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Mapping and Estimating the Size of Key Affected Populations in Iran: Methodological Issues

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Abstract

Background: Reliable estimates of key affected populations (KAPs), including people who inject drugs (PWID) and people who use drugs (PWUD), are essential for effective human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) and harm reduction programming. This study compares how 3 methodological adjustments collectively modify PWID/PWUD size estimates across 4 Iranian cities.

Methods: Using data from mapping exercises in 4 Iranian cities (Ahvaz, Sari, Yazd, and Tehran), we applied 3 methodological adjustments: (1) frequency adjustment (correcting for infrequent hotspot attendance); (2) duplication adjustment (accounting for multihotspot visitors); and (3) hidden population adjustment (incorporating KAPs avoiding mappable sites). Input parameters were derived from field surveys and national studies, including the Iranian Mental Health Survey.

Results: Frequency adjustment increased initial PWID estimates (eg, Ahvaz: from 843 to 2104), while duplication adjustment reduced them by 29% to 37%. Hidden population adjustment (assuming 76% of PWID avoid hotspots) yielded final estimates of 1966 (Ahvaz), 854 (Sari), 663 (Yazd), and 28 (Tehran). PWUD estimates followed similar trends, although hidden population adjustments were limited by data gaps.

Conclusion: Standard hotspot mapping significantly underestimates KAP sizes if methodological biases are unaddressed. Our 3-step adjustment framework enhances accuracy but highlights limitations, including reliance on mobility assumptions and accuracy of the available national survey data. These findings advocate for integrating correction factors into KAP surveillance systems to optimize resource allocation for harm reduction.

Keywords: People who inject drugs, Key affected populations, Mapping, Size Estimation, Iran

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Introduction

Knowledge of the accurate estimation of the key affected population (KAPs) is essential for developing, monitoring, and evaluating harm reduction programs for controlling the human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) epidemic and other diseases related to high-risk behavior, such as hepatitis B, hepatitis C, and sexually transmitted diseases (1-4). Several methods, such as capture-recapture, multiplier, and network scale-up techniques, are employed to estimate the size of KAPs (5-8).

Although these methods are useful to calculate a more accurate number of hidden populations, they cannot determine the geographic distribution of key populations (9, 10).

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↑What is "already known" in this topic:
The mapping and size estimation method is an appropriate technique for size estimation of the key affected population (KAPs) and their geographic distribution.

→What this article adds:
It is necessary to apply some corrections, such as adjustment for the frequency of hotspot visits by KAPs, duplication adjustment, and hidden population adjustment, as the mapping and size estimation results for key affected populations (KAPs) may contain some biases because they only take into account the visible population in the mappable hotspots.

The hotspot mapping and size estimation method is another technique used to estimate the size of key populations and their geographic location (9-12). This approach involves field visits and interviews with key informants to locate hotspots, estimate the number of people who inject drugs (PWID), and people who use drugs (PWUD), and assess the prevalence of high-risk behaviors in these areas. The major limitation of this method is that it only includes the visible KAPs who currently come to the mappable hotspots. Some situations should be considered in the mapping and size estimation of key populations: (A) Some KAP members may do not visit the hotspots as frequent as they could be included in the mapping period (they may come once a week or once a month to mappable hotspots); (B) the KAP members may visit multiple hotspots and they could multiple counted by field team based on their mobility; (C) The proportion of KAP population may not come to the general mappable hotspot and have a high-risk behavior practice in the private places. The proportion of the hidden population of KAPs should also be considered in the population size estimation (13, 14). This study compares how 3 methodological adjustments—frequency adjustment (for irregular hotspot attendance), duplication adjustment (for multi-hotspot visitors), and hidden population adjustment (for those avoiding mappable sites)—individually and collectively modify PWID/PWUD size estimates across 4 Iranian cities, quantifying their impacts on surveillance accuracy for harm reduction programming."

Methods

Based on the data of hotspot mapping and size estimation of PWIDs and PWUDs that were previously carried out and documented in 4 Iranian cities: Ahvaz, Sari, Yazd, and Tehran's District 2, we described the implementation of 3 adjustment techniques: frequency adjustment, duplicate adjustment, and hidden population adjustment (15).

