

Updated Data and Methods for the 2023 UNAIDS HIV Estimates

Cari van Schalkwyk, PhD,^a Mary Mahy, PhD,^b Leigh F. Johnson, PhD,^c and Jeffrey W. Imai-Eaton, PhD^{d,e}

Abstract: Each year, supported by the Joint United Nations Programme on HIV/AIDS (UNAIDS), country teams across the globe produce estimates that chart the state of their HIV epidemics. In 2023, HIV estimates were available for 174 countries, accounting for 99% of the global population, of which teams from 150 countries actively engaged in this process. The methods used to derive these estimates are developed under the guidance of the UNAIDS Reference Group on Estimates, Modeling, and Projections (www.epidem.org). Updates to these methods and epidemiological analyses that inform parameters and assumptions are documented in this supplement.

Key Words: UNAIDS estimates, Reference Group, UNAIDS methods, HIV modelling

(*J Acquir Immune Defic Syndr* 2024;95:S1–S4)

INTRODUCTION

Each year, supported by the Joint United Nations Programme on HIV/AIDS (UNAIDS), country teams across the globe produce estimates that chart the state of their HIV epidemics. In 2023, HIV estimates were available for 174 countries, accounting for 99% of the global population, of which teams from 150 countries actively engaged in this process. The methods used to derive these estimates are developed under the guidance of the UNAIDS Reference Group on Estimates, Modeling, and Projections (www.epidem.org). Updates to these methods and epidemiological

analyses that inform parameters and assumptions are documented in biennial special journal editions.^{1–9}

This supplement summarizes the methods of tools in the Spectrum software package—a suite of mathematical modeling tools used to develop UNAIDS HIV estimates.^{10,11} Furthermore, the supplement introduces new indicators for district-level HIV treatment targets¹² and describes updated methods and epidemiological data to estimate new infections among key populations, which encompasses sex workers, men who have sex with men, people who inject drugs, transgender people, and clients of female sex workers.^{13–15} In addition, we present new epidemiological analyses that inform model assumptions and parameters, covering topics including breastfeeding duration among mothers living with HIV (MLHIV),¹⁶ mortality rates of those living with HIV on antiretroviral treatment (ART),¹⁷ and trends in antenatal HIV testing and prevalence.^{18,19}

Highlights of 2023 HIV Estimates

The most recent results from the HIV estimates are available at aidsinfo.unaids.org. As of the end of 2022, 39.0 million [uncertainty bounds: 33.1 million–45.7 million] people were living with HIV. This number has increased slightly in recent years, a trend attributed to prolonged life expectancy because of effective treatment and ongoing new HIV infections. Fifty-three percent of those living with HIV are women and girls. Sixty-five percent of people living with HIV (PLHIV) reside in sub-Saharan Africa; however, only half of the new HIV infections were in sub-Saharan Africa, reflecting greater progress at reducing new infections in this region compared with other parts of the world. There were 1.3 million [1.0 million–1.7 million] new HIV infections in 2022. Although the number of new infections is declining, the pace is insufficient to meet the targets set by the United Nations Political Declaration on HIV/AIDS, which aims for fewer than 350,000 new infections by 2030. New HIV infections are still rising in 2 UNAIDS regions, Eastern Europe and Central Asia, and Middle East and North Africa, predominantly among men.

One of the most alarming statistics is that there were 630,000 [480,000–880,000] AIDS-related deaths in 2022, despite the availability of ART. Sixty percent of all AIDS-related deaths were in sub-Saharan Africa, and 44% were among women and girls (compared with 53% of all PLHIV). Women are more likely to be on treatment than men, and men tend to acquire HIV at older ages than women, placing them

From the ^aSouth African Centre for Epidemiological Modelling and Analysis (SACEMA), Stellenbosch University, Stellenbosch, South Africa; ^bData for Impact Department, The Joint United Nations Program on HIV/AIDS (UNAIDS), Geneva, Switzerland; ^cCentre for Infectious Disease Epidemiology and Research, School of Public Health, University of Cape Town, Cape Town, South Africa; ^dMRC Centre for Global Infectious Disease Analysis, School of Public Health, Imperial College London, London, United Kingdom; and ^eCenter for Communicable Disease Dynamics, Department of Epidemiology, Harvard T. H. Chan School of Public Health, Boston, MA.

The authors have no funding or conflicts of interest to disclose.

Correspondence to: Cari van Schalkwyk, PhD, South African Centre for Epidemiological Modelling and Analysis (SACEMA), Stellenbosch University, Stellenbosch, South Africa (e-mail: carivs@sun.ac.za).

Copyright © 2023 The Author(s). Published by Wolters Kluwer Health, Inc. This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

at an elevated risk of rapid disease progression and increased mortality.

