Summarizing the Results and Methods of the 2019 Joint United Nations Programme on HIV/AIDS HIV Estimates

Kelsey K. Case, Leigh F. Johnson, Mary Mahy, Kimberly Marsh, Virginie Supervie, Jeffrey W. Eaton

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EDITORIAL

Summarizing the results and methods of the 2019 Joint United Nations Programme on HIV/AIDS HIV estimates

Kelsey K. Case[a], Leigh F. Johnson[b], Mary Mahy[c], Kimberly Marsh[c], Virginie Supervie[d] and Jeffrey W. Eaton[a]

UNAIDS and other partners provide support to countries to develop estimates of HIV and related indicators on an annual basis. These estimates are used to monitor epidemic trends, guide program planning and resource allocation, and inform policy decision-making. The collection of articles in this AIDS supplement provide the headline results for the 2019 UNAIDS estimates and describe the new developments in the methods used to produce these estimates.

Introduction

The Joint United Nations Programme on HIV/AIDS (UNAIDS) publishes annually updated estimates of the global HIV epidemic. These estimates are developed by countries with the support of UNAIDS and partners. National HIV programs, UNAIDS and other international organizations and donors utilize these as consensus estimates to guide program planning, policy decision-making and resource allocation, to monitor epidemic trends, and to track progress towards global goals and targets.

In 2019, 170 countries, representing 99% of the global population, used Spectrum modelling software to develop estimates of HIV and related indicators. The methods underpinning these estimates are continually refined and evolve in response to changing epidemic dynamics, new data availability, new research, and in support of the needs of programs and decision makers. This process is guided by the UNAIDS Reference Group on Estimates, Modelling and Projections (www.epidem.org).

Recent methodological developments have tracked themes in the global HIV response:

(1) Increasing policy attention to HIV incidence and trends in new HIV infections as the ultimate indicator of sustained success at HIV prevention;
(2) Evaluating progress in scaling-up HIV testing, antiretroviral treatment, and viral suppression as countries approach 2020, the year for achieving the '90–90–90' target;

[a]Department of Infectious Disease Epidemiology, Imperial College London, London, UK, [b]Centre for Infectious Disease Epidemiology and Research, University of Cape Town, Cape Town, South Africa, [c]Strategic Information Department, UNAIDS, Geneva, Switzerland, and [d]Sorbonne Université, INSERM, Institut Pierre Louis d'Epidémiologie et de Santé Publique, Paris, France.

Correspondence to Kelsey K. Case, MSc, PhD, Department of Infectious Disease Epidemiology, Imperial College London, London, UK.

E-mail: k.case@imperial.ac.uk

(3) Availability of more detailed, granular and heterogenous data with which to understand the HIV epidemic across settings. New data sources include expanded HIV biomarkers in general population household surveys in sub-Saharan Africa, increased availability and granularity of routine HIV service delivery data about HIV testing, treatment, and antenatal care, and an increasing number of countries across global regions relying on HIV case surveillance and vital registration to understand their HIV epidemic.

This collection of articles, produced on a biennial basis, describes the new developments in the methods used to produce these estimates. For the first time, this Supplement also includes headline results from the 2019 UNAIDS estimates and reports on progress towards global goals and targets. Two articles present the headline results [1,2], four articles describe developments in the modelling methods and tools used to produce the estimates [3–6], and three articles describe developments in the data used to inform modelling methods and parameters [7–9].

The HIV epidemic and progress towards 90−90−90 in 2019

Global declarations called for a 75% reduction in new HIV infections and AIDS deaths between 2010 and 2020 through achieving 90−90−90 HIV testing, treatment, and viral suppression targets, alongside implementation of effective HIV primary prevention [10]. Mahy *et al.* [1] report positive progress toward these targets in the 2019 UNAIDS estimates, but substantial gaps remain. Globally, there were an estimated 37.9 million (32.7−44.0 million) people were living with HIV with 1.7 million (1.4−2.3 million) new infections and 770 000 (570 000 to 1.1 million) AIDS-related deaths in 2018. Compared with 2010, HIV incidence at the global level has declined 16% whereas estimates of AIDS deaths have declined 33%, the latter largely attributable to treatment scale-up. These declines are not on track to meet global targets; only three countries are on track to reach the 75% incidence reduction target. The greatest declines in AIDS deaths have occurred in the Eastern and Southern Africa region. However, new HIV infections are estimated to have marginally increased in Latin America and both new HIV infections and AIDS deaths are estimated to have increased in the Eastern Europe and Central Asia and in the Middle East and North Africa regions. Across all regions, declines in incidence and AIDS deaths have been greater among women compared with men.

Two countries that contribute substantially to the global HIV burden made notable adjustments to their estimates

this year based on new data available. Nigeria produced estimates at the state level informed by the 2018 household-based survey, which found lower HIV prevalence than previous surveys. The resultant estimate of the number of people living with HIV (PLHIV) in Nigeria was revised from 3.1 to 1.9 million. China has produced estimates for each region and report 500 000 more PLHIV than previous estimates produced by UNAIDS based on data publicly available. These changes impact the regional and global estimates of HIV burden.

