

 Open access • Posted Content • DOI:10.1101/2020.10.20.20216283

## **Trends in knowledge of HIV status and efficiency of HIV testing services in sub-Saharan Africa (2000-2020): a modelling study of survey and HIV testing program data**

— [Source link](#) 

Katia Giguère, Jeffrey W. Eaton, Kimberly Marsh, Leigh F. Johnson ...+8 more authors

**Institutions:** McGill University, Imperial College London, United Nations, University of Cape Town ...+2 more institutions

**Published on:** 23 Oct 2020 - medRxiv (Cold Spring Harbor Laboratory Press)

**Topics:** Population

Related papers:

- [Comprehensive HIV/AIDS knowledge and HIV testing among men in sub-Saharan Africa: a multilevel modelling.](#)
- [Accuracy of self-reported HIV testing history and awareness of HIV-positive status among people living with HIV in four Sub-Saharan African countries](#)
- [The continuum of HIV care in South Africa: implications for achieving the second and third UNAIDS 90-90-90 targets.](#)
- [Towards achieving the fast-track targets and ending the epidemic of HIV/AIDS in Ethiopia: Successes and challenges.](#)
- [Rates of HIV testing and diagnosis in South Africa: successes and challenges.](#)

Share this paper:    

View more about this paper here: <https://typeset.io/papers/trends-in-knowledge-of-hiv-status-and-efficiency-of-hiv-4xi7koc0te>

# Trends in knowledge of HIV status and efficiency of HIV testing services in Sub-Saharan Africa (2000-2020): a modelling study of survey and HIV testing program data

Katia Giguère<sup>1</sup>, Jeffrey W. Eaton<sup>2</sup>, Kimberly Marsh<sup>3</sup>, Leigh F. Johnson<sup>4</sup>, Cheryl C. Johnson<sup>5,6</sup>, Eboi Ehui<sup>7</sup>, Andreas Jahn<sup>8,9</sup>, Ian Wanyeki<sup>3</sup>, Francisco Mbofana<sup>10</sup>, Fidèle Bakiono<sup>11</sup>, Mary Mahy<sup>3</sup>, and Mathieu Maheu-Giroux<sup>1</sup>

<sup>1</sup> Department of Epidemiology, Biostatistics, and Occupational Health, School of Population and Global Health, McGill University, Montréal, Canada (Katia Giguère, PhD, Mathieu Maheu-Giroux, ScD)

<sup>2</sup> MRC Centre for Global Infectious Disease Analysis, Department of Infectious Disease Epidemiology, Imperial College London, St Mary's Hospital, London, United Kingdom (Jeffrey W. Eaton, PhD)

<sup>3</sup> Strategic Information Department, The Joint United Nations Program on HIV/AIDS (UNAIDS), Geneva, Switzerland (Kimberly Marsh, PhD, Ian Wanyeki, MSc, Mary Mahy, ScD)

<sup>4</sup> Centre for Infectious Disease Epidemiology and Research, University of Cape Town, Cape Town, South Africa (Leigh F. Johnson, PhD)

<sup>5</sup> Global HIV, Hepatitis and Sexually Transmitted Infections Programme, World Health Organization, Geneva, Switzerland (Cheryl C. Johnson, MA)

<sup>6</sup> Department of Clinical Research, London School of Hygiene and Tropical Medicine, London, UK (Cheryl C. Johnson, MA)

<sup>7</sup> Programme national de lutte contre le Sida, Abidjan, Côte d'Ivoire (Eboi Ehui, PhD)

<sup>8</sup> Department for HIV and AIDS, Ministry of Health and Population, Lilongwe, Malawi (Andreas Jahn, PhD)

<sup>9</sup> Ministry of Health, Lilongwe, Malawi and I-TECH, Department of Global Health, University of Washington, Seattle, USA (Andreas Jahn, PhD)

<sup>10</sup> Conselho Nacional de Combate ao HIV/SIDA, Maputo, Mozambique (Francisco Mbofana, MPH)

<sup>11</sup> Conseil national de lutte contre le Sida et les infections sexuellement transmissibles (CNLS-IST), Ouagadougou, Burkina Faso (Fidèle Bakiono, PhD)

## Corresponding author:

Mathieu Maheu-Giroux

Department of Epidemiology, Biostatistics and Occupational Health | McGill University

Purvis Hall

1020 Pine Avenue West

Montreal, QC, Canada H3A 1A2

email: [mathieu.maheu-giroux@mcgill.ca](mailto:mathieu.maheu-giroux@mcgill.ca)

telephone: (+1) 514-398-5110

## 1 **Abstract**

2 **Background:** Knowledge of HIV status (KOS) among people living with HIV (PLHIV) is essential for  
3 an effective national HIV response. This study estimates progress and gaps in reaching the UNAIDS  
4 2020 target of 90% KOS, and the efficiency of HIV testing services (HTS) in sub-Saharan Africa (SSA),  
5 where two thirds of all PLHIV live.