The UNAIDS estimates also track progress toward the 95–95–95 targets: 95% of PLHIV know their HIV-positive status, 95% of those who know their status are on treatment, and 95% of those on treatment are achieving viral suppression. In 2022, the global achievement against these targets was 86%–89%–93%, a marked improvement from the 71%–67%–83% estimated in 2015. However, this progress is not consistent across all populations—an important stipulation in the Political Declaration on HIV, which aims to end inequalities.²⁰ Among children, the progress toward the targets was 63%–91%–81%, emphasizing the difficult task of identifying children who might have acquired HIV during pregnancy or breastfeeding and not yet diagnosed or interrupted treatment.

Estimation Tools in HIV Modeling

The Spectrum software package is a core tool for nearly every nation producing HIV estimates. Stover and Glauubius provide a detailed description of 2 tools in Spectrum¹⁰: the Demographic Projection Model (DemProj) and the AIDS Impact Model (AIM). For most countries, DemProj uses national population estimates and rates of mortality, fertility, and net migration rates estimated by the United Nations Population Division World Population Prospects to model the national population from 1970 through 2030. AIM integrates HIV incidence estimates from incidence modeling tools to assess the impacts of HIV and produce key HIV indicators, such as HIV prevalence and AIDS-related deaths. The choice of incidence tools is tailored according to the types of HIV surveillance data available in each country. One such tool, the AIDS Epidemic Model, is a transmission dynamic model that provides HIV incidence data to AIM and is used across 13 Asian countries. Brown et al¹¹ describe the structure and data requirements of this model, with illustrative applications].

Since 2020, UNAIDS has supported countries in sub-Saharan Africa to estimate PLHIV, treatment coverage, and new infections at the district level using the Naomi model, a Bayesian small area estimation model.²¹ Esra et al¹² introduce new indicators implemented in the Naomi model for the UNAIDS 2023 estimates, which quantify the estimated number of PLHIV who would *seek care* in a district to guide improved program target setting.

HIV Estimation for Key Populations

Since 2016, UNAIDS has published the distribution of new HIV infections among key populations, including female sex workers, men who have sex with men, people who inject drugs, transgender persons, sex partners of these groups, and the remaining population. Data were compiled and analyzed by UNAIDS at global and regional level. However, there are limited consistent, high-quality empirical data and systematic empirical methods to inform these estimates.

The research by Stevens et al¹⁴ provides important insights in new HIV infections among key populations in sub-Saharan Africa. The collation of empirical data on HIV incidence and mathematical modeling shows a significantly

higher risk of acquiring HIV among key populations. Analysis of the empirical data combined with estimates from transmission models suggests that around 6% of new HIV infections were among female sex workers, men who have sex with men, and people who inject drugs.¹⁴

Expanding on this, Silhol et al¹⁵ summarize results from mathematical models of HIV transmission on new infections among non-key population partners of key populations and clients of sex workers. Previously, UNAIDS used regional infection ratios (the ratio of new infections from key population members to their partners compared with new infections among the key population) based on a review of empirical estimates. Silhol et al¹⁵ calculate an improved set of infection ratios, which aligned with modeled estimates for the ratio concerning female sex workers. However, the research suggested lower ratios for men who have sex with men and people who inject drugs, particularly in Eastern and Southern Africa, based on the additional model-based estimates.

For progress toward more systematic syntheses of key population data and estimates from diverse sources, and to meet global needs for estimates of time trends in HIV indicators among key populations, Korenromp et al¹³ propose revised methods for producing estimates of new infections by key population over time. Estimates of the proportions of new HIV infections in each population group are derived at the national level for 172 countries (in contrast to regional levels in previous UNAIDS publications). These are aggregated to regional and global levels. Proportions are obtained from transmission dynamic models in 94 countries, country estimates from Spectrum using the Estimation and Projection Package tool for estimating HIV incidence by key population in 15 countries, and in 40 countries, the reporting of new diagnoses by HIV acquisition risk factor was adequate to estimate new infections. Globally, the percentage of new HIV infections that were among key populations and their partners increased from 44% in 2010 to 55% in 2022.

Epidemiological Analyses to Inform Models

The impact of HIV across different communities and regions requires precise tools for measurement and prediction. By integrating detailed epidemiological analyses into these tools, models can more accurately reflect epidemiologic data and trends.

Allorant et al¹⁹ used data from population-level surveys to shed light on the trends and determinants of HIV testing both within and outside antenatal care (ANC) in sub-Saharan Africa. A significant increase was observed in recent HIV testing coverage between 2005 and 2021, although there were significant variations between countries and subregions. In 2005, only 2% of women received an HIV test in the past 24 months as part of ANC, a figure that rose to 11% in 2021. The study underscores the value of integrating HIV testing into ANC for eliminating vertical transmission in sub-Saharan Africa, and importantly, ANC-based HIV testing addresses inequalities by reaching women from socioeconomically disadvantaged backgrounds and those residing in rural areas.

