the crude size of the target group was computed using the NSU formula as follows:

Formula (3): $$e = t * \frac{\sum_{j=1}^{L} m_{ij}}{\sum_{i=1}^{L} c_i}$$

Post Corrections

Visibility Factor

The NSU method assumes that respondents are fully aware of individual behaviors within their social networks. However, sensitive behaviors such as injection drug use are often concealed, leading to transmission errors and underestimation. To address this, a Visibility Factor (VF) of 0.54 was applied for PWIDs. This value was derived from the results of Maghsoudi et al, who computed correction factors for NSU errors in estimating MARPs.[5]

Popularity Factor

Another assumption of the NSU is that all individuals in the general population have an equal likelihood of recognizing members of the target group within their social networks. In reality, marginalized populations may possess smaller social networks, which can skew estimates. This relative network size error was addressed using a Popularity Factor (PF), estimated at 0.70 for PWIDs.[5]

The target group size was adjusted using the following formula:

Formula (4): $$\hat{e} = t * \frac{\sum_{j=1}^{L} m_{ij}}{\sum_{i=1}^{L} c_i} \times \frac{1}{PF} \times \frac{1}{VF}$$

Construction of Uncertainty Interval

To determine the 95% Uncertainty Interval (UI) for both *C* and *e*, a bootstrap procedure was implemented with 1,000 iterations. This approach involved drawing 1,000 independent samples with replacement from the original dataset, allowing for the calculation of statistics for each sample based on the 16 names and their averages. The lower and upper bounds of the UI were established by the 2.5% and 97.5% percentiles of the sorted statistics.

Results

A total of 768 participants were enrolled in this study, with an equal distribution of males and females. The mean age of the participants was 30.11 years (SD = 8.57). Among respondents, 60% of males and 55% of females reported having completed higher education. A summary of additional demographic characteristics is provided in Table 1.

Initial calculations of the raw C-value were derived from 16 nominal subgroups, yielding a preliminary value of 210. After computing the ratio of actual to estimated values, two reference groups were excluded from the final C-value estimation. The average number of active social network contacts among individuals aged 18-45 years in Shiraz was 203, comprising 103 males and 100 females. This indicates that each participant in this age demographic was, on average, connected to 203 individuals (103 males and 100 females) within the target population.

Following the removal of the two nominal subgroups and recalculation of estimates, the Pearson correlation coefficient between actual subgroup sizes and those estimated using the back-calculation method was found to be 0.99 ($P < .0001$), indicating an exceptionally high level of accuracy in the method's estimations. Social network sizes by demographic characteristics are presented in Table 2.

Participants reported knowing 326 individuals who are PWIDs. According to the latest National Population and Housing Census in Iran, 866,160 individuals aged 18-45 resided in Shiraz. Crude and adjusted estimates for the PWID population size are summarized in Table 3.

According to Table 3, the highest prevalence of PWID was observed in the 35-39, 30-34, and 25-29-year age groups, while the lowest prevalence was found among individuals aged 18-24 years.

Discussion

Active Social Network

This study employed a known-population approach and

Table 1. Demographic Characteristics of Participants

Variable	Category	Frequency (%)
Age (years)	18-24	247 (32.2)
	25-29	142 (18.5)
	30-34	127 (16.5)
	35-39	95 (12.4)
	40-45	157 (20.4)
Education Level	Ability to read and write	58 (7.6)
	High school diploma	268 (34.9)
	Academic	442 (57.6)
Socioeconomic Status	High	256 (33.3)
	Moderate	256 (33.3)
	Low	256 (33.3)

Note. PWID: People who inject drugs.

16 first names as reference groups to estimate the sizes of participants' active social networks. Previous research has demonstrated the high accuracy of this method in estimating the sizes of active social networks.[3,5,17] Our findings indicate that the average active social network size among individuals aged 18-45 years in Shiraz comprises 203 individuals, containing 103 males and 100 females.

Variability in social network size estimates across different studies can be attributed to methodological differences, including variations in sampling techniques, geographical contexts, and demographic factors. For example, Kilworth et al reported a mean social network size of 286 individuals using a similar known population approach.[22] Similarly, Gue et al urilized backward estimation among 19 reference groups in China, yielding an average social network size of 310 for individuals aged 18 to 60 years in China.[23] In Iran, Rastegari et al found an average active social network size of 308 for individuals over 18 years old.[11]

The discrepancies in these findings may arise from the broader population coverage in those studies compared to our focused analysis within a single city. Moreover, the narrower age range in our study likely contributed to a smaller C-value. For example, Shati et al reported a C-value of 259 for individuals aged 18 and older in Tehran,[13] which is comparable to our findings but may reflect differences in the age range considered. It is crucial to acknowledge that geographical, cultural, and demographic factors can significantly influence these variations.