6 **Methods:** We used data from 183 population-based surveys (N=2.7 million participants) and national  
7 HTS programs (N=315 country-years) from 40 countries as inputs into a mathematical model to examine  
8 trends in KOS among PLHIV, median time from HIV infection to diagnosis, HIV testing positivity, and  
9 proportion of new diagnoses among all positive tests, adjusting for retesting.

10 **Findings:** Across SSA, KOS steadily increased from 6% (95% credible interval [95%CrI]: 5% to 7%) in  
11 2000 to 84% (95%CrI: 82% to 86%) in 2020. Twelve countries and one region, Southern Africa, reached  
12 the 90% target. In 2020, KOS was lower among men (79%) than women (87%) across SSA. PLHIV aged  
13 15-24 years were the least likely to know their status (65%), but the largest gap in terms of absolute  
14 numbers was among men aged 35-49 years, with over 700,000 left undiagnosed. As KOS increased from  
15 2000 to 2020, the median time to diagnosis decreased from 10 to 3 years, HIV testing positivity declined  
16 from 9% to 3%, and the proportion of first-time diagnoses among all positive tests dropped from 89% to  
17 42%.

18 **Interpretation:** On the path towards the next UNAIDS target of 95% diagnostic coverage by 2030, and  
19 in a context of declining positivity and yield of first-time diagnoses, we need to focus on addressing  
20 disparities in KOS. Increasing KOS and treatment coverage among older men could be critical to reduce  
21 HIV incidence among women in SSA, and by extension, reducing mother-to-child transmission.

22

23

24

25

26

27 **Funding:** We acknowledge funding from the *Steinberg Fund for Interdisciplinary Global Health*  
28 *Research* (McGill University), the *Canadian Institutes of Health Research*, and the *Bill and Melinda*  
29 *Gates Foundation*. MMG holds a *Canada Research Chair* (Tier 2) in *Population Health Modeling*. KG  
30 was supported by a Postdoctoral Fellowship from the *Fonds the recherche du Québec – Santé*. JWE was  
31 supported by UNAIDS, the *Bill and Melinda Gates Foundation*, and the *UK Medical Research Council*  
32 (MR/R015600/1).

## 33 **Research in Context**

### 34 **Evidence before this study**

35 One of the major health policy objective of the last decade in the global HIV response has been the  
36 adoption of targets to end the AIDS epidemic by 2030. UNAIDS and its partners put forth in 2014 the  
37 90-90-90 objective to increase HIV diagnosis, treatment, and viral load suppression. They called for 90%  
38 of all people living with HIV to have knowledge of their HIV status (KOS) by 2020. There is clear  
39 evidence of increases in treatment coverage in sub-Saharan Africa (SSA), but little attention has been  
40 devoted to the “*first 90*” and trends in KOS have not been systematically reviewed and compared.

41 We searched PubMed from inception to March 2020 without language restriction with the terms  
42 “HIV”[Title/Abstract] AND (“test\*”[Title/Abstract] OR “diagnos\*”[Title/Abstract] OR  
43 “knowledge”[Title/Abstract]) AND (“Africa”[MeSH] OR “Africa”[Title/Abstract]), the websites from  
44 the *Joint United Nations Programme on HIV/AIDS* (UNAIDS), and the *World Health Organization* for  
45 HIV testing reports and guidelines. Several studies and reports present KOS estimates for selected  
46 countries but none comprehensively examined KOS trends by country, age, and sex, or provided  
47 estimates of HIV testing services (HTS) efficiency.

### 48 **Added value of this study**

49 Due to incomplete HIV surveillance data, and to non-disclosure of HIV positive status in most  
50 population-based surveys, assessment of KOS is challenging and not uniform in SSA. By triangulating  
51 household survey data about the proportion of adults ever tested for HIV and HTS program data on the  
52 total annual number of HIV tests performed among adults using a mathematical model of testing  
53 behaviors, this study is the first to systematically and comprehensively assess how KOS and HTS  
54 efficiency evolved in SSA over 20 years, and with stratification by sex, age, and region.

