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Counting the vulnerable: estimating the population size and assessing the HIV care continuum among women who inject drugs in Southern Mozambique

Cynthia Semá Baltazar[1*], Auria Ribeiro Banze[1], Rachid Muleia[1], Diogo Chavana[1], Stélio Craveirinha[2], Manuel Condula[3], Jessica Seleme[4], Isabel Sathane[4], Joshua Fortmann[5], Pedro Manuel[5], Jordan McOwen[5], Anne F. McIntyre[6†] and Makini Boothe[7†]

Abstract

Background Women who inject drugs (WID) face multifaceted challenges and remain one of the most invisible and vulnerable HIV-impacted populations, disproportionately affected by stigma, health disparities, and structural inequalities. Accurate population size estimation and analysis of the HIV care continuum among this group are crucial for effective programmatic planning. This study aims to describe the main characteristics of the WID participants in the southern region of Mozambique, analyze the self-reported progress towards the 2nd and 3rd targets of the 95-95-95 framework (ART uptake and viral suppression), and estimate the size of this population.

Methods We conducted a cross-sectional study using a three-source capture-recapture (3 S-CRC) method to estimate the population size of WID in the southern provinces of Mozambique, covering Maputo City, Maputo Province, Gaza, and Inhambane. A separate structured survey was administered during each round to gather socio-demographic and HIV-related information, and the survey results from the first encounter of each participant were used for descriptive results to avoid double or triple reporting from recapture encounters. The HIV care cascade was analyzed, focusing on the second 95% (those aware of their HIV status and currently on antiretroviral therapy (ART) and the third 95% (viral suppression among those on ART), based on self-reported status. Non-parametric Bayesian modeling was applied for estimation, based on the 2022 country population projections. Data were analyzed using R software.

Results A total of 159 WID were enrolled in Maputo City, 239 in Maputo Province, 29 in Gaza, and 168 in Inhambane. The majority in Maputo City (54.7%), Maputo Province (52.7%), and Inhambane (73.2%) were aged 25–31. Nearly 90% of WID reported engaging in sex work. The HIV care continuum analysis revealed significant gaps in ART uptake and

[†]Anne F. McIntyre and Makini Boothe are joint senior authors on this work.

*Correspondence:
Cynthia Semá Baltazar
cynthiasema@yahoo.com

Full list of author information is available at the end of the article

adherence, with Maputo City and Inhambane in particular falling well below the UNAIDS 95-95-95 targets, at 61.0% and 78.9% of self-reported HIV-positive WID reporting current ART treatment, respectively. In all provinces, self-reported viral suppression rates were below the 95% target. The median population size estimation was 240 (173–411; 0.05–0.13% of the adult female population aged 18–49) for Maputo City, 1160 (557-2491; 0.08–0.37%) for Maputo Province, 40 (29–78; 0.01–0.02%) for Gaza, and 650 (381-1083; 0.09–0.27%) for Inhambane.

Conclusion This study provides the first population size estimates for WID in Mozambique and identifies critical gaps in the HIV care continuum. The insights gained underscore the urgent need for focused, comprehensive health services to address the complex needs of WID and inform public health planning. Improving efforts to meet global HIV targets and enhance health outcomes for WID in Mozambique may lead to progress in addressing challenges and achieving better public health outcomes.

Keywords Women who inject drugs, HIV, Mozambique, Population size estimation, Capture-recapture, HIV care continuum

Introduction

Globally, people who inject drugs (PWID) are one of the most vulnerable, marginalized, and stigmatized populations at elevated risk for HIV infection. Current estimates suggest that of the 14.8 million PWID worldwide, approximately 2.7 million are women who inject drugs (WID) [1], and several studies show this number is growing [1, 2]. Additionally, within the population of PWID, it is estimated that 11.6% are WID [1]. This figure, however, may be significantly underestimated due to factors such as criminalization, discrimination, and stigma, which tend to keep WID hidden and lead to gender-disaggregated data being scarce [3].

In sub-Saharan Africa, HIV incidence is notably high among adolescent girls and young women aged 15 to 24 years who, despite constituting just 10% of the population, were responsible for 25% of new HIV infections in 2020 [4]. Additionally, within the population of individuals who inject drugs in the sub-Saharan region, women constitute an estimated 10.8% [1].

