HIV estimates through 2018: data for decision-making

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Background: Global targets call for a 75% reduction in new HIV infections and AIDS deaths between 2010 and 2020. UNAIDS supports countries to measure progress towards these targets. In 2019, this effort resulted in revised national, regional and global estimates reflecting the best available data.

Methods: Spectrum software was used to develop estimates for 170 countries. Country teams from 151 countries developed HIV estimates directly and estimates for an additional 19 country were developed by UNAIDS based on available evidence. 107 countries employed models using HIV prevalence data from sentinel surveillance, routinely collected HIV testing and household surveys while the remaining 63 countries applied models using HIV case surveillance and/or reported AIDS deaths. Model parameters were informed by the UNAIDS Reference Group on Estimates, Modeling and Projections.

Results: HIV estimates were available for 170 countries representing 99% of the global population. An estimated 37.9 million (uncertainty bounds 32.7–44.0 million) people were living with HIV in 2018. There were 1.7 million (1.4–2.3 million) new infections and 770 000 (570 000–1.1 million) AIDS-related deaths. New HIV infections declined in five of eight regions and AIDS deaths were declining in six of eight regions between 2010 and 2018.

Conclusion: The estimates demonstrate progress towards ending the AIDS epidemic by 2030, however, through 2018 declines in new HIV infections and AIDS-related deaths were not sufficient to meet global interim targets. The UNAIDS estimates have made important contributions to guide decisions about the HIV response at global, regional and country level.

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Background

The HIV epidemic has affected populations around the world. Ministers of health, ministers of finance, donors and programme managers require high-quality data to determine how to respond and fund the HIV response [1]. Critical to those decisions is sound epidemiological data on new HIV infections and AIDS-related deaths. Global and country leaders have also set ambitious targets that, if met, will reduce the impact of the epidemic on future populations and end AIDS by 2030. Specific targets were set within the United Nations Political Declaration on HIV/AIDS in 2016 to reduce new HIV infections and AIDS-related deaths by 75% between 2010 and 2020 and by 95% between 2010 and 2030 [2]. Countries agreed to report on their progress towards the Sustainable Development Goals using HIV incidence [3].

To understand progress towards these targets and plan the response to the HIV epidemic, countries require measures of new HIV infections, people living with HIV (PLHIV), and AIDS-related deaths. UNAIDS and partners work with countries to improve capacity to measure these indicators. Efforts to develop surveillance systems include

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developing and producing guidelines on surveillance, moving countries towards sustainable routine data systems including case surveillance and using routine testing of pregnant women for surveillance, estimating key population size estimates, and considering how and when to implement surveys.

However, there are few reliable approaches to derive these indicators. Most measures of HIV incidence and mortality have biases or limited representativeness [4–6]. Cross sectional population-based surveys can be used to estimate HIV prevalence and incidence (and efforts are underway to incorporate mortality) in countries where HIV prevalence is sufficiently high to capture this relatively rare event with a reasonably large, and affordable, sample size. However, due to the high costs and human resources required for surveys, they are only conducted every 3–5 years, usually with significant donor contributions, making it difficult to regularly report on progress or trends over time. These surveys are also usually not sufficiently powered to provide credible estimates of HIV incidence by age, sex or at lower geographic levels [7]. Mortality can be captured through vital registration but the cause of death in these data are often flawed, especially for stigmatizing diseases such as HIV [8,9]. Other innovative efforts to measure mortality such as mortuary studies and postcensus surveys have been developed but are not conducted routinely [10,11].

In the absence of high-quality measures, models, informed by multiple data sources and well founded assumptions, can produce robust estimates of HIV incidence, prevalence and mortality in a country [12]. Even in middle-income and high-income countries with reliable case surveillance and vital registration systems modelled estimates are needed to know the number of PLHIV who have not been diagnosed and to quantify the delay between new infection and diagnosis [13].