Glauubius et al¹⁶ systematically analyzed breastfeeding practices among women living with HIV compared with

HIV-negative women in sub-Saharan Africa, an important determinant of mother-to-child transmission. Spectrum's estimates of postnatal new child HIV infections depend on the breastfeeding duration among MLHIV and the associated risks of vertical transmission during breastfeeding. Using household survey data, Glaubius et al¹⁶ found that, across all regions, HIV-negative mothers were more likely to breastfeed and for a longer duration compared with MLHIV. In 2019, based on these findings, Spectrum assumptions were changed from assuming the same breastfeeding durations for mothers with and without HIV to shorter durations for MLHIV, leading to lower estimates of postnatal mother-to-child HIV transmission.²¹ These findings also emphasize the need for support to enable optimal breastfeeding practices among MLHIV.

Trickey et al¹⁷ assessed Spectrum estimates of mortality among PLHIV in European countries, using data from the Antiretroviral Therapy Cohort Collaboration (ART-CC). Comparing mortality rates in ART-CC data with the Spectrum model, Trickey et al¹⁷ found that all-cause mortality rates in Spectrum were consistent with the mortality observed in the cohort data for the same period after controlling for age and country. However, a significant proportion of excess mortality (mortality over and above the generally population rates) among PLHIV on ART in ART-CC was due to non-AIDS causes. This suggests that the current UNAIDS approach, which uses the difference between total mortality among PLHIV in treatment cohorts and national reference life tables to approximate AIDS-related mortality rates, may overestimate AIDS-related deaths or underestimate total (non-AIDS) deaths to PLHIV.

Stevens et al¹⁸ analyzed HIV surveillance data from Mozambique to identify critical challenges with using routine HIV testing data from ANC services to monitor HIV epidemic trends and estimate the need for prevention of mother-to-child transmission services. Since 2017, the reported number of antenatal clients increased more rapidly than the recorded number of live births and the model-estimated births. The number of women reported as receiving antiretrovirals for prevention of mother-to-child transmission substantially exceeded the estimated number of births to women living with HIV, coupled with an implausible decline in HIV prevalence. In this study, data from nationally representative surveys were used to adjust HIV prevalence data from routine ANC testing, and Spectrum models fitted to the adjusted data resulted in lower ART coverage among pregnant women living with HIV in most provinces and a 35% increase in the estimated number of new child infections. The study concluded that the number of children living with HIV in Mozambique might be grossly underestimated because of inherent biases in routine ANC testing, which is further compounded by the poor quality of ANC data.

CONCLUSIONS

Reliable and consensus HIV epidemiological estimates are the cornerstone for the global response to HIV. The data and methods used to derive the estimates continually evolve

in response to emerging data, changing epidemiology and transmission dynamics, and new strategic information need to guide and monitor the response.

Although the revised data and methods described here represent substantial strides and steady improvements, the quality and confidence in the estimates differ substantially across locations and populations affected by HIV. Accurate estimates require appropriate models and epidemiological analysis, but fundamentally, they depend on high-quality, timely, and relevant underlying HIV data. However, there is wide variability in the quality of these foundational data. In many cases, the regions or populations where progress has been most limited correspond to areas where the underlying data informing estimates are the weakest. Multiple rounds of statistically representative national household surveys in high HIV burden countries, especially in Eastern and Southern Africa, provide solid evidence of the effectiveness at reducing new HIV infections and AIDS-related deaths in the region, and granular information to continue to optimize programs. Conversely, in other regions such as Western and Central Africa, Eastern Europe and Central Asia, the Middle East, and North Africa, concerning epidemic trends reported in the global estimates are often belied by scant, outdated, and inconsistent data.

Meeting global goals to end AIDS requires renewed commitments to improve data, and improve use of existing data, to identify, document, and end inequalities, particularly among those most marginalized and stigmatized. Systematically analyzing data about key populations, a major focus in this supplement and recent global research including the UNAIDS Reference Group on Estimates, Modeling, and Projections, represents important progress. However, these efforts are only a first step in a strategy to develop new modeling tools to ensure that monitoring equity among key and marginalized populations is at the center of UNAIDS estimates processes in all HIV epidemic settings. As with all elements of an effective HIV response, ensuring communities are partners in understanding and interpreting new data and models is critical to addressing complexities interpreting these data, filling critical data gaps, and ensuring data quality, ownership, and effective use.