WID often face more complex challenges than their male counterparts and are frequently unrecognized and left out of discussions about PWID. Psychological, cultural, social, and economic factors contribute to the heightened risk of HIV and other sexually transmitted infections (STIs) for WID alongside the high-risk biologic exposure to needles during injection drug use. Cultural stereotypes, differing societal expectations and roles for women exacerbate these challenges, adversely impacting their access to and engagement with health-promoting and disease preventing services, including harm reduction programs [5, 3, 6]. Many WID engage in sex work, which heightens their risk of exposure to STIs and HIV. This also increases their vulnerability to physical and sexual violence from clients, intimate partners, and the police, a recurring challenge mentioned in several studies addressing health risks for WID. Despite these challenges, WID have been largely 'invisible,' as they remain under-researched and underrepresented in many health interventions focused on PWID.

Among WID drug use is often intertwined with other complex factors, such as gender-based violence, limited access to healthcare, and socio-economic disadvantages. These vulnerabilities contribute to higher risks of mortality and HIV infection compared to their male counterparts [7, 8]. There is a lack of key information available about their access to harm reduction programs and progress along the 95-95-95 care cascade [5]. The overlapping challenges WID face calls for the need for tailored interventions and supportive health systems [9].

A focused and effective epidemic response for WID at scale necessitates the development of programs and policies based on reliable, empirical population size estimates and descriptive statistics about the population [4]. There are considerable gaps in the available data about WID, despite the critical importance of this information for planning and allocating resources for integrated services specifically tailored to their needs. This scarcity of data is particularly acute in low- and middle-income countries, such as Mozambique.

Mozambique, with an HIV prevalence of 12.5%, has one of the world's highest HIV burdens [10]. Nearly 2.5 million people live with HIV in the country, and it is among the top three countries in terms of new HIV infections [11]. The impact of the epidemic on women is especially pronounced, with a prevalence of 15% among women compared to 9.5% in men [10]. Among key populations (KP), PWID face the highest HIV burden; approximately 50.1% of PWID in Maputo (south) and 19.9% in Nampula (north) are infected with HIV [12–14]. The situation is even more dire for WID, who are often marginalized within this already vulnerable group [12, 15].

In Mozambique, despite the documented HIV burden PWID, women within this group remain especially underrepresented in research and invisible in programmatic responses. Data on their population size, demographic profile, and HIV treatment cascade are scarce.

This study seeks to fill that gap by estimating the size of WID and analyzing their self-reported progress along the HIV care continuum in four provinces of southern Mozambique. Gaining a more comprehensive understanding of these aspects is essential for developing strategies that effectively address the unique needs of WID and reducing the overall HIV burden in these communities.

Methods

Study design and sites

In 2022, Mozambique initiated a national comprehensive KP size estimation exercise with programmatic mapping that included female sex workers, men who have sex with men, PWID, and transgender people. The approach to estimating the population size employed the three-source capture-recapture methodology (3 S-CRC), a statistical technique used to estimate the size of KP in a specific setting. The 3 S-CRC methodology extends the traditional capture-recapture approach, which involves sampling individuals from a population on two different occasions [16–18] and adds a third capture occasion to enhance the accuracy of the population size estimate, which greatly enhances the precision of the statistical analysis methods.

The methodology is based on four key assumptions: first, that the population is closed during the study period, meaning no individuals enter or leave the population; second, that each individual has an equal probability of being captured in each sampling round; third, that the capture events are independent of each other; and fourth, that individuals can be accurately identified across all sampling occasions. These assumptions are essential to ensure the validity of the population size estimates and the overall reliability of the results 19).

Each capture round was conducted at pre-identified hotspots, defined as venues where key population members congregate or engage in injecting behaviors. A specific questionnaire was administered, and a unique item was offered to every eligible KP individual who consented to participate in the survey during each visit to the hotspot. The 3 S-CRC exercise was conducted concurrently for all four key populations, using separate unique items for each group. Although some individuals overlapped across different populations, each individual was enrolled under a single population group to avoid duplication. During analysis, any participant who met the criteria of being a women and reported injection drug use, was included in the PID population results (ex: women who were enrolled under the sex work criteria who also reported drug use were counted in both populations but could only be captured once in each round of the CRC study procedures).

In preparation for the 3 S-CRC, a comprehensive list of KP hotspots was compiled with input from various stakeholders, including community-based organizations and implementing partners serving KP members. This list was organized by provinces and districts for detailed examination during focus group discussions and key informant interviews conducted as part of the formative assessment. A mapping exercise was completed that involved visiting all of the hotspots on the list to validate that they were currently active hotspots, and the list was also updated to include newly identified KP hotspots. Hotspots that were no longer active were removed from the list. All known KP hotspots in each province were included.

The survey was being conducted nation-wide using a phased approach in all provinces of Mozambique and will produce estimates separately for each province. Due to the timing of study implementation, analysis that follows includes data collected in the southern regions of Mozambique, including Maputo City, Maputo Province, Gaza Province, and Inhambane Province where data were collected between July and December 2022.