### 55 **Implications of the available evidence**

56 The last two decades witnessed remarkable increases in KOS across SSA, but stark sex, age, and regional  
57 disparities remain, even in countries that have met the 90% target overall. Concomitant decreases in  
58 median time to diagnosis, HIV testing positivity, and proportion of new diagnoses among all positive  
59 tests highlight one of the major challenges faced by testing programs – targeting of HTS to achieve  
60 greatest yield of new diagnoses as the undiagnosed population shrinks and diagnosis delays are reduced.  
61 With national HIV control programs now contemplating how to reach the next UNAIDS target of 95%

62 diagnostic coverage by 2030, there is a need to focus on addressing disparities in KOS and to better  
63 understand retesting patterns.

## 64 **Introduction**

65 Efficient and effective HIV testing services (HTS) are a key component to efforts to end the AIDS  
66 epidemic. A positive diagnosis enables people living with HIV (PLHIV) to receive life-saving  
67 antiretroviral therapy (ART)<sup>1</sup> and, for pregnant women living with HIV, risk of mother-to-child HIV  
68 transmission can be almost entirely prevented.<sup>2</sup> At the population level, early diagnosis and treatment  
69 could reduce incidence by dramatically lowering viremia such that those with a suppressed viral load are  
70 unable to contribute to onward transmission.<sup>3</sup> HTS also helps identify people who are vulnerable to HIV  
71 acquisition and link them to effective HIV prevention services (e.g., voluntary male medical  
72 circumcision, pre-exposure prophylaxis).<sup>4</sup>

73 In sub-Saharan Africa (SSA), where more than two-thirds of PLHIV reside,<sup>5</sup> HTS were initially provided  
74 through voluntary counselling and testing upon request in stand-alone sites.<sup>6</sup> As HIV treatment became  
75 more widely available, provider-initiated HIV testing and counselling emerged, expanding HIV testing  
76 services to all patients in health facilities. HTS was also integrated into antenatal care, which greatly  
77 increased testing coverage among pregnant and postpartum women.<sup>6</sup> Such facility-based services were  
78 gradually expanded and implementation of community-based services enabled underserved rural and  
79 marginalized key populations to be reached by HTS and treatment.<sup>7-9</sup> The development of new testing  
80 technologies and strategies — including point-of-care rapid diagnostic tests, self-testing, partner testing  
81 and home-based testing — provided opportunities to accelerate delivery of results and linkage to care.<sup>10</sup>

82 Recognizing the individual and population benefits of HIV testing and treatment, in 2014, the *Joint*  
83 *United Nations Program for HIV/AIDS* (UNAIDS) proposed ambitious targets to strengthen the HIV  
84 treatment and care cascade such that, by 2020, 90% of PLHIV know their status, 90% of those diagnosed  
85 receive ART, and 90% of those treated have a suppressed viral load; with each target increasing to 95%  
86 by 2030.<sup>11</sup> These targets are widely adopted globally, and have motivated shifts in the delivery of HTS,  
87 especially in SSA countries with the greatest epidemic burden. Countries monitor and report annually to  
88 UNAIDS their progress towards these targets.

89 However, the proportion of PLHIV who know their status is particularly challenging to monitor in SSA  
90 because neither the number of PLHIV, nor the number who are diagnosed, are directly counted. Estimates  
91 for PLHIV typically come from mathematical models synthesising HIV serosurvey and antenatal testing  
92 data — for example, the UNAIDS-supported Spectrum model.<sup>12</sup> Aggregate HTS data including the

93 number of HIV tests conducted and number of HIV diagnoses, are routinely collected, but reports are  
94 often not deduplicated and rates of retesting and re-diagnosis can be high.<sup>13,14</sup> Household surveys provide  
95 cross-sectional data about testing history by HIV status at intervals roughly every five years in most  
96 countries, but only a few surveys directly ask respondents if they are aware of their HIV status, a sensitive  
97 question that has high potential for non-disclosure.<sup>15-17</sup> These challenges are compounded by imprecise  
98 estimates for the number of new infections by age, sex and geographical area, and by incomplete  
99 ascertainment of mortality among the previously diagnosed and undiagnosed population.

100 Nearing the UNAIDS' interim 2020 target deadline, we sought to evaluate progress towards the 'first 90'  
101 HIV diagnosis target in SSA, describe the impact of HTS programs on knowledge of HIV positive status  
102 (KOS) and timeliness of HIV diagnosis over the 2000-2020 period, and identify remaining gaps in who  
103 is being reached by HTS. We synthesized data from 40 SSA countries about HIV testing history from  
104 population-based surveys, HTS program data, and HIV epidemic indicators using a validated  
105 mathematical model specifically designed to estimate KOS.<sup>13</sup> In addition to trends in KOS and diagnosis  
106 gaps, we estimated time from HIV infection to diagnosis, probability of getting tested within one year of  
107 infection or before reaching a CD4 cell count threshold lower than 350 CD4 cells per  $\mu\text{L}$ , positivity  
108 (proportion of HIV-positive tests among all tests), diagnosis yield (proportion of new diagnoses among  
109 all tests), and proportion of new diagnoses among positive tests.