Adjustment for the Visitation Frequency of KAPs to Hotspots

Other KAPs may visit the hotspots more frequently than others during the mapping and size estimation data collection procedure. Notwithstanding the variation in hotspot activity levels on different days of the week, some KAPs can have a tendency to frequent particular hotspots. It is less likely that KAPs who only visit the hotspot occasionally—that is, once a week or once a month—will be visible, which leads to an underestimation of their population. The algorithm below is used to correct the possible undercount of PWIDs and PWUDs in the 4 Iranian cities (13, 14):

$$S_1 = \left(Ci * P_f * f_p\right) + \left(Ci * P_f * f_p\right) + \left(Ci * P_f * f_p\right) \ldots$$

Where:

S_1= the estimated total size of KAPs in X district (i) after adjusting for the frequency.

Ci = the estimated number of current KAPs at the site (during the period of hotspot mapping).

P_f= the proportion of KAPs visiting the hotspots in a X district, with the frequency of f_p.

f_p = the frequency of the hotspot visited by KAPs.

The frequency of FP in every district is derived from mobility and behavioral information in the data gathering process of the mapping and size estimation exercise, eg, f_p=1 for KAPs who have daily hotspot visiting, f_p= 7 for KAPs visiting the hotspot once a week, and f_p= 30 for KAPs visiting the hotspot once a month. Moreover, the P_f in every city was extracted from the data gathered by the field team in the mapping practice (eg, in Yazd, 73% of the KAPs observed at the hotspots come daily, 26% of them visit the hotspots once a week, and only 1% of them come once a month. To obtain an accurate frequency adjustment, the pattern of hotspot visiting frequency by KAPs should be distributed randomly over time. If there are significant and strong patterns over time regarding referring KAPs to the hotspots, this adjustment may be applied inaccurately (14).

Adjusting for Duplication of KAPs Going to Multiple Hotspots

When we start to conduct mapping of hotspots, some KAP members may visit multiple hotspots, and it is possible to double-count them by field team members, or the Key informants may report those who have already been counted in other hotspots during the interview by field team members. This problem may result in the overestimation of active PWIDs or PWUDs in the targeted area. To deal with the duplicate records, we used the following formula (13, 14) to adjust for duplication of KAPs going to multiple hotspots in every city:

$$S_2 = S_1 - {}^{1}\!/_{2}\,(Di)$$

Where:

S_2= the estimated number of KAPs after adjusting for duplication.

S_1= the estimated size of KAPs after adjusting for frequency.

Di = the estimated number of current KAPs in district i who visited multiple hotspots.

The percentage or number of KAPs who visit several hotspots, assuming that the KAP member visits each hotspot at the same frequency, is the data needed for this adjustment. We acquired this data by having the field team map and estimate the extent of hotspots while conducting key informant interviews in each hotspot.

Hidden Population Correction

An additional factor incorporated in our analysis was the proportion of KAPs who were estimated not to come to the mappable hotspots and remain hidden. It means that some KAPs with high-risk behaviors are interested in private places, such as a private house, rather than the public hotspots, and they may not be visible in the mappable hotspots. We used the following formula (13, 14) to adjust for undercounting due to the hidden population in each city:

$$S_3 = {}^{S_2}\!/_{P}$$

Where:

S_3= the adjusted total size of KAPs (after adjusting for frequency, duplicate, and hidden population).

S_2 = the adjusted number of KAPs after adjusting for frequency and duplicates.

P = the estimated proportion of KAPs who do not visit the mappable hotspots.

To find out what percentage of KAPs visit the mappable locations, a larger poll of the KAP population is ideally recommended. To ascertain the percentage of the concealed population, however, the national or regional research that is now accessible could be utilized (13, 14).

We used the data from both the Iranian Mental Health Survey and national estimates of illicit drug user populations derived from network scale-up methods to determine the proportion of KAPs who do not visit the mappable hotspots in Iran (16, 17).