Sampling and survey participants

WID were defined as any person who identified as a woman aged 18 years or older who injected drugs (i.e., illicit, nonprescribed, or illegal substances) at least once in the preceding 12 months. Exclusion criteria included already participating in the current round of the capture, inability to give informed consent, or refusal to participate.

To estimate the sample size for each capture round, we compared the recorded number of KP present in each hotspot during mapping and validation with population size estimates from previous biobehavioural surveys (BBS) [19] to produce reasonable approximations for WID in each province. During each encounter with WID in the hotspots, team members described the population size estimate activity and asked the KP whether they had been approached during this sampling round. Participants were offered an inexpensive and memorable object (a "gift") unique to each of the three capture rounds (i.e., keychain, wallet, or lipstick). This process was repeated by different unique object distribution teams for each of three distinct capture rounds (3 S-CRC), performed approximately one week apart.

This survey included all districts of Maputo Province, Gaza, and Inhambane. Field teams visited each district during all three capture rounds. Prior to data collection, provincial teams collaborated with community informants and civil society organizations to conduct rapid hotspot validation exercises and identify active sites where WID congregate. This approach ensured comprehensive geographic coverage across both urban and rural settings. Site selection within each district was purposive, based on evidence of WID activity, and adjusted

dynamically between rounds to maximize outreach and minimize missed populations.

In subsequent capture rounds, participants were asked to either show the gifts they received in earlier rounds or, if they did not have it with them, describe what they had received in the earlier rounds. Presenting or describing the correct gift was defined as a capture from previous rounds. Accurate recall or presentation of the object served as the basis for identifying recaptures and distinguishing previously captured individuals from new ones, thereby minimizing the risk of double-counting.

Survey measures

The questionnaire included socio-demographic information including age, sex at birth, gender identity, education, primary source of income, whether the individual traveled to the current or another local government area for work, and whether they engaged in transactional sex. Additionally, the questionnaire included self-reported information about HIV testing and serostatus, including whether participants had ever been tested for HIV and whether they were tested in the last 12 months. The questionnaire also asked about the use of antiretroviral therapy (ART), whether participants had been tested for HIV viral load within the last 12 months, and the results of their most recent viral load test. These questions allowed the survey team to estimate progress towards the UNAIDS 95-95-95 targets for HIV testing and treatment. Eligibility for the survey was defined as responding "yes" to the following question: *During the last 12 months, have you injected drugs without a medical prescription?* Sex work was defined as exchanging sex for money, goods, or services in the past 6 months.

The questionnaire was administered by trained field staff, who were either members of the key population (KP) or individuals experienced and comfortable in working with KP members. All participants were required to provide informed consent before taking part in the survey.

Data analysis

Descriptive statistics were used to summarize socio-demographic characteristics and self-reported HIV testing and treatment indicators. Categorical variables were presented as frequencies and percentages, while continuous variables were summarized using medians and interquartile ranges (IQR). The analyses were performed using R software version 4.2.1.

Population size estimation

Population size estimates for WID were derived using non-parametric Bayesian latent class models (BLCM) using the 3 S-CRC. Non-informative uniform priors were selected for the population size parameter and detection probabilities. Conditional independence between capture events was assumed. Posterior distributions were estimated using Markov Chain Monte Carlo (MCMC) methods, and convergence diagnostics were performed via trace plots and effective sample size evaluations.

The 3 S-CRC method involves collecting data on three independent occasions, allowing for the identification of overlapping individuals across different capture rounds. This provides multiple samples from the same population, which enhances the robustness of the population size estimate by reducing biases that may arise from incomplete capture [16, 20].

In the BLCM framework, the observed capture histories from the 3 S-CRC are modeled as latent classes, representing the different probabilities of being captured in each round. The BLCM analysis was implemented using the "rjags" package in R, a well-established package for Bayesian inference using Markov Chain Monte Carlo (MCMC) methods. This approach accounts for potential heterogeneity in capture probabilities and helps reduce underestimation due to incomplete capture [21]. The 2022 population census projections were used as the reference population for women 15–49 years. Data were analyzed with R software v.4.2.1.

A capture event was defined when an individual accepted the gift presented by the field team. Recaptures were identified during the second and third rounds of capture when individuals displayed or accurately described the gifts they had received in prior rounds to the distributors.

The reference population sizes were based on the total adult female population aged 18–49 years (including both urban and rural areas) in each province, according to the 2022 population projections: Maputo City (322,446), Maputo Province (672,987), Gaza (385,144), and Inhambane (404,163) 63) [22].