## 110 **Methods**

### 111 **Overview**

112 We previously developed and validated a compartmental deterministic mathematical model (named  
113 *Shiny90*), to synthesize multiple data sources into a coherent framework to longitudinally estimate KOS.  
114 This model has been described in detail elsewhere.<sup>13</sup> Briefly, *Shiny90* models the transition of individuals  
115 aged  $\geq 15$  years between six stages: 1) HIV-susceptible who have never been tested, 2) HIV-susceptible  
116 ever tested, 3) PLHIV who have never been tested, 4) PLHIV unaware who have ever been tested, 5)  
117 PLHIV aware (not on ART), and 6) PLHIV on ART. Household surveys and HTS program data are used  
118 to estimate the rates of HIV testing among adults not living with HIV and those living with HIV, where  
119 HIV testing rates vary with calendar time, sex, age, previous HIV testing status, awareness of status, and,  
120 for PLHIV, CD4 cell count category (as a marker of risk of AIDS-related symptoms motivating care-  
121 seeking and HIV testing).<sup>13</sup> In this way, the proportion of PLHIV who know their status estimated by

122 *Shiny90* is bound by ART coverage (minimum) and the proportion of PLHIV who have ever been tested  
123 and received the results (maximum).

#### 124 **Data sources and model calibration**

125 *Shiny90* uses inputs for HIV incidence, mortality, and ART coverage estimated and reported by national  
126 governments using the UNAIDS-supported *Spectrum* modeling software and its *Estimation and*  
127 *Projection Package*.<sup>12</sup> The *Spectrum* model calculates epidemic statistics stratified by age, sex, CD4 cell  
128 count category, and ART status. Parameter estimates for HIV disease progression and mortality, as well  
129 as demographic rates, are also informed by *Spectrum*.

130 Two main data sources are used for estimation of HIV testing rates during model calibration:

131 1) The proportion of individuals ( $\geq 15$  years old) who self-report having ever been tested for  
132 HIV and received the result of the last HIV test from national household surveys conducted  
133 between 2000-2019. Estimates were stratified by sex, age (15-24, 25-34, and 35-49 years old), and,  
134 if available, HIV sero-status. Sources of national household surveys included *Demographic and*  
135 *Health Surveys* (DHS; <https://dhsprogram.com/Data/>), *AIDS Indicator Surveys* (AIS), *Multiple*  
136 *Indicator Cluster Surveys* (MICS; [www.mics.unicef.org/surveys](http://www.mics.unicef.org/surveys)), *Population-based HIV Impact*  
137 *Assessments* (PHIA; <https://phia-data.icap.columbia.edu/files>), and other country-specific surveys  
138 (Figure 1). The model was calibrated to data on the proportion ever tested for HIV, but we did not  
139 calibrate to self-reported awareness of status data, due to evidence of non-disclosure.<sup>15-17</sup>

140 2) Data on the total annual number of HIV tests performed among individuals aged  $\geq 15$  years  
141 and, where available, total number of positive HIV tests (2000-2019) reported by national HIV  
142 testing programs. HTS program data are particularly informative about changes in testing levels  
143 after the most recent available population-based survey.<sup>13</sup>

144 For the analyses reported here, we used the *Shiny90* country files submitted to UNAIDS in 2020  
145 ([www.unaids.org/en/dataanalysis/datatools/spectrum-epp](http://www.unaids.org/en/dataanalysis/datatools/spectrum-epp)), including *Spectrum*, surveys, and program  
146 data. Additional programme data sources are listed in appendix (pp 47-50).

147 Sub-saharan African countries with at least one available survey stratified by HIV sero-status, or  
148 countries with surveys not stratified by HIV sero-status but having at least one HTS program data set  
149 including total number of positive tests between 2000-2019 were included in analyses. These were the  
150 minimal set of survey and HTS program data that were required to calibrate the model for a given  
151 country. Countries with a population under 250,000 people, or without available survey data, or with



152 only survey data not stratified by HIV sero-status and no HTS program data between 2000-2019 were  
153 excluded from analyses.