The UNAIDS 90−90−90 target reflects the 2020 goal of 90% of PLHIV knowing their status, 90% of PLHIV who know their status accessing antiretroviral therapy (ART), and 90% of those on ART having sustained viral suppression. Marsh *et al.* [2] report on the global progress towards this target in 2018. It was estimated that globally 79% (67−92%) of all PLHIV know their status, 78% (69−82%) of those who know their status are accessing treatment, and 86% (72−92%) of those on treatment have suppressed viral loads. There have been steady increases in diagnosis and access to treatment at the global level with an estimated 23 million (20.5−24.3 million) people on treatment in 2018, but the rate of treatment scale-up will need to increase to meet the 2020 target of 30 million people receiving treatment. The Eastern and Southern Africa region, where the greatest proportion of PLHIV reside, has made consistent gains each year toward the 90−90−90 target. However, there is substantial variability in progress across regions and differences overall and by sex. In nearly all regions, progress is greater among women compared with men, and many countries and regions are unlikely to reach the 90−90−90 target by 2020.

Development of estimation tools

Almost all countries use the Spectrum model to produce estimates of HIV-related indicators for the UNAIDS estimates. Within Spectrum, there are different estimation tools developed in response to the data available in different settings, and in support of the needs of programs and decision makers.

Stover *et al.* [3] describe key updates implemented in the AIDS Impact Model in Spectrum. These include revised estimates of AIDS-related mortality among adults not on ART, dependent on $CD4^+$ and ART coverage, which reflect the changing pattern of mortality as ART coverage increases over time. Second, a new procedure has been developed to estimate country-specific patterns of HIV incidence by age and sex from HIV prevalence in national surveys. This is intended to improve the age and sex-specific estimates of HIV prevalence and produce more accurate estimates of pregnant women in-need of prevention of mother-to-child transmission (PMTCT).

Third, the paediatric model in Spectrum has been refined to reflect newly available data about retention of pregnant women on treatment at delivery, and slightly higher estimates of HIV transmission in the postpartum period. The age-specific pattern of ART initiation among children has also been modified to reflect the increasing proportion of children who start ART under 2 years and over 10 years of age. Finally, a new tool has been added to disaggregate national or provincial HIV estimates to the district level. This tool aims to support local program planning and decision-making while providing a set of localized estimates that are consistent with the estimates obtained at the national level.

The Estimation and Projection Package (EPP) within Spectrum is the tool used to estimate HIV incidence from general population surveys and surveillance of HIV prevalence in antenatal care. Eaton *et al.* [4] describe two key updates for estimating HIV incidence trends in sub-Saharan Africa: the modification to include age and sex stratification, and the development of a new functional form for modelling the HIV transmission rate. Historically, EPP has not been stratified by age and sex. As HIV epidemics mature, it has become increasingly important to capture the changing demographics including a shifting of prevalence to older ages and changing patterns of prevalence among pregnant women. The EPP Age-Sex Model (EPP-ASM) was developed to explicitly capture the demographic dynamics of the HIV epidemic over time in a manner consistent with the age-structured Spectrum model. EPP-ASM also provides the structure to produce more detailed and granular estimates in the future. Within EPP and EPP-ASM, a new functional form for modelling the HIV transmission rate has been developed. The 'r-hybrid' model combines two approaches to model the changing transmission rate over the epidemic, using one model to capture the initial growth and decline of HIV incidence and a second model for recent incidence trends. The authors demonstrate that EPP-ASM and the r-hybrid model can improve estimation and projection of HIV prevalence trends in generalized epidemic settings.

In concentrated and low-level HIV epidemics where the primary data for tracking the HIV epidemic are case reports of HIV diagnoses and AIDS death reports from vital registration, alternative estimation methods have been developed. Mahiane *et al.* [5] document the development of the Case Surveillance and Vital Registration (CSAVR) tool in Spectrum. This approach capitalizes on the robust HIV case surveillance and vital registration systems available in many middle-income and high-income countries. A family of curve fitting models with different functional forms are described, which estimate HIV incidence from case report, mean CD4$^+$ at diagnosis and AIDS deaths data. The CSAVR tool was used by 43 countries to produce estimates for the 2019 UNAIDS estimates.