Effective sample sizes for each stratum were calculated using the shinyrecap tool. Uninformative uniform priors were used, as there was no prior information available to inform the specification of alternative priors. Consequently, no additional sensitivity analyses were conducted. Instead, convergence of the MCMC posterior was assessed through trace plots and evaluation of effective sample sizes, which supported the robustness of the estimates.

Measurement of the 95-95-95 clinical cascade

Measurement of 95-95-95 clinical cascade was based on self-report. The first metric of the 95-95-95 care cascade could not be calculated due to the absence of HIV testing, making it impossible to determine the number of survey participants who were unaware of their HIV-positive status. However, self-reported information on HIV testing and serostatus was collected. The second 95 was based on

the percentage of participants who knew their HIV-positive status and reported that they were currently on antiretroviral therapy (ART), excluding those who had used ART previously but were not currently on ART. The third 95 was based on the self-reported percentage of participants with viral suppression among those actively receiving ART. Viral suppression was defined as a viral load of less than 1000 copies/mL, according to self-reported responses. WID on ART who had never been tested for viral load or were unaware of their result were excluded from this calculation.

Although recaptures were tracked during the second and third capture rounds for the purpose of 3 S-CRC estimation, each participant was interviewed only once during their first capture. Data on HIV testing history and care outcomes were analyzed using only the first completed questionnaire per individual to avoid duplicate information in the analysis.

Due to the relatively small sample sizes in some provinces, particularly in Gaza, confidence intervals were not calculated for the self-reported HIV testing and status data. The variability in sample sizes and the potential for reduced statistical power may lead to less reliable confidence intervals. For these reasons, the estimates provided are point estimates without confidence intervals. Future studies with larger sample sizes may incorporate confidence intervals to provide more robust statistical insights.

Ethical considerations

In this study, strict adherence to ethical standards was maintained. Every participant was required to provide informed consent, ensuring they understood the nature and purpose of the study. To protect their privacy and confidentiality, no identifying information (e.g., name and residence) was collected. The study protocol was approved by the National Institute of Health Ethical Review Board (CIE-INS), the Mozambique National Bioethics Committee for Health in Mozambique (CNBS). This activity was reviewed by the U.S. Centers for Disease Control and Prevention (CDC), deemed not research, and was conducted consistent with applicable federal law and CDC policy[1].

Results

Participants demography and transactional sex

Throughout the 3 S-CRC process, a total of 159 WID participated in the study in Maputo City, 239 in Maputo Province, 29 in Gaza, and 168 in Inhambane (Table 1).

The median age of WID participants varied across locations: 26 years [IQR:22–31] in Maputo City, 25 years [IQR:22–29] in Maputo Province, 23 years [IQR:21–25] in Gaza, and 27 years [IQR:24–30] in Inhambane. In Maputo City, the majority of WID were over the age of 25 years (54.7%), had a primary level of education (53.5%), and worked in informal trade (48.1%). In Maputo Province, while the majority were also over the age of 25 (52.7%), a higher percentage had a secondary level of education (60.1%). In Gaza, the majority were in the 15–24-year age group (62.1%) and had a primary level of education (51.7%). In Inhambane, a larger proportion of WID were over the age of 25 years (73.2%) and had a secondary level of education (66.1%) (Table 1).

The overwhelming majority of WID also reported engaging in sex work. In Maputo City, 145 (95.4%) reported engaging in sex work, with 71 (45.5%) citing it as their primary source of income. In Maputo Province, 202 (92.7%) reported engaging in sex work, with 144 (67.6%) indicating it as their primary source of income. In Gaza, 26 (96.3%) reported engaging in sex work, with 18 (64.3%) identifying it as their primary source of income. In Inhambane, 140 (83.3%) reported engaging in sex work, with 104 (64.6%) citing it as their primary source of income (Table 1).

Self-reported HIV status and testing services

In Maputo City, 87.4% of WID reported having ever tested for HIV, and 47.8% of all WID reported having tested within the past 12 months. In Maputo Province, 83.6% of WID had ever tested; 53.6% in the last 12 months, and 32.0% self-reported as HIV-positive. In Gaza, which had the smallest number of participants, lifetime HIV testing was 79.3%, and testing in the most recent period was 51.7%. In Inhambane, lifetime HIV testing was 87.4%, recent testing was 74.7%, and self-reported HIV-positivity among WID participants was 13.0% (Table 2).

Self-reported HIV treatment cascade

Figure 1 displays the reported treatment and viral load suppression status among the participants of the study, which aligns with the 2nd and 3rd 95-95-95 targets.