154 For each country, the model estimates rates of HIV testing by sex, age, HIV status, and testing and  
155 treatment history were estimated from the household survey and HTS program data in a Bayesian  
156 framework. The mode of the posterior distribution was estimated via optimisation with the Broyden-  
157 Fletcher-Goldfarb-Shanno algorithm<sup>18</sup> and the posterior density was approximated via Laplace  
158 approximation around the posterior mode.<sup>13</sup> Conceptually, the HTS program data inform rates of HIV  
159 testing in the population, while changes in the proportion ever tested by HIV status, sex, and age,  
160 alongside estimates of HIV incidence and mortality, inform the proportion of tests conducted among  
161 those being HIV tested or diagnosed for the first time versus repeat testing.<sup>13</sup>

### 162 **Estimating knowledge of HIV status, positivity, and yield**

163 Using *Shiny90* we calculated annual (2000-2020) proportions of PLHIV with KOS (% of all PLHIV who  
164 have ever tested HIV-positive and are thus aware of their HIV status), positivity (% of all HIV tests that  
165 are positive), yield of new diagnoses (% of new diagnoses out of all HIV tests), and the proportion of  
166 new diagnoses out of all positive tests. For post-2019 model predictions, rates of HIV testing were  
167 assumed to remain constant at their 2019 values, but with amplified uncertainty guided by variation in  
168 historical testing rates. These projections were also guided by historical increases in ART coverage, with  
169 coverage achieved in 2020 extrapolated from the 2016-2019 rates of ART initiation. No adjustments  
170 were made for the possible impact of coronavirus disease 2019 (COVID-19) disruptions. All indicators  
171 can be stratified by sex and age group, and aggregated to regional level by weighting each country's  
172 indicator by the number of estimated PLHIV from *Spectrum* for that calendar year.

### 173 **Estimating time to diagnosis**

174 From the annual sex-, age-, HIV testing history-, and CD4 cell count-specific testing rates, we  
175 calculated several cross-sectional indicators using period life table methods<sup>19</sup> that account for the  
176 competing risk of AIDS-related death. These include: time from HIV infection to diagnosis, probability  
177 of getting tested within one year following infection and before reaching a CD4 count threshold lower  
178 than 350 cells per  $\mu\text{L}$ . These indicators were calculated annually by constructing individual period life  
179 tables for each of the 16 baseline strata of sex (men, women), age groups (15-24, 25-34, 35-49, and 50+  
180 years), and HIV testing history (never tested, ever tested). Because the estimates are from period life  
181 tables, they reflect the distribution of time to diagnosis if a person who seroconverted in a given year was  
182 to experience that year's HIV testing rates by age and CD4 category for their remaining lifetime. Details



183 of the calculations are presented as supplementary materials (appendix p 1). For each calendar year  
184 between 2000 and 2020, we estimated these indicators for the 16 age/sex/testing history strata separately.  
185 They were then aggregated to the desired demographic or geographic level (e.g., age, sex, country, region  
186 [Western, Central, Eastern, and Southern Africa]) by weighting each stratum by the estimated number of  
187 new HIV infections in that stratum for that year (obtained from *Spectrum*).

## 188 **Uncertainty**

189 We obtained uncertainty intervals by drawing 1,000 samples from the posterior distribution of the testing  
190 rates estimated by *Shiny90*. We summarized all indicators using the median, 2.5<sup>th</sup> and 97.5<sup>th</sup> percentile  
191 of their posterior distribution. We performed analyses using R version 3.5.1 and the Rcpp packages.<sup>20</sup>  
192 The code for *Shiny90* is available on a public repository ([www.github.com/mrc-ide/first90release](https://www.github.com/mrc-ide/first90release)). We  
193 followed the *Guidelines for Accurate and Transparent Health Estimates Reporting* (GATHER, appendix  
194 p 51).<sup>21</sup>

## 195 **Ethical approval**

196 All analyses were performed on anonymized and deidentified data. All DHS/AIS survey protocols have  
197 been approved by the Internal Review Board of ICF International in Calverton (USA) and by the relevant  
198 country authorities for other surveys (MICS and PHIA). Further information on the ethics approval can  
199 be found in the individual country reports. Ethics approval for secondary data analyses was obtained  
200 from McGill University's Faculty of Medicine Institutional Review Board (A10-E72-17B).

## 201 **Role of the Funding Source**

202 The funders of the study played no role in study design, data collection, data analysis, data interpretation,  
203 or writing of the report. The corresponding author had full access to all the data in the study and had final  
204 responsibility for the decision to submit for publication.

## 205 **Results**

206 A total of 40 countries, 183 population-based surveys (>2.7 millions surveyed individuals), and 315  
207 country-years of HTS program data reports informed our model (Figure 1). Four SSA countries (Cabo  
208 Verde, Central African Republic, Guinea-Bissau, Mauritius) were excluded from the analyses due to  
209 insufficient data inputs for model calibration, and one (Sao Tome and Principe), because of high

210 uncertainty in epidemic statistics for small population sizes (<250,000 people). Results of the *Shiny90*  
211 model calibration are presented in Text S2 (appendix pp 2-42).