UNAIDS and partners work with country teams to develop modelled HIV estimates using Spectrum software [14]. The country teams, including national epidemiologists, programme managers, UNAIDS country staff and other partners, ensure the country has ownership of the estimates and can use the modelling software for their own purposes of strategic planning and impact monitoring and for donor requests and reporting [15]. The estimates are used to measure success in operationalizing national HIV plans and adjusting those plans as needed.

Since 1998 UNAIDS has reported on the status of the HIV epidemic using modelled estimates in its flagship reports [1,16–18] and on its public database (aidsinfo.unaids.org). This article is the first journal article describing the full set of global and regional UNAIDS HIV estimates, although articles describing country specific estimates [19] and specific populations [20,21] have been published previously. The objective of this article is to provide an overview of the global and regional HIV epidemic and trends through 2018 and describe the use of those data for decision-making.

Methods

National HIV estimates are produced on an annual basis by country teams supported by UNAIDS staff and partners. In 2019, UNAIDS facilitated 12 regional workshops building the capacity of approximately 450 national officers, as well as United Nations and bilateral development partners' strategic information staff. At the workshops participants develop expertise in the use of Spectrum to create rigorous, country-owned estimates. The country-developed Spectrum files are reviewed by UNAIDS headquarters and regional staff for quality assurance. Once completed the estimates are approved by authorities in countries before they are compiled for release in UNAIDS' reports and publicly-accessible database. (The list of contributors to those national Spectrum files is available from UNAIDS upon request.) More information on the process of developing estimates is available elsewhere [22].

The UNAIDS Reference Group on Estimates, Modeling and Projections provides transparent guidance on the software ensuring the best science is used to estimate the epidemic, inform model assumptions, and use the latest statistical and mathematical modelling approaches. The group's meeting reports are available on the Reference Group website (www.epidem.org).

The methods used in the 2019 round of HIV estimates are described in other articles in this supplement. Summaries of the methodological developments made to the models over the course of the 15 years of development have been published biennially in peer-reviewed journals since 2004 [23–29]. In brief country teams used Spectrum software that was prepopulated with demographic data from the United Nations Population Division, World Population Prospects 2017 [30]. These underlying demographic data are updated as the United Nations Population Division releases new population estimates. Country teams can also modify the demographic data if they have evidence from a very recent census or survey that is not included in the World Population Prospects. In addition, country teams can create subnational Spectrum files (one file for each province), depending on the availability of subnational population, surveillance and programmatic data.

Trends in HIV incidence are calculated through different options depending on the data available. In most generalized epidemic countries, HIV prevalence data from nationally representative household surveys, and antenatal clinic attendees are used to estimate trends in HIV prevalence over time [31]. In concentrated epidemics surveillance data on HIV prevalence from key populations, integrated behavioural and biological surveys, and key population size estimates are used to determine prevalence

trends over time. These prevalence trends are transformed into incidence based on country data on how many people are receiving antiretroviral therapy (ART) and region-specific assumptions about survival on and off ART [32]. In 13 Asian countries the AIDS Epidemic Model (AEM, formerly referred to as the Asian Epidemic Model) is used to estimate the incidence curve. The AEM model uses data on behaviours and transmission probabilities between different subpopulations to estimate an incidence curve [33]. In South Africa a country-specific model, Thembisa, is used to estimate the incidence trends incorporating data from antenatal clinic sentinel surveillance, household surveys, programme data and behavioural data [34]. Finally, in countries with good-quality case surveillance and AIDS mortality from vital registration data, the incidence curve is informed by a model using new diagnoses and assumptions about time from infection to diagnosis, cumulative case surveillance and AIDS deaths [35]. In 2019, 63 countries used the case surveillance modelling method or the European Center for Disease Control methods to determine incidence trends [36].

The incidence estimates generated with these different options are then used in the Spectrum AIDS Impact Module where they are distributed by age and sex based on household survey data, if available, or regional-specific and epidemic-specific assumptions for the remaining countries. Using the incidence patterns the population is then progressed over time from infection to treatment (or lack of treatment) to death. Additional programmatic data that are used in the model include the number of men, women and children receiving ART and the number of pregnant women receiving antiretroviral medicines to prevent vertical transmission. Spectrum estimates the number of child infections based on a child model that incorporates estimates of fertility among women living with HIV, antiretroviral regimens received by those women, breastfeeding duration and assumptions about transmission and survival of those children.