In Maputo City, 61% of WID who self-reported their HIV-positive status were currently taking HIV treatment, and 60% reported having received a result of viral suppression from their most recent viral load test within the past year. In Maputo Province, 92% of WID who self-reported their HIV-positive status were currently taking HIV treatment and 59% reported viral suppression based on their most recent test within the past year. In Gaza, 100% who self-reported their HIV-positive status reported that they were currently taking HIV treatment, with 80% reported having received a result of viral suppression within the past year. In Inhambane, 78.9% of WID who self-reported their HIV-positive status were

[1] See e.g., 45 C.F.R. part 46, 21 C.F.R. part 56; 42 U.S.C. § 241(d); 5 U.S.C. § 552a; 44 U.S.C. § 3501 et seq.

Table 1 Sociodemographic profile of women who inject drugs in Southern region of Mozambique, 2022–2023

Characteristics	Maputo City (*n* = 159)		Maputo Province (*n* = 239)		Gaza (*n* = 29)		Inhambane (*n* = 168)	
	n	%	n	%	n	%	n	%
Age group, years								
18–24	72	45.3	113	47.3	18	62.1	45	26.8
+ 25	87	54.7	126	52.7	11	37.9	123	73.2
Median age [IQR]	26 [22–31]		25 [22–29]		23 [21–25]		27 [24–30]	
Education								
Never attended school	4	2.5	14	5.9	2	6.9	17	10.1
Primary	85	53.5	76	31.9	15	51.7	28	16.7
Secondary	67	42.1	143	60.1	10	34.5	111	66.1
Higher Education	1	0.6	3	1.3	2	6.9	12	7.1
Other[a]	2	1.3	2	0.8	-	-	-	-
Unknown/Refused			1					
Occupation/Primary source of income								
Unemployed	1	0.6	19	8.9	3	10.7	13	8.1
Student	2	1.3	4	1.9	3	10.7	5	3.1
Professional career	6	3.8	5	2.3	1	3.6	3	1.9
Informal trade[b]	75	48.1	36	16.9	3	10.7	31	19.3
Sex work	71	44.7	144	67.6	18	64.3	104	64.6
Other[a]	1	0.6	5	2.3				
Unknown/Refused	3		26		1		12	
Sex work in the last 6 months	145	95.4	202	92.7	26	96.3	140	83.3
Unknown/Refused			21		2			–

[a] Other includes unspecified or less common categories that were not detail in the questionary

[b] Informal trade refers to economic activities that are not regulated by the government, typically involving small-scale and unregistered businesses such as street vending, market trading, or other forms of self-employment. This sector is often characterized by lack of social protections and formal contracts, but it provides a means of income for many individuals in low-resource settings.

Table 2 Self-Reported HIV testing and HIV-positive status among woman who inject drugs in Southern region of Mozambique, 2022–2023

	Maputo City (*n* = 159)		Maputo Province (*n* = 239)		Gaza (*n* = 29)		Inhambane (*n* = 168)	
	n = 159	%	*n* = 239	%	*n* = 29	%	*n* = 168	%
Ever tested for HIV	139	87.4	200	83.6	23	79.3	146	87.4
HIV testing in past 12 months	76	47.8	128	53.6	15	51.7	109	74.7
Self-reported HIV-positive	87	62.6	64	32.0	5	21.7	19	13.0

currently taking HIV treatment, and 53% reported having received a result of viral suppression from their last viral load test within the past year.

Population size Estimation among women who inject drugs

The median population size estimation for WID in Maputo City was 240 (plausibility bounds 173–411), representing approximately 0.05% to 0.13% of the adult female population aged 18–49 years. In Maputo Province, the median estimate was 1160 WID (plausibility bounds 557-2491), which is about 0.08–0.37% of the adult female population aged 18–49 years. In Gaza, the estimated median population size of WID was 40 years (plausibility bounds 29–78), constituting around 0.01% to 0.02% of the adult female population aged 18–49 years. In Inhambane, the median estimate was 650 WID (plausibility bounds 381-1083), amounting to approximately 0.09% to 0.27% of the adult female population aged 18–49 years (Table 3).

Discussion

This study provides critical insights into the population size, socio-demographics, and HIV care continuum of WID in southern Mozambique. The estimated WID population varied significantly across provinces, with the largest in Maputo Province (1160) and the smallest in Gaza (40). Most WID were aged 25 years or older and engaged in sex work, further increasing their vulnerability to HIV. The HIV care cascade revealed substantial gaps in ART uptake and viral suppression, with both Maputo City and Inhambane falling short of global 95-95-95 targets.