212 Across SSA, the proportion of adults 15 years and older (both those living and not living with HIV)  
213 estimated to have been tested increased by 48 percentage points from 2000 to 2020 (Table 1). Testing  
214 coverage was highest in Southern Africa with 85% (95%CrI: 83 to 88%) of adults projected to have ever  
215 been tested in the region in 2020.

216 The proportion of adult PLHIV with KOS increased steadily from 5.7% (95%CrI: 4.6 to 7.0%) in 2000  
217 to 84% (95%CrI: 82 to 86%) in 2020 in SSA (Table 1). While KOS increased dramatically in all four  
218 SSA regions, KOS was consistently lower in Western and Central Africa as compared to Eastern and  
219 Southern Africa (Figure 2A; Figure S1: appendix p 43). Within the regions, national estimates were also  
220 highly heterogeneous, especially in Eastern Africa with a 77 percentage point difference between the  
221 countries with the lowest and highest KOS estimates. Overall, we projected that 12 countries (Figure 3)  
222 and one region, Southern Africa, will have reached at least 90% KOS in 2020. Countries with higher  
223 KOS tended to be those in which the annual number of tests relative to the total population aged  $\geq 15$   
224 years was highest (Figure S2: appendix p 44).

225 Our results also suggest disparities in KOS by sex and age. Across SSA in 2020, men had lower KOS  
226 (79%, 95%CrI: 76 to 81%) than women (87%, 95%CrI: 85 to 89%), and 15-24 year-olds were the least  
227 likely to know their status (65%, 95%CrI: 62 to 69%; Figure 2B-C, Table S4: appendix p 53). Such  
228 disparities were also observed among the 12 countries projected to achieve at least 90% of KOS overall  
229 in 2020. Of these countries, only six are projected to achieve 90% of KOS among men, and none are  
230 projected to do so among the 15-24 year-olds.

231 While the proportion of PLHIV aware of their status was lower among younger adults, the absolute  
232 number of PLHIV was also lower. Consequently, in absolute numbers, the largest group of undiagnosed  
233 PLHIV in SSA were men aged 35-49 years, with >700,000 left undiagnosed and 305,000 diagnoses  
234 needed to reach 90% awareness of status (Figure 4, Table S3: appendix p 52).

235 The median time from HIV infection to diagnosis (or death) decreased by 7 years from 2000 to 2020 for  
236 all of SSA (Table 1; Figure 5A). That is, if projected HIV testing rates in 2020 persisted into the future,  
237 50% of people infected in 2020 would be diagnosed (or, with small probability, suffer AIDS-related  
238 mortality) within 2.6 years of seroconverting. National trends are presented in Figure S3 (appendix p 45).

239 Consistent with the estimated decreases in median time to diagnosis, the probability of receiving an HIV  
240 test within 1 year following infection or before reaching a CD4 count threshold lower than 350 cells per

241  $\mu$ L increased respectively by 31 and 52 percentage points from 2000 to 2020 in SSA (Table 1; Figure  
242 5B-C).

243 The proportion of all HIV tests that are positive (positivity) decreased by 6 percentage points from 2000  
244 to 2020 (Table 1; Figure S4: appendix p 46), and the proportion of new diagnoses among all tests  
245 (diagnosis yield) decreased by 7 percentage points. Concomitantly, the proportion of new diagnoses  
246 among positive tests decreased by 47 percentage points over the study period (Table 1). That is, we  
247 project that 58% of PLHIV undergoing testing in 2020 will have been previously diagnosed with HIV.  
248 For each of the previous outcomes, five-yearly estimates are presented by sex and age stratification and  
249 by region in Tables S4 to S8 (appendix pp 53-57).

## 250 **Discussion**

251 Across SSA, impressive gains were achieved in KOS with 84% (95%CrI: 82 to 86%) of PLHIV being  
252 aware of their HIV positive status, and 12 countries and the region of Southern Africa that are projected  
253 to reach the 90% KOS target in 2020. Concomitant with these improvements, we estimated that median  
254 time from HIV acquisition to diagnosis would be reduced to 2.6 years (95%CrI: 1.8 to 3.5) over that  
255 period.