Indicators produced in Spectrum are available by 5-year age group and sex. In addition to incidence, mortality and prevalence the software package also produces estimates of orphan-hood due to HIV, mother-to-child transmission rate, births to women living with HIV, deaths due to all causes among PLHIV, estimates of $CD4^+$ distribution among those not on ART, ART status at death, population on ART by age, among other indicators.

Estimates for 2019 were produced for the years 1970 through 2018. Each indicator is estimated with an uncertainty range that reflects the surveillance data used in the model as well as the uncertainty around the parameters used in Spectrum. Figure 1 shows the model structure of the AIDS Impact module.

Estimates teams from 151 countries developed their own estimates while a further 19 country estimates were produced by UNAIDS using data abstracted from publicly available sources. Since 2015, 20 countries have created subnational estimates, allowing more granular understanding of the epidemic in those countries [37]. In 2019, 20 sub-Saharan African countries disaggregated their national estimates to the district-level (the second lower subnational level) for even finer planning. Countries used different methods to disaggregate the estimates including the HIVE model, the distribution of prevalence among women attending antenatal clinics, and small area estimates [38,39].

Lists of the countries included in each of the UNAIDS regions are available at www.unaids.org.

Results

Globally there were an estimated 37.9 million (32.7–44.0 million) PLHIV in 2018. This represents an increase from 24.9 million (21.5–28.9 million) in 2000 and 31.7

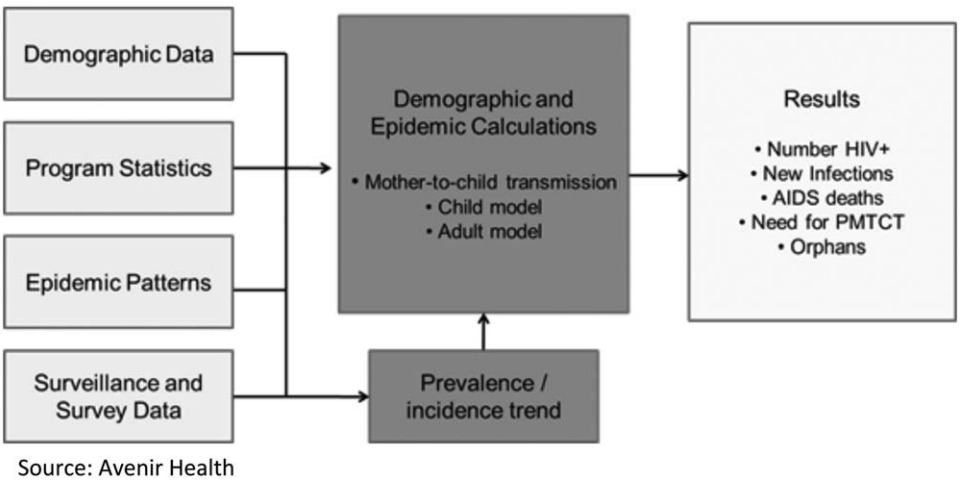

Fig. 1. Model structure of AIDS impact module in Spectrum.