Results

The raw data of hotspot mapping and size estimation of PWIDs that were previously conducted and reported in the 4 cities of Iran were presented in Table 1 (15). Ahvaz demonstrated the highest crude estimate of PWIDs (843, range: 703-987), followed sequentially by Sari (346, range: 307-666), Yazd (228, range: 221-471), and Tehran's district 2 (18, range: 18-34). Moreover, the highest unadjusted number of PWUD was reported in Ahvaz (1242, range: 606-1285), followed sequentially by Sari (788, range: 373-1044), followed by Tehran's district 2 (684, range: 642-728), and Yazd (123, range: 76-317).

The results of frequency adjustment indicated that this correction produced a substantial increase in the number of PWIDs in 4 cities regarding the proportion of KAPs visiting the hotspot daily, once in week, and once in month in each city (P1 to P3 in Table 1). The frequency-adjusted number of PWIDs was (2104.13, range: 1754.69-2463.55) in Ahvaz, (968.80, range: 859.60-1864.80) in Sari, (649.80, range: 629.85-1342.35) in Yazd, and (26.64, range: 26.64-50.32) in district 2 of Tehran. Ahvaz had the highest frequency-adjusted number of PWUDs (3100.03, range: 1512.58-3207.36), following Sari (2206.40, range: 1044.40-2923.20), Tehran (1012.32, range: 950.16-1077.44), and Yazd (350.55, range: 216.60-903.45) (Table 1).

The number of PWIDs and PWUDs decreases as a result of the duplication adjustment (Table 1). Following this modification, the number of PWIDs decreased from 2104.13 to 1493.93 in Ahvaz, from 968.80 to 649.10 in Sari, from 649.80 to 503.60 in Yazd, and from 26.64 to 21.18 in Tehran's district 2.

Moreover, the number of PWUDs in Ahvaz declined from 3100.03 to 2201.02, in Sari declined from 2206.40 to 1478.29, in Yazd declined from 350.55 to 271.68, and in Tehran declined from 1012.32 to 804.79 (Table 1).

To adjust the hidden population adjustment, the proportion of PWIDs who did not visit the mappable hotspots was estimated to be 76% based on the 2 national studies in Iran (16, 17). The highest final estimation of PWIDs after conducting the hidden population adjustment was in Ahvaz (1965.70, range: 1639.25-2301.12), Sari (854.08, range: 757.81-1643.97), Yazd (662.63, range: 642.28-1368.85), and district 2 of Tehran (27.86, range: 27.86-52.63) (Table 1). However, we were unable to conduct the hidden population adjustment for PWUDs due to a lack of national evidence to determine the proportion of PWUDs who do not visit the mappable hotspots in Iran.

Table 1. Results of correction factors to estimate the size of PWIDs and PWUDs in Iran

Type of adjustment	Variables	Ahvaz	Sari	Yazd	Tehran
Raw data (Unadjusted)					
	PWID	843 (703-987)	346 (307-666)	228 (221-471)	18 (18-34)
	PWUD	1242 (606-1285)	788 (373-1044)	123 (76-317)	684 (642-728)
Frequency adjustment	P1	0.81	0.70	0.73	0.92
	P2	0.17	0.30	0.26	0.08
	P3	0.02	0.00	0.01	0.00
	PWID	2104.13 (1754.69-2463.55)	968.80 (859.60-1864.80)	649.80 (629.85-1342.35)	26.64 (26.64-50.32)
	PWUD	3100.03 (1512.58-3207.36)	2206.40 (1044.40-2923.20)	350.55 (216.60-903.45)	1012.32 (950.16-1077.44)
Duplication adjustment					
	Di (for PWIDs)	1428.86	1230.77	604.06	10.92
	Di (for PWUDs)	1798.02	1456.22	406.55	389.57
	PWID	1493.93 (1245.83-1749.12)	649.10 (575.93-1249.42)	503.60 (488.13-1040.32)	21.18 (21.18-40.00)
	PWUD	2201.02 (1073.93-2277.23)	1478.29 (699.75-1958.54)	271.68 (167.87-700.17)	804.79 (755.38-856.56)
Hidden population adjustment					
	*P	0.76	0.76	0.76	0.76
	PWID	1965.70 (1639.25-2301.12)	854.08 (757.81-1643.97)	662.63 (642.28-1368.85)	27.86 (27.86-52.63)