256 Despite this progress, our results highlight substantial regional, national, sex, and age disparities in KOS  
257 in SSA. KOS was consistently lower in Western and Central Africa than Eastern and Southern Africa.  
258 In those regions, HIV prevalence is lower but key populations — including sex workers, men who have  
259 sex with men, and people who inject drugs — account for a higher HIV burden. For example, they  
260 generally represent a small fraction of the population but accounted for 42% of all new HIV infections  
261 in 2019 in the region of Western and Central Africa.<sup>5</sup> Stigma and discrimination towards key populations  
262 are common in many health facilities, which may lead to delayed HIV testing, concealment of HIV  
263 positive status, and/or poor uptake of HIV services.<sup>22</sup> A recent systematic review and meta-analysis has  
264 shown that, among men who have sex with men in Africa, lower testing and KOS were associated with  
265 more hostile legislation, and that KOS remained low in the region.<sup>23</sup> To improve coverage of HIV health  
266 services in Western and Central Africa, antidiscrimination and protective laws to eliminate stigma and  
267 discrimination among key populations should be implemented and enforced, health workers trained and  
268 sensitized, and key population-friendly services provided.<sup>22</sup> Eastern Africa, despite having high KOS  
269 across the region, includes the two countries with the lowest KOS—South Sudan and Madagascar. While  
270 new HIV infections declined overall in Eastern African countries between 2010 and 2019, new infections  
271 in South Sudan and Madagascar are estimated to have increased by 17% and 191%, respectively.<sup>5</sup> This

272 underscores that reducing new HIV infections, ‘*turning off the tap*’ of undiagnosed PLHIV, is key to  
273 reaching KOS targets.

274 In all four SSA regions, and consistent with previous studies, men are less likely to know their HIV status  
275 compared to women.<sup>24-28</sup> Overall, the diagnosis gap is such that there is a 8% point difference between  
276 men and women in 2020. Large differences in KOS are also observed between age groups, with the  
277 lowest proportion diagnosed being among PLHIV aged 15-24 years. Importantly, all countries have yet  
278 to reach 90% KOS in this younger group. This gap between age groups is the natural consequence of  
279 HIV transmission dynamics. HIV incidence is highest and average time since infection is short — and  
280 thus cumulative exposure to testing is lower — in this age group compared to older ones.<sup>12</sup> To achieve  
281 90% KOS among 15-24 years-old would require a simultaneous increase in testing with greater  
282 investment in HIV prevention to increase coverage of high impact prevention interventions.

283 While we found that KOS was proportionally the lowest among men aged 15-24 years old, the largest  
284 group of undiagnosed PLHIV was men aged 35-49 years, with >700,000 projected to be undiagnosed in  
285 2020. Lower uptake of HIV testing among men may be explained by fewer opportunities for testing as  
286 well as other social and system-wide barriers such as harmful gender norms<sup>7,29</sup> and inaccessible or  
287 unfriendly services.<sup>30</sup> Engaging men in HIV prevention efforts is critically important, not only for their  
288 own needs, but also for their sexual partners. An increase in KOS and of treatment coverage among older  
289 men could be critical to reduce HIV acquisition rates among women, and by extension, reducing mother-  
290 to-child transmission. Among different testing approaches, community-based testing, door-to-door HTS,  
291 home-based couples testing, workplace programs, mobile testing services, social network interventions,  
292 incentives to test, self-testing, and partner notification have shown success in increasing diagnostic  
293 coverage among men.<sup>31</sup> As part of these efforts, facilitating linkage and retaining men with HIV care  
294 remains a key challenge for further progress towards HIV testing and treatment targets.

295 Despite improvements, especially in Southern Africa where the median time to diagnosis (or AIDS-  
296 death) was estimated at 1.5 years (95%CrI: 0.9 to 2.3) in 2020, we projected that across SSA and at  
297 current testing levels, 50% of PLHIV will not be diagnosed within 3 years following their infection, and  
298 29% will not get tested before reaching a CD4 count threshold lower than 350 cells per  $\mu\text{L}$  in 2020. These  
299 diagnostic delays impede rapid ART initiation at high CD4 counts which, in its absence, contribute to  
300 increased HIV morbidity and onward HIV transmission.<sup>1,32-34</sup> Reducing diagnostic delays on their own  
301 will likely not be enough to improve individual and population health outcomes. Earlier diagnosis should

302 be accompanied by rapid ART linkage and long-term adherence to ART — these are crucial to  
303 minimizing morbidity and reducing HIV incidence.<sup>32,33,35</sup>