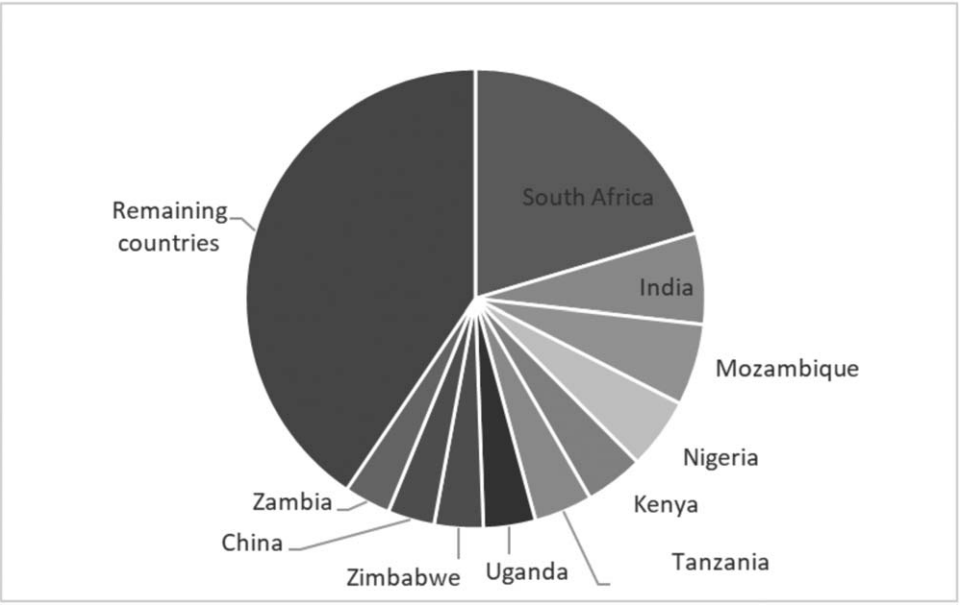

Fig. 2. Distribution of people living with HIV in the 10 highest burden countries, 2018.

million (27.3–36.8 million) in 2010. This increase is due in part to the success of treatment programmes increasing survival among PLHIV. Over 54% of PLHIV reside in Eastern and Southern Africa and a further 15% reside in Asia and the Pacific. Over 50% of PLHIV reside in eight countries (Fig. 2). Just over half (52%) of PLHIV are women. An estimated 1.7 million (1.3–2.2 million) children under age 15 were living with HIV in 2018. Almost two-thirds (63%) of children living with HIV are in sub-Saharan Africa. This number of children living with HIV is declining over time as fewer children are becoming infected due to successful prevention of mother-to-child transmission programmes and older children living with HIV are aging into the adult age group. (Country level data by age and sex are available on UNAIDS website at aidsinfo.unaids.org.)

In the 2016 Political Declaration on HIV/AIDS countries committed to a 75% reduction in new HIV infections and a 75% reduction in AIDS-related deaths between 2010 and 2020 [2]. To be on track to reach the 75% decline regions and countries should have reached 60% decline by 2018 (assuming a linear decline).

An estimated 1.7 million (1.4–2.3 million) people were newly infected with HIV in 2018 down from 2.1 million (1.6–2.7 million) new infections in 2010. New HIV infections declined by 16% globally between 2010 and 2018, and no region was on track to reach the 75% reduction. In three regions (Eastern Europe and Central Asia, the Middle East and North Africa and Latin America) estimated new HIV infections increased between 2010 and 2018 (Table 1). Among countries the declines in new infections in Cambodia, Rwanda and Viet Nam were over 60% between 2010 and 2018 among all age groups. Globally, new HIV infections among women ages 15 years and older declined by 17% compared with 9% among men ages 15 years and older. While new infections among children decreased by 41%.

AIDS deaths have seen sharper declines with a 33% decline since 2010 globally reflecting the scale-up of antiretroviral therapy. The greatest declines in AIDS deaths occurred in Eastern and Southern Africa with a 44% decline since 2010 while AIDS deaths in Western and Central Africa only declined by 29% over the same period (Table 1). Burundi, Democratic Republic of the Congo, Dominican Republic and Portugal showed declines that put them on track to reach the 2020 target for AIDS deaths. An estimated 770 000 (570 000–1.1 million) people died of AIDS-related deaths in 2018. Declines in AIDS-related deaths varied by sex. Globally, among adult women 15 years and above AIDS deaths declined by 40% compared with 21% among men of the same age group. AIDS deaths among children declined by 51% globally, some of this decline is due to children aging into the adult cohort.