Table 2. Social Network Size by Demographic Variables

Variable	Subgroups	Network size	SD of Network Size
Sex	Male	200	44.3
	Female	205	44.02
Age Group	18-24	200	38.9
	25-29	195	42.9
	30-34	203	44.5
	35-39	197	44.9
	40-45	216	49.4
Education Level	Ability to read and write	222	57.9
	High school diploma	205	45.1
	Academic	199	40.9
Socioeconomic Status	High	199	41.6
	Moderate	205	45.8
	Low	204	45.0

Note. SD: Standard deviation.

People Who Inject Drugs

In the present study, the estimated frequency of PWIDs among the 18-45-year-old population in Shiraz was determined to be 561 per 100,000 or 0.5%. In contrast, Shokoohi et al reported a prevalence of 1.2% in Kerman for the same age group,[3] highlighting a significant difference. The comparatively lower prevalence observed in our study may be influenced by the inclusion of both genders, given that the vast majority of PWIDs in Iran are male.

Using the NSU method, Jafari et al identified a frequency of 280 per 100,000,[24] which is significantly lower than our estimate. Variations in the age distribution of the target populations likely explain this discrepancy. Nikfarjam et al observed lower prevalence rates in individuals under 18 and over 45 years.[25]

Moreover, a study conducted by Narouee et al reported a frequency of 1,263 per 100,000 among the population over 18 years in Iranshahr, Sistan and Baluchistan Province,[2] a figure nearly double our estimate. The elevated prevalence in Sistan and Baluchistan region may be attributed to its geographical proximity to Afghanistan and Pakistan, as well as high regional rates of unemployment and poverty.

In Jahrom, Fars Province, a previous study indicated a PWID prevalence of 0.26% among males aged 18-45 years.[14] This lower estimate could potentially stem from methodological limitations, including the lack of error correction mechanisms in the applied methods, which could lead to an underestimation of the actual sizes of MARPs.

The relatively narrow 95% UI for our PWID size estimation indicates good internal consistency, suggesting limited sampling variation. Nevertheless, this range may still reflect the potential for reporting biases inherent in network-based estimates and should be interpreted as a plausible range rather than an exact count.

Conclusion

Our findings highlight several practical implications for public health planning and policy formulation. First, they underscore an urgent need to expand harm-reduction and outreach initiatives, with a particular focus on needle-exchange programs and opioid substitution therapy services. The integration of PWID population size estimates into municipal health planning can facilitate the proportional allocation of preventive resources and allow

Table 3. Crude and Adjusted Size Estimates of PWIDs by Age Groups

Age Group	Σmi	Σci	t	Crude e	Adjusted e	Rate in 100000
18-24	23	49464.10	176534	82.08	219.97	125
25-29	32	27746.65	182977	211.02	565.53	309
30-34	56	25870.21	206486	446.97	1197.87	580
35-39	125	18672.08	159478	1067.62	2861.22	1794
40-45	90	34052.71	140685	371.82	966.47	687
Total (95% UI)	326	155805.75	866160	1812.30	4857 (4231-5483)	561(488-633)

Note. PWID: People who inject drugs.

for ongoing monitoring of program coverage over time. Secondly, to strengthen the accuracy of population size estimates for PWIDs and other MARPs, future research should employ diverse methodologies. Triangulating the NSU method with alternative approaches can improve precision, support the evaluation of service reach, and substantively inform HIV prevention and control strategies. Thirdly, the systematic estimation of MARP sizes will enable longitudinal tracking of t public health policy impacts, thus supporting evidence-based decision-making and resource optimization.

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Authors' Contribution

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Competing Interests

The authors declare no conflict of interests.

Ethical Approval

The study protocol was approved by the Ethics Committee at Shiraz University of Medical Sciences (Ethical Code: IR.SUMS.REC.1398.217). All participants provided written informed consent after being informed about the anonymity of their data and the voluntary nature of their participation. To protect participant rights and confidentiality, interviews were conducted without collecting personal identifiers, allowing respondents to skip any question they found uncomfortable. All data were analyzed only in aggregate form to minimize the risk of stigma and safeguarding participant privacy.

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