For persons living with HIV, knowledge of HIV status is the critical initial step to receiving care and treatment and achieving viral suppression. This 'first 90' of the UNAIDS 90−90−90 target is an important indicator but difficult to measure directly. Maheu-Giroux *et al.* [6] describe the development of a mathematical model to estimate the first 90 in sub-Saharan Africa. The 'first 90' model uses national population-based surveys on HIV testing history and program data from HIV testing services to estimate the proportion of PLHIV who know their status over time. This is a major advance on previous methods, which often relied on self-reported 'knowledge of HIV status' among survey participants, which has been shown to be under-reported [11−14]. The authors describe the methods used and validate the results using data from three countries in sub-Saharan Africa. They demonstrate the model can reproduce trends in testing behavior over time and can consistently predict the proportion of individuals who know their status by age and sex. Age-specific and sex-specific estimates for other HIV testing indicators include the total number of tests, first tests, positive tests, and new diagnoses, which can be used to inform and strengthen HIV-testing services. Estimates from the first 90 model were published by all 17 countries with national population surveys in Eastern and Southern Africa, and by 16 of 20 countries in Western and Central Africa, for the 2019 UNAIDS estimates.

New data and epidemiological analysis

Recent data from cohorts of patients receiving ART have been used to inform updated assumptions about the regional patterns of mortality on treatment in Spectrum. These updates are important because they incorporate new data since the advent of the 'treat-all' ART era, which capture patterns of mortality with earlier ART initiation. Johnson *et al.* [7] conduct an updated analysis of the regional patterns of mortality after ART initiation in Africa, Asia and the Americas, analyzing patient cohort data from the International Epidemiology Databases to Evaluate AIDS (IeDEA) network up to 2017. An imputation approach to account for unascertained mortality among those lost to follow-up is applied in the African regions. The authors find that after controlling for treatment duration and baseline CD4$^+$ count, mortality after ART initiation has declined over time in all regions, although with slower and more modest declines observed in Africa. However, there is substantial variability in the mortality rates on ART between and within regions, and across programs, which remain even when controlling for key variables.

New data from patient cohorts in Europe were used to improve the Spectrum mortality assumptions for high-income settings. Trickey *et al.* [8] compare data from the ART Cohort Collaboration (ART-CC) to the Spectrum

estimates to validate mortality rates and excess mortality for PLHIV on ART in European countries. The authors find that for all-cause mortality, the ART-CC data suggest higher observed mortality in the early ART period, which declined more steeply and to lower levels in more recent years than the Spectrum assumptions. Further, while the excess mortality rates among PLHIV were similar, the estimated proportion of deaths because of AIDS in Spectrum were higher than in the cohort data. The Spectrum assumptions were updated with the mortality rates from the ART-CC and IeDEA data for the 2019 UNAIDS estimates resulting in improved estimates of AIDS deaths in many settings.

Finally, transitioning from sentinel surveillance of HIV prevalence in antenatal care to leveraging routinely conducted HIV testing at antenatal care to screen for PMTCT programs has been a major shift in tracking the HIV epidemic in sub-Saharan Africa [15]. Historically, HIV prevalence from surveillance in antenatal care was a key data source used to estimate trends of HIV prevalence, incidence and AIDS deaths. As many countries transition from sentinel surveillance to routine monitoring in PMTCT programs, the implications of this switch and the biases that may arise are important to understand. Maheu-Giroux *et al.* [9] use PMTCT data from Malawi to investigate the impact on estimates of HIV prevalence if there is suboptimal coverage of routine HIV testing among pregnant women. The authors find that imperfect coverage can bias HIV prevalence estimates. In Malawi, HIV prevalence was higher in facilities with high testing coverage, thus use of results from only those facilities with optimal testing coverage resulted in an overestimation of HIV prevalence. These findings indicate the need for careful evaluation and appropriate adjustment of HIV prevalence data from routine testing data when used to monitor epidemic trends.

Conclusion

This supplement describes substantial methodological developments underpinning the tools used by countries to understand and respond to their HIV epidemics. Innovations have focused on refining estimation of HIV incidence trends, new data about AIDS mortality and the effectiveness of antiretroviral treatment programs, and new tools for tracking knowledge of HIV status. The UNAIDS 2019 estimates, which incorporate these methodological advancements, indicate that most countries are not on track to meet global targets. New HIV infections and AIDS-related deaths have increased in Eastern Europe and Central Asia and the Middle East and North Africa regions, and progress towards global targets has been greater among women than men.

The epidemic of the next decade will unfold differently than that of the past. Looking forward, it is certain that the methods and data that characterize the HIV epidemic will continue to evolve alongside the epidemic and global response. Keeping pace with the epidemiological changes will require innovation of estimation and modelling tools that describe HIV transmission dynamics in order to anticipate where pockets of HIV transmission are likely to occur in the future, rather than extrapolating from the past. Understanding patterns of mobility and migration, the epidemiology of HIV amongst key populations, and the locations and populations at greater risk of HIV transmission and acquisition, will be central to ensure that all persons equitably receive the HIV care, treatment, and prevention services required to end AIDS as a public health threat by 2030.

Finally, new tools are needed for monitoring sustained viral load suppression, ensuring the halting of individual HIV disease progression and onward transmission. This will become an increasing focus as HIV testing and treatment programs transition from identifying and initiating large numbers of untreated persons to maintaining large cohorts of patients on successful lifelong treatment.

Acknowledgements

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