In 2019, two countries made substantial changes to their estimates based on newly available evidence. These changes had important impacts on the regional estimates. China created Spectrum estimates for each of their 34 regions in 2018. The estimated number of PLHIV in the country was about 500 000 higher than what had previously been estimated by UNAIDS based on publicly available information [40]. In 2018, Nigeria conducted a statistically well powered household survey to estimate prevalence in each of the 36 states and the capital territory.

Table 1. New HIV infections, AIDS-related deaths and people living with HIV, globally and by region 2000, 2010 and 2018 and progress towards targets of reducing new HIV infections and AIDS-related deaths by 75% by 2020.

	2000			2010			2018			
	New HIV infections	New HIV infections, lower bound	New HIV infections, upper bound	New HIV infections	New HIV infections, lower bound	New HIV infections, upper bound	New HIV infections	New HIV infections, lower bound	New HIV infections, upper bound	% change from 2010 to 2018[a]
Global	2800000	2200000	3600000	2100000	1600000	2700000	1700000	1400000	2300000	−16%
Asia and the Pacific	540000	460000	650000	340000	290000	410000	310000	270000	380000	−9%
Caribbean	27000	19000	40000	19000	13000	28000	16000	11000	24000	−16%
Eastern and southern Africa	1500000	1200000	2000000	1100000	850000	1500000	800000	620000	1000000	−28%
Eastern Europe and central Asia	71000	65000	76000	120000	110000	130000	150000	140000	160000	29%
Latin America	120000	89000	150000	97000	75000	120000	100000	79000	130000	7%
Middle East and North Africa	15000	6300	30000	18000	7700	36000	20000	8500	40000	10%
Western and central Africa	440000	290000	660000	320000	210000	480000	280000	180000	420000	−13%
Western and central Europe and North America	75000	65000	86000	77000	66000	88000	68000	58000	77000	−12%

	AIDS deaths	AIDS deaths, lower bound	AIDS deaths, upper bound	AIDS deaths	AIDS deaths, lower bound	AIDS deaths, upper bound	AIDS deaths	AIDS deaths, lower bound	AIDS deaths, upper bound	
Global	1400000	1000000	1900000	1200000	860000	1600000	770000	570000	1100000	−33%
Asia and the Pacific	210000	170000	300000	270000	210000	380000	200000	160000	290000	−24%
Caribbean	20000	15000	28000	11000	8300	15000	6700	5100	9100	−38%
Eastern and southern Africa	800000	600000	1100000	550000	410000	720000	310000	230000	400000	−44%
Eastern Europe and central Asia	12000	8700	15000	36000	27000	46000	38000	28000	48000	5%
Latin America	46000	34000	63000	40000	30000	55000	35000	25000	46000	−14%
Middle East and North Africa	3200	1800	5400	7700	4400	13000	8400	4800	14000	9%
Western and central Africa	280000	200000	410000	230000	160000	330000	160000	110000	230000	−29%
Western and central Europe and North America	22000	17000	29000	19000	14000	25000	13000	9400	16000	−35%

	HIV population	HIV population, lower bound	HIV population, upper bound	HIV population	HIV population, lower bound	HIV population, upper bound	HIV population	HIV population, lower bound	HIV population, upper bound
Global	24900000	21500000	28900000	31700000	27300000	36800000	37900000	32700000	44000000
Asia and the Pacific	4400000	3800000	5300000	5400000	4700000	6500000	5900000	5100000	7100000
Caribbean	300000	260000	360000	300000	260000	350000	340000	290000	390000
Eastern and southern Africa	13400000	11800000	15000000	17000000	15000000	19000000	20600000	18200000	23200000
Eastern Europe and central Asia	390000	350000	430000	990000	900000	1100000	1700000	1500000	1900000
Latin America	1000000	830000	1300000	1500000	1200000	1800000	1900000	1600000	2400000
Middle East and North Africa	78000	50000	120000	180000	110000	280000	240000	160000	390000
Western and central Africa	4200000	3300000	5200000	4500000	3600000	5700000	5000000	4000000	6300000
Western and central Europe and North America	1200000	1000000	1300000	1800000	1500000	2000000	2200000	1900000	2400000

Uncertainty bounds are based on the uncertainty in the surveillance data used to estimate incidence and the parameters in the model. The estimates are rounded due to the uncertainty in the estimates. AIDS-related deaths only include deaths due to HIV disease and do not include other causes of death. Countries included in each region are available at aidsinfo.unaids.org. Country, age and sex specific data are available at aidsinfo.unaids.org.