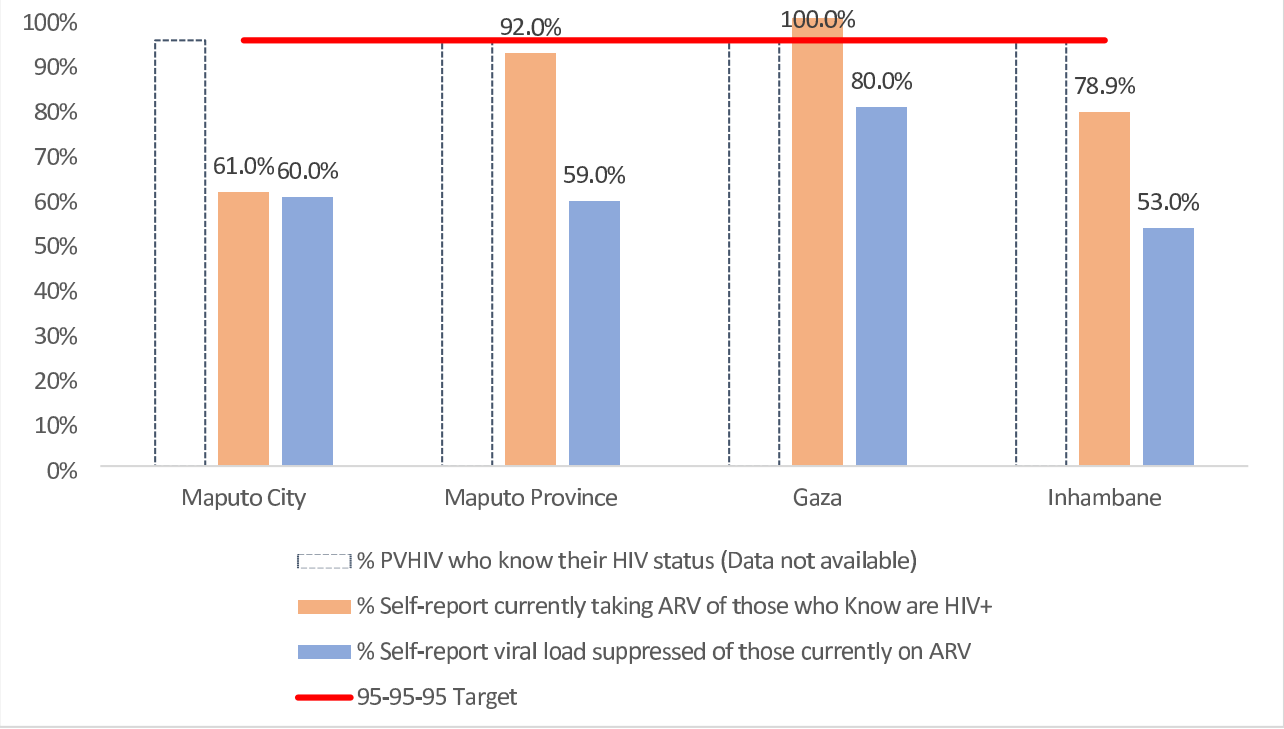

Fig. 1 Self-Reported HIV Treatment and Viral Load Suppression Among WID in Four Provinces of Southern Mozambique (*Note* The first bar, representing the 1st 95% target, is intentionally blank and included for context only. It is not calculated from the study data but serves to highlight that this metric was not calculated.) *Sample size comment.

Table 3 WID population size Estimation using 3 S-CRC, Southern region Mozambique, 2022

Province	Median population size estimate WID	Lower bound (95% CI)	Upper bound (95% CI)	Size of reference population	Population proportion	Lower (%)	Upper (%)
Maputo City	240	173	411	322,446	0.07	0.05	0.13
Maputo Province	1160	557	2491	672,987	0.17	0.08	0.37
Gaza	40	29	78	385,144	0.01	0.01	0.02
Inhambane	650	381	1083	404,163	0.16	0.09	0.27

In our study, we employed Bayesian nonparametric latent class models to estimate the population size of WID in the southern region of Mozambique, focusing on Maputo City, Maputo Province, Gaza Province, and Inhambane Province. The use of a three-source capture-recapture methodology combined with Bayesian nonparametric models strengthened the robustness of our population size estimates. These approaches allowed for greater accuracy by addressing potential biases in capture probability and improving the representativeness of the sample [16, 18].