304 As the undiagnosed population shrinks and diagnosis delays are reduced, targeting of HTS to achieve  
305 greatest yield of new diagnoses is one of the major challenges faced by testing programs.<sup>36</sup> Although we  
306 noted an ecological correlation between a country's testing volume with respect to its population of  
307 reproductive age and KOS, we also estimated a decline in positivity and in the yield of new diagnoses.  
308 Such declining yields are an inevitable consequence of reaching saturation in testing programs — as long  
309 as testing rates are lower in previously-diagnosed individuals than in undiagnosed, we can expect yields  
310 to decline as KOS increases. Our analyses also highlight substantial retesting of PLHIV already aware  
311 of their status. We projected that 58% of positive tests will be performed on previously diagnosed PLHIV  
312 in SSA in 2020. In previous studies conducted in SSA between 2004 and 2018, retesting among PLHIV  
313 with known HIV status was also common, ranging from 13% to 68%.<sup>14,37-41</sup> Retesting can be motivated  
314 by multiple factors, one of them being the ability to confirm the accuracy of the initial test result.<sup>41-43</sup>  
315 Another important driver of retesting may be avoiding disclosing prior knowledge of HIV positive status  
316 due to societal stigma or denial. A recent study conducted among persons undergoing HIV testing at a  
317 health facility in South Africa found that 50% of patients testing HIV-positive had previously been in  
318 HIV care (and hence previously diagnosed). Among these, half did not disclose prior knowledge of HIV  
319 status to their health care provider.<sup>14</sup> Further research is needed to assess the potential benefits of retesting  
320 for reengaging PLHIV in care.

321 This analysis has some limitations. First, *Shiny90* does not provide estimates of diagnosis coverage  
322 among <15 years-old, nor can it disaggregate metrics by key population groups. Second, we could have  
323 overestimated KOS in some low HIV prevalence countries where key populations are disproportionately  
324 affected by HIV if these groups are underrepresented in population-based surveys. Third, uncertainty in  
325 the PLHIV denominator, HIV incidence estimates, and ART coverage are not accounted for. This does  
326 not affect the validity of point estimates, but their precision could be overestimated. Fourth, we assumed  
327 that HIV testing does not result in false negative or false positive results. The assumption of no false  
328 negative HIV test result may have slightly over-estimated KOS and probability of getting tested within  
329 1 year or before reaching a CD4 count threshold lower than 350 cells per  $\mu\text{L}$ , and under-estimated median  
330 time to diagnosis or (AIDS-related death). The number of HIV diagnoses reported in HTS programme  
331 data could be inflated if WHO-recommended retesting to verify HIV diagnosis before ART initiation  
332 was incorrectly counted as separate HIV diagnoses, which our model would not be able to identify from  
333 routinely reported data. Fifth, we also assumed that self-reporting of HIV testing histories was accurate

334 but social desirability and recall biases could result in underestimation of the proportion ever tested and,  
335 ultimately, of KOS.<sup>44</sup> However, validation of self-reported HIV testing histories by mean of antiretroviral  
336 biomarkers data from PHIA surveys from eSwatini, Malawi, Tanzania, and Zambia using Bayesian latent  
337 class model suggest that, self-reported HIV testing history being highly sensitive, underestimation of the  
338 proportion ever tested and of KOS should be low (*Xia et al. preprint*).<sup>45</sup> Sixth, earlier estimates of  
339 diagnosis delays are informed by relatively few population-based survey estimates and HTS program  
340 data. Given the cross-sectional nature of these metrics, they could be more sensitive to the elicited  
341 model's prior distributions in early years. Finally, the impact of measures taken to prevent the spread of  
342 COVID-19 in some countries could have affected both HIV incidence and HTS.<sup>46</sup> Such unaccounted  
343 factors could potentially lead to slightly lower KOS estimates than those projected in 2020, although a  
344 notable decrease would be unlikely since already diagnosed PLHIV would remain so.

345 Although previous studies examined HIV testing uptake or self-reported KOS at community or country  
346 level, the present analysis is believed to be the first to systematically and comprehensively assess how  
347 HTS efficiency evolved in SSA over 20 years. By using a unified framework to compare HTS metrics,  
348 consistency and comparability of results between the different outcomes, countries, and regions is  
349 improved. A second strength is the large number of surveys and program data used for triangulation,  
350 improving the precision and robustness of our results. Third, in assessing time to diagnosis (or AIDS-  
351 related death) and other related metrics, we provide valuable information to help programs optimize HTS  
352 efficiency.<sup>47</sup> With clear individual and population-health benefits of early treatment initiation, reducing  
353 diagnostic delays and improving linkage to care will contribute towards the ultimate goal to end AIDS  
354 epidemics by 2030.

## 355 **Conclusion**

356 In 2014, the world adopted the goal of achieving 90% HIV diagnosis by 2020. Sub-Saharan Africa, the  
357 