[a]Percent change between 2010 and 2018 are based on unrounded values.

The survey estimated HIV prevalence was considerably lower than previously published survey data. When the new survey data were included and the previous surveys were excluded from Spectrum the estimated number of PLHIV in Nigeria was adjusted from 3.1 million [2.1 - 4.4 million] to 1.9 million [1.4 - 2.6 million] [41]. Changes in the PLHIV in China and Nigeria affect both estimates of programme achievement such as antiretroviral therapy coverage and declines in incidence and AIDS-related mortality. The adjustments to the estimates for both China and Nigeria were based on new information, resulting in a revised full set of historical HIV estimates.

Discussion

The HIV estimates developed in 2019 suggest that, based on progress through 2018, no region or country had reached the 2020 targets of a 75% reduction in new HIV infections or AIDS-related deaths from 2010 estimates. In addition, no region had reached a 60% decline by 2018, the decrease required to be 'on track' to reach a 75% decline by 2020. Given the available evidence on the effectiveness of HIV prevention and treatment, the lack of global and regional progress is alarming. Especially troubling is that more than 30 years into the epidemic three of eight regions have increasing HIV incidence and two have increasing mortality.

Coverage of antiretroviral therapy scaled-up quickly between 2005 and 2018, however the year on year increases in recent years are stagnating [42]. The impact of this stagnation will slow the decline in AIDS deaths as well as new HIV infections. The estimated number of PLHIV continues to increase reflecting in part the success of reaching more people with antiretroviral therapy and the subsequent reductions in AIDS-related deaths.

Country-specific progress within regions provides more specific data on successes and where more effort is needed. Three countries were on track to reach the decline in new HIV infections and four countries were on track to reach the reduction in AIDS-related deaths by 2018. These countries reached a 60% decline in new infections or AIDS-related deaths respectively.

In addition to the UNAIDS HIV estimates, the Institute for Health Metrics and Evaluation, based at the University of Washington, USA, has also published estimates of regional and global HIV incidence and mortality [43]. These estimates have used publicly available UNAIDS Spectrum files from previous rounds. The Spectrum files are modified to fit within an envelope of total deaths as determined by the Global Burden of Disease estimates. The results are largely consistent with the UNAIDS estimates from previous rounds but do not reflect the latest surveillance or antiretroviral therapy data. They also fail to capture the most recent modifications implemented by the country teams that produce, analyze and fully understand the data going into the models.

As a result of this effort, 170 countries (with populations of at least 250 000) have the capacity to produce, or access, robust estimates and measures of progress towards the Political Declaration on HIV targets. Programme managers and policy makers in these countries use this information, in addition to other programmatic data, to plan and respond to their HIV epidemic. Many countries further use the Spectrum model to determine interventions that are the most effective and efficient to meet national targets [44,45]. PEPFAR's priority countries use subnational estimates of PLHIV derived from Spectrum to decide on geographical focus and to inform programme targets [15].

At global and regional level the UNAIDS HIV estimates are used to make critical decisions about the HIV response. Reporting on the slow decline in HIV incidence spawned the UNAIDS Prevention Gap report and the corresponding Global Prevention Coalition and multiple country prevention plans to refocus their HIV response to prevention [17,45,46]. Also, the estimates have been used as evidence for the US Government to continue funding PEPFAR, the largest donor in the HIV response [47,48]. The Global Fund to fight AIDS, Tuberculosis and Malaria relies on the UNAIDS estimates to determine eligibility for funding and determine impact [49].