One observation from our study is that the majority of WID we encountered in both Maputo City and Province are between 24 and 31 years old, though the age distribution between these two groups is relatively similar. The previous BBS among PWID conducted in the same province found similar results [12, 23]. Similar age distributions among WID have been reported in studies from South Africa and Kenya, where young women constitute a significant portion of the population who inject drugs and are disproportionately affected by HIV-related vulnerabilities [24, 25]. The predominance of younger women in our sample may reflect both the actual age distribution of WID in these settings and potential limitations in capturing older WID through hotspot-based sampling. Nonetheless, this observed trend raises concern about the specific vulnerabilities faced by younger WID, including elevated risks of exploitation, early initiation into drug use, pregnancy, and barriers to accessing health services [5, 6]. Secondly, a particularly alarming trend was the self-reported HIV-positive status among WID, which was notably higher than the HIV prevalence observed in the general population of women in the two main urban areas (Maputo City: 62.6% WID vs. 21.0% general population of women; Maputo Province: 32.0% WID vs. 18.6% general population of women) [10]. The difference in these point estimates suggests increased HIV vulnerability among WID compared to the general

female population. In our sample, the vast majority of WID also reported engaging in sex work a well-established risk factor for HIV acquisition which may contribute significantly to the elevated prevalence. Although specific behaviors such as injection equipment sharing were not assessed, the intersection of drug use and sex work likely compounds risk and underscores the need for integrated prevention and care strategies [12, 23].

Our study found that nearly 90% of WID also engaged in sex work, aligning with the observations in the sub-Saharan African region, where the majority WID engage in such activities [24, 24–27]. This intersection is well-documented and represents a critical area of concern for public health interventions. These dual factors often lead to increased exposure to unsafe sexual and physical violence, unsafe practices, including needle sharing and unprotected sexual encounters, increasing the risk to HIV, hepatitis B, syphilis and other STI [3, 5, 6, 28, 29]. Moreover, the stigmatization and marginalization experienced by those at this intersection further hinder their access to essential health services, including testing, treatment, and preventive care [3, 28, 30].

Our analysis also reveals significant gaps in self-reported ART uptake and retention on treatment among WID in Maputo City and Inhambane, lagging behind the global 95% targets for current ART status and viral suppression. Despite the ambitious achievement for 100% ART treatment uptake among WID aware of their HIV-positive status, the proportion of WID we encountered in Maputo City and Maputo Province fell far below the 3rd 95 target, with less than 60% of participants reporting viral suppression. This pattern of limited engagement with HIV care among WID in Mozambique aligns with findings from previous research. For instance, results from the first biobehavioral survey conducted among PWID in the country during 2013-14 highlighted that only 63.2% of PWID were aware of their HIV status, and 49.0% reported being linked to care for their HIV infection, although the majority were men [29]. It should be noted that these results are not directly comparable to our study, as the BBS results are derived from probability-based samples and weighted estimates, primarily involving men. Another study found that linkage to HIV care was observed in only 40.5% of newly diagnosed PWID [23]. Factors contributing to these gaps may include stigma, lack of access to health services tailored to the needs of WID, and socio-economic barriers that disproportionately affect this population [23, 30, 31].

Our findings reveal a substantial variation in the estimated median population size of WID across the studied provinces. Gaza has the lowest median WID population (44), while Maputo Province has the highest (1162). This disparity suggests a potential geographic influence on WID prevalence, with urban areas possibly having higher WID compared to more rural provinces. It's important to note that these are just median estimates, and the plausibility bounds indicate a significant range within each province. Further research is needed to explore the underlying reasons for the observed variations and identify factors contributing to the geographic distribution of WID in Mozambique.

To our knowledge, this study represents the first attempt to estimate the number of WID in Mozambique, marking a significant step forward in understanding and addressing the needs of this vulnerable population. However, this study is not without limitations, particularly concerning the methods used for population size estimation. One major limitation relates to the accuracy of the Bayesian nonparametric latent class models used in conjunction with the 3 S-CRC methods. The reliability of these models is directly dependent on the quality and completeness of the data sources. As the HIV care continuum data relied on self-reported HIV status, ART use, and viral load results, there is a risk of recall bias and social desirability bias. However, population size estimation (PSE) relied on visual or verbal confirmation of distributed objects across capture rounds, thereby reducing dependence on self-report for those components. Additionally, variability in the quality and consistency of the three data sources across different locations may have introduced biases. These potential biases may have differed by province, given the variability in hotspot locations, participant demographics, and local recruitment efforts. Moreover, the absence of HIV testing among participants limited our ability to perform a comprehensive analysis of the UNAIDS 95-95-95 targets. Without objective testing data, our understanding of the HIV care continuum remains incomplete, which constrains the strength of the study's conclusions regarding HIV care and treatment in this population. A further limitation pertains to the survey's coverage and representation of WID. The survey depended on encountering WID at hotspots, so if there are WID who never visit PWID hotspots and have different characteristics than WID who visit hotspots, they would not be represented in the findings of the study or the population estimations. Identifying and recruiting WID is inherently challenging due to their marginalized status and potential reluctance to engage with researchers, leading to potential under-sampling. Additionally, the analysis did not account for potential clustering of responses within hotspots, which may introduce bias or affect the precision of certain estimates, particularly in provinces with larger sample sizes. This under-sampling risk is compounded by the variability in hotspot locations and the characteristics of those who frequent them. Such factors may result in skewed data that does not fully represent the diversity and breadth of experiences within the WID community. As