REFERENCES

1. Maheu-Giroux M, Ciaranello AL, Salomon JA, et al. Refining global HIV estimates for decision-making: advances in analytic and modelling methods used by the Joint United Nations Programme on HIV/AIDS. *J Int AIDS Soc*. 2021;24(suppl 5):e25790.
2. Case KK, Johnson LF, Mahy M, et al. Summarizing the results and methods of the 2019 Joint United Nations Programme on HIV/AIDS HIV estimates. *AIDS*. 2019;33(suppl 3):S197–S201.
3. Case KK, Gregson S, Mahy M, et al. Editorial: methodological developments in the Joint United Nations Programme on HIV/AIDS estimates. *AIDS*. 2017;31(suppl 1):S1–S4.
4. Case KK, Hallett TB, Gregson S, et al. Development and future directions for the Joint United Nations Programme on HIV/AIDS estimates. *AIDS*. 2014;28(suppl 4):S411–S414.
5. Stanecki K, Garnett GP, Ghys PD. Developments in the field of HIV estimates: methods, parameters and trends. *Sex Transm Infect*. 2012; 88(suppl 2):ii1–ii2.
6. Ghys PD, Garnett GP. The 2009 HIV and AIDS estimates and projections: methods, tools and analyses. *Sex Transm Infect*. 2010; 86(suppl 2):ii1–ii2.

7. Ghys PD, Walker N, McFarland W, et al. Improved data, methods and tools for the 2007 HIV and AIDS estimates and projections. *Sex Transm Infect.* 2008;84(suppl 1):i1–i4.
8. Ghys PD, Walker N, Garnett GP. Improving analysis of the size and dynamics of AIDS epidemics. *Sex Transm Infect.* 2006;82(suppl 3):iii1–iii2.
9. Walker N, Stanecki KA, Brown T, et al. Methods and procedures for estimating HIV/AIDS and its impact: the UNAIDS/WHO estimates for the end of 2001. *AIDS.* 2003;17:2215–2225.
10. Stover J, Glaubius R. Methods and assumptions for estimating key HIV indicators in the UNAIDS annual estimates process. *J Acquir Immune Defic Syndr.* 2024 [epub ahead of print].
11. Brown T, Peerapatanapokin W, Siripong N, et al. The AIDS Epidemic Model 2023 for estimating HIV trends and transmission dynamics in Asian epidemic settings. *J Acquir Immune Defic Syndr.* 2024 [epub ahead of print].
12. Esra R, Mmelesi M, Ketlogetswe AT, et al. Improved indicators for subnational unmet antiretroviral therapy need in the health system: updates to the Naomi model in 2023. *J Acquir Immune Defic Syndr.* 2024 [epub ahead of print].
13. Korenromp EL, Sabin K, Stover J, et al. New HIV infections among key populations and their partners in 2010 and 2022, by World Region: a multi-sources estimation. *J Acquir Immune Defic Syndr.* 2024 [epub ahead of print].
14. Stevens O, Anderson R, Stover J, et al. Comparison of empirically derived and model-based estimates of key population HIV incidence and the distribution of new infections by Population Group in Sub-Saharan Africa. *J Acquir Immune Defic Syndr.* 2024 [epub ahead of print].
15. Silhol R, Anderson RL, Stevens O, et al. Measuring HIV acquisitions among partners of key populations: estimates from HIV transmission dynamic models. *J Acquir Immune Defic Syndr.* 2024 [epub ahead of print].
16. Glaubius R, Stover J, Johnson LF, et al. Differences in breastfeeding duration by maternal HIV status: a pooled analysis of nationally representative surveys in Sub-Saharan Africa. *J Acquir Immune Defic Syndr.* 2024 [epub ahead of print].
17. Trickey A, Glaubius R, Pantazis N, et al. Estimation of improvements in mortality in spectrum among adults with HIV receiving antiretroviral therapy in high-income countries. *J Acquir Immune Defic Syndr.* 2024 [epub ahead of print].
18. Stevens O, Boothe M, Tiberi O, et al. Triangulation of routine antenatal HIV prevalence data and adjusted HIV estimates in Mozambique. *J Acquir Immune Defic Syndr.* 2024 [epub ahead of print].
19. Allorant A, Muset P, Hodgins C, et al. Temporal trends and determinants of HIV testing at antenatal care in Sub-Saharan Africa: a pooled analysis of population-based surveys (2005–2021). *J Acquir Immune Defic Syndr.* 2024 [epub ahead of print].
20. United Nations General Assembly. *Political Declaration on HIV and AIDS: Ending Inequalities and Getting on Track to End AIDS by 2030.* https://www.unaids.org/sites/default/files/media_asset/2021_political-declaration-on-hiv-and-aids_en.pdf
21. Eaton JW, Dwyer-Lindgren L, Gutreuter S. Naomi: a new modelling tool for estimating HIV epidemic indicators at the district level in sub-Saharan Africa. *J Int AIDS Soc.* 2021;24:e25788.
22. Stover J, Glaubius R, Kassanjee R, et al. Updates to the Spectrum/AIM model for the UNAIDS 2020 HIV estimates. *J Int AIDS Soc.* 2021;24:e25778.