Recent population-based surveys have started estimating national HIV incidence [50] providing a useful comparison with the model-derived incidence. UNAIDS estimates are consistent with national HIV incidence collected through these cross-sectional surveys. If the survey incidence data are available at the same subnational level as the model, those data can be included in the curve fitting process in Spectrum. In seven of eleven countries with survey-derived incidence, the information was not available at the required subnational level to allow for direct inclusion in Spectrum. In those countries the aggregated national estimate of incidence from Spectrum was within the confidence interval of the survey (Fig. 3).

Only a few countries have conducted household surveys with the statistical power to measure HIV prevalence among children. Prevalence among children is not an input to Spectrum but can be used to validate the modelled estimates. An analysis of the 2018 UNAIDS estimates found prevalence among children 0–14 years was within the confidence intervals of the household surveys in five of six countries [51]. The 2019 estimates, using an improved methodology, remain within the survey confidence intervals for ten of eleven countries with available data (data not shown).

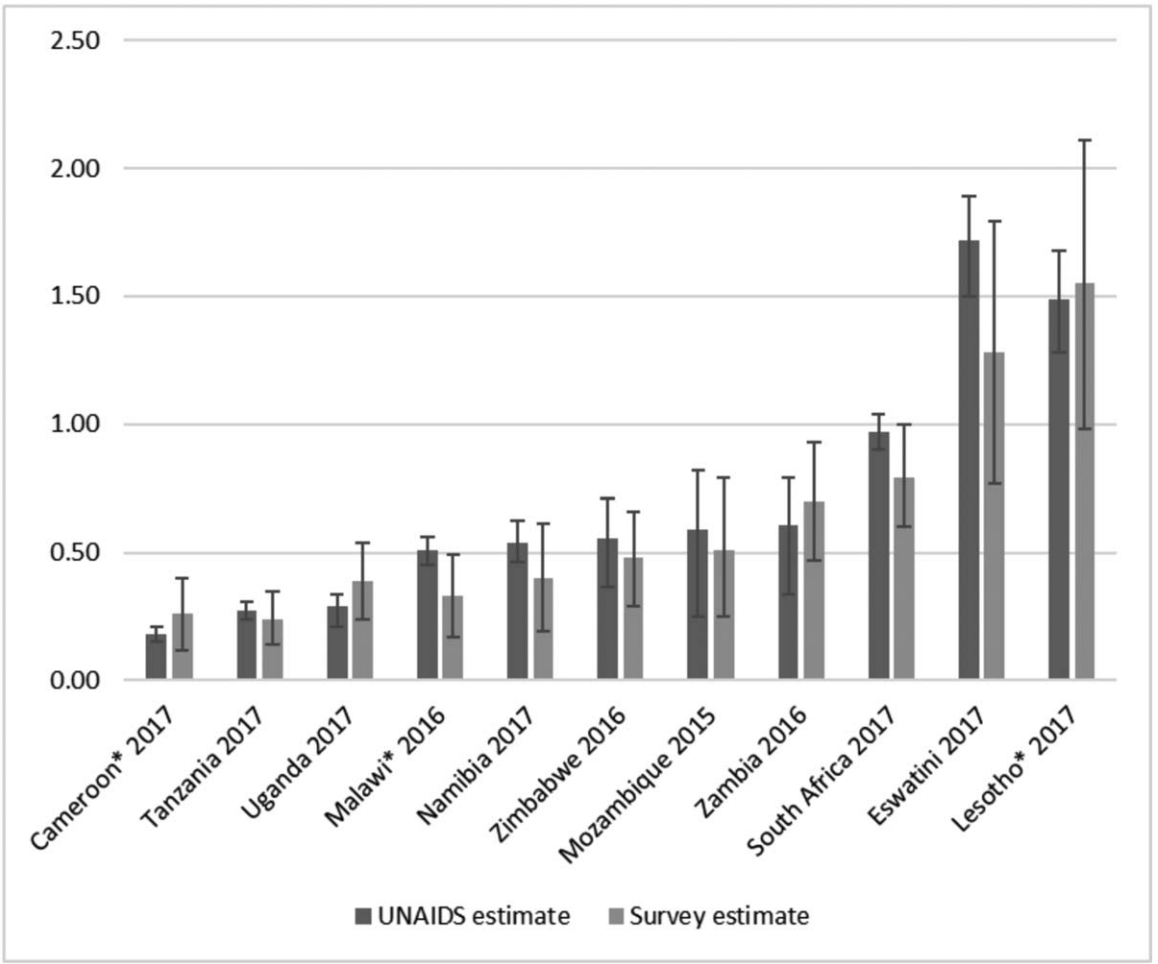

Fig. 3. Adult (15–49 years) HIV incidence, UNAIDS estimates and surveys, 2015–2018. Countries noted with an asterisk have included the survey incidence value in the model. The year of the survey is provided in parentheses. The UNAIDS estimate is for the survey year. Survey results are based on a recent infection algorithm including limiting antigen avidity assay, viral load, and antiretroviral medicines. The recent Ethiopia PHIA survey is not included because the survey did not include rural areas. Sources for the survey data are: Mozambique: https://www.dhsprogram.com/pubs/pdf/AIS12/AIS12_SE.pdf Cameroon, Tanzania, Uganda, Malawi, Namibia, Zimbabwe, Zambia, Eswatini, Lesotho: https://phia.icap.columbia.edu/ South Africa: https://serve.mg.co.za/content/documents/2018/07/17/7M1RBtUShKFJbN3NL1Wr_HSRC_HIV_Survey_Summary_2018.pdf.

A number of limitations exist within the estimates; four important limitations are mentioned here.

First, the reliance on programme data leaves the estimates vulnerable to weak data systems, which potentially bias results. For example, estimating AIDS deaths requires an accurate number of people receiving antiretroviral therapy. These data can be over counted if clinics are not able to identify and deduplicate individuals recorded to be on treatment at multiple clinics. In the past 2 years countries, with support from US Government, WHO, UNICEF, Global Fund