the HIV care continuum data relied on self-reported HIV status, ART use, and viral load results, there is a risk of recall bias and social desirability bias. However, population size estimation (PSE) relied on visual or verbal confirmation of distributed objects across capture rounds, thereby reducing dependence on self-report for those components. Despite these limitations, this study provides critical insights into the needs of WID in Mozambique, offering valuable information for developing targeted public health strategies By describing the WID population in greater detail than previously available in Mozambique, the study also allows researchers and public health professionals to identify what critical knowledge gaps needed to inform health programs to this population, which can be used to guide future research.

Conclusion

In conclusion, our study sheds light on the complex landscape of WID in Mozambique and highlights the urgent need for focused, comprehensive health services tailored to this population's needs. Addressing the identified gaps in ART uptake and adherence, alongside developing age-sensitive and inclusive intervention strategies, may mitigate the health risks faced by WID. These actions can contribute to progress toward global HIV targets and help reduce health inequalities.

To achieve these goals, we recommend integrating harm reduction services into existing healthcare facilities or referral to specialized facilities for methadone treatment and other opioid substitution therapies (OST), with a specific focus on gender-sensitive approaches that acknowledge the unique vulnerabilities faced by WID. WID are often at heightened risk of physical and sexual violence, stigma, and exploitation compared to the broader PWID population. Implementing gender-specific interventions, such as creating safe spaces within healthcare settings where women feel comfortable seeking services, may significantly improve access to care and health outcomes for WID by addressing their unique needs and challenges. Furthermore, expanding access to HIV testing and treatment through mobile clinics and community-based initiatives may reach this marginalized population.

Offering mental health and psychosocial support, particularly to address stigma and substance use, may play a vital role in improving the well-being of WID and enhance their engagement with healthcare services. Partnering with community-based organizations (CBOs) may enhance culturally sensitive services, as these organizations play a key role in peer-led education and support. Additionally, establishing strong data collection and monitoring systems may help track health outcomes and continuously improve services to meet the needs of WID.

By adopting these strategies, Mozambique may better support WID, improve health outcomes, and make significant progress towards achieving global HIV targets and reducing health inequalities.

Supplementary Information

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Supplementary Material 1

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Author contributions

CSB, as the principal investigator, conceptualized the study and wrote the original manuscript. ARB supervised the study's implementation. RM, DC, JF, and JM developed study tools and conducted data analysis. SC, MC, JS, IS, and PM supported field activities. JM, AM, and MB were involved in study implementation and provided critical revisions to the manuscript. All authors reviewed and approved the final version.

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Data availability

The data used in this manuscript are fully available from the Mozambique National Institute of Health (INS) data repository. This resource is available to researchers who fulfill the criteria for accessing confidential data. The data originates from the KP Mapping and Population Size Estimation Study. Researchers interested in these data sets can contact the authors or obtain further information through the INS website at [https://ins.gov.mz/institucional/unidade-organicas/direccoes/directora-de-inqueritos-e-observacao-de-saude/solicitacao-de-dados/](https://ins.gov.mz/institucional/unidade-organicas/direccoes/directora-de-inqueritos-e-observacao-de-saude/solicitacao-de-dados) .

Declarations

Competing interests

The authors declare no competing interests.

Author details

[1]Instituto Nacional de Saúde, P.O. Box 264, Maputo, Mozambique
[2]MozPud, Maputo, Mozambique
[3]UNIDOS, Maputo, Mozambique
[4]National HIV/STI Control Program, Public Health Directorate, Ministry of Health, Maputo, Mozambique
[5]Division of Global HIV and Tuberculosis, Global Health Center, Centers for Disease Control and Prevention, Maputo, Mozambique
[6]Division of Global HIV and Tuberculosis, Global Health Center, Centers for Disease Control and Prevention, Atlanta, GA, USA
[7]Joint United Nations Programme for HIV/AIDS (UNAIDS), Maputo, Mozambique

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