P1, Proportion of KAPs visiting the hotspot daily, P2, Proportion of KAPs visiting the hotspot once in week, P3= Proportion of KAPs visiting to the hotspot once in month, Di, Estimated number of current KAPs in district i who are estimated to operate from multiple hotspots. *P, Estimated proportion of KAPs who do not come to mappable sites

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Discussion

The findings of this study underscore the critical importance of methodological adjustments in accurately estimating the size of key affected populations, particularly PWID and PWUD in Iran. Our three-step adjustment framework—frequency adjustment, duplication adjustment, and hidden population adjustment—revealed significant variations in population size estimates compared to raw, unadjusted data. These adjustments address inherent biases in traditional hotspot mapping, including under-counting due to infrequent hotspot attendance, overcounting from multi-hotspot visitors, and the exclusion of hidden populations avoiding mappable sites.

The frequency adjustment led to a substantial increase in PWID and PWUD estimates across all four cities. For example, in Ahvaz, the PWID estimate rose from 843 to 2,104 after accounting for infrequent hotspot visitors. This highlights the limitations of relying solely on visible populations during mapping periods, as many KAPs may not frequent hotspots on a daily basis. This adjustment aligns with previous studies in Nepal (13), South Asia (14), Kenya (18), and India (19), emphasizing the need to account for visitation patterns to avoid underestimation. However, these studies have also emphasized that frequency adjustment alone is insufficient and that further adjustments for duplication and hidden populations are needed to achieve more accurate PWID estimates (13, 14, 18, 19).

The duplication adjustment reduced initial estimates by 29–37%, addressing the overcounting of individuals who visit multiple hotspots. This correction is particularly relevant in urban settings, such as Tehran, where mobility between hotspots is higher. The results emphasize the necessity of deduplication in mapping exercises to prevent inflated estimates that could misguide resource allocation. Our duplication adjustment methodology aligns with recent research from India, which applied duplication adjustments for key affected populations (KAPs) across three contexts: a) KAPs at hotspots within a district, b) KAPs with network operators in the district, and c) KAPs in link worker villages. In the final step, they calculated the total estimated size in a district by summing the three adjusted estimated sizes (19). However, a key assumption to keep in mind when applying the duplication adjustment is that the proportion of PWIDs frequenting multiple hotspots remains consistent across different areas within a county (13, 19). The strength of the present study compared to this study is that it considers frequency adjustment and hidden population adjustment in addition to duplication adjustment, which can improve the accuracy of the final estimates. Incorporating the hidden population adjustment—assuming 76% of PWID avoid mappable hotspots—yielded the most comprehensive estimates in this study. For instance, the final PWID estimate in Ahvaz after all three adjustments (1,966) was significantly higher than the raw data (843). However, the lack of national data on PWUDs' hidden populations limited this adjustment for PWUDs, pointing to a critical gap in surveillance systems. This aligns with global literature advocating for integrated methods to capture hidden populations (6, 13, 15, 18-20).

Our results resonate with international studies demonstrating the variability in KAP size estimates when methodological biases are unaddressed. For example, Musimbi et al.(18) and Kumar et al.(19) similarly highlighted the underestimation of PWID in hotspot mapping without frequency adjustments. The duplication issue mirrors findings from Nepal, where multi-hotspot visitors led to overestimation (13). The hidden population challenge is universal, as noted in India, Kenya and Tanzanian studies (12, 18, 19), reinforcing the need for innovative surveillance techniques as a prerequisite for performing hidden population adjustments. Incorporating additional methods for estimating the population size of PWIDs, alongside traditional mapping and size estimation techniques such as key informant interviews and enumeration, can enhance the accuracy of population estimates. A recent study conducted in Afghanistan applied multiple estimation approaches—including multiplier methods, capture-recapture, and the wisdom of the crowds technique—in conjunction with mapping to assess the number of PWIDs. These various methods were integrated using the Anchored Multiplier, a Bayesian framework, to generate consolidated point estimates(20).