to fight AIDS, Tuberculosis and Malaria, and UNAIDS, have made considerable effort to improve the recording of the number of people on antiretroviral therapy. Trends in recent new infections rely on prevalence data from routine antenatal clinic testing. If those data are biased because women with known positive HIV status are not captured when calculating prevalence, or women found to be negative at initial antenatal care visit are retested later in the pregnancy, the derived incidence trends might be biased. While some limitations of the models are reflected in the uncertainty bounds the measurement biases and the uncertainty caused by these biases are not easily quantified and are thus not included [52].

Second, in concentrated epidemics the surveillance systems for key hard-to-reach populations are particularly challenging and the surveillance data are often not comparable over time due to changing survey and sampling methods [53,54]. The sizes of key populations, a critical input to the Spectrum model for concentrated epidemics, are difficult to estimates accurately which can lead to important under or over

estimation of HIV epidemics in concentrated epidemics [55].

Third, although HIV prevalence among children appears to be reasonably robust in generalized epidemics, estimating the paediatric HIV epidemic in concentrated epidemics remains a challenge because no robust measures exist of fertility among key populations living with HIV. Other limitations in all epidemics include potentially weak assumptions about AIDS mortality among children not receiving ART due to the lack of evidence, which, appropriately, will not be available in the future.

Finally, additional research is needed to improve the assumptions about time from seroconversion to diagnosis when using case surveillance to estimate incidence.

The UNAIDS 2019 estimates provide evidence that the world is off track from reaching established targets for reductions in new HIV infections and AIDS-related deaths globally and in all regions. The UNAIDS estimates provide countries with the ability to measure progress towards the 2016 Political Declaration goals and the Sustainable Development Goal target 3.3.1. The estimates continue to be a cornerstone for Global Fund impact measurement and for demonstrating the benefits of the US Government's Emergency Plan for AIDS Relief. The process of developing UNAIDS estimates builds capacity in countries to understand epidemics and to refine and focus services to PLHIV to reduce new HIV infections and AIDS-related deaths.

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Conflicts of interest

There are no conflicts of interest.

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