The study's strength lies in its systematic approach to addressing biases; however, several limitations must be acknowledged: 1) Assumption dependency; the adjustments rely on assumptions about mobility and hotspot visitation patterns, which may not apply uniformly across all regions or populations. Specifically, based on the three adjustment methods—frequency adjustment, duplicate adjustment, and hidden population adjustment—three key assumptions must be considered. The first assumption is that the timing of visits by PWIDs to hotspots remains consistent over a three-day period. Consequently, data from three consecutive days, collected at different intervals, can be used to estimate the number of PWIDs operating from a hotspot in a single day. The second assumption posits that the proportion of PWIDs visiting multiple hotspots is evenly distributed across different areas within a district. The third assumption states that the proportion of PWIDs not visiting any hotspot remains consistent throughout various parts of the district (13, 19).2) Data Gaps and Temporal Validity; the hidden population adjustment for PWUDs was limited by insufficient national data, and reliance on historical data for PWIDs (e.g., the Iranian Mental Health Survey) may not accurately reflect current trends in drug use behaviors or hotspot dynamics, highlighting the need for updated national or regional behavioral surveys. 3) Data Collection Methodology; the mapping and size estimation approach depends on information obtained from key informants rather than direct head counts, which may introduce inaccuracies such as overestimation or underestimation. These discrepancies can result from recall bias, social desirability bias, or limited visibility of specific subgroups, potentially leading to misestimating of certain populations.

To improve the accuracy of key affected population (KAP) size estimation, it is recommended that surveillance

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systems routinely integrate adjustment factors such as frequency, duplication, and hidden population corrections into standard mapping protocols. Additionally, investment in national surveys is crucial to obtain updated behavioral data, especially concerning people who use drugs (PWUDs), which are essential for refining hidden population adjustments. Furthermore, given that mobility patterns and hotspot dynamics differ across regions, these adjustments should be carefully tailored to the specific local contexts to enhance their relevance and precision.

Conclusion

The implementation of 3 techniques of adjustment using the data of mapping and population size estimation in Iran highlights the importance of its role in achieving more accurate estimates of PWIDs and PWUDs estimates. However, there are 2 limitations to extrapolating these adjustments to the national level. It is believed that the mobility and visibility pattern of KAPs observed in the mappable hotspots are the same across all hotspots in every city whenever the frequency adjustment and duplication adjustment for undercounting and overcounting corrections are carried out, respectively. Furthermore, using the results of the Iranian Mental Health Survey and a national population size estimation study using the network scale-up method, we identified the mappable hotspots in hidden population adjustment. However, this may not accurately reflect the most recent high-risk behavior situation of KAPs, which may have changed over time.

Authors' Contributions

All authors fulfill the International Committee of Medical Journal Editors (ICMJE) authorship criteria. Specific contributions include: Protocol development & study design: M.K., H.S., A.H., and S.A.M.; conceptual framework: M.K., H.S., A.H., and S.A.M.; data acquisition & curation: M.K. and H.S.; methodological design: M.K., H.S., A.H., and S.A.M.; Formal statistical analysis: M.K. and S.A.M.; funding procurement: H.S., A.H., and S.A.M.; project administration: H.S. and S.A.M.; manuscript drafting: M.K.; critical revision & editorial input: H.S., A.H., and S.A.M.; final approval: all authors.

Ethical Considerations

This study utilized aggregated, nonidentifiable secondary data from previously conducted mapping exercises and national surveys, where ethical approvals were obtained by the original researchers. All primary data collection in the original studies adhered to ethical guidelines, and the Research Ethics Committee of Iran University of Medical Sciences granted ethical approval for both the study methodology and ethical protocols.

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Conflict of Interests

The authors declare that they have no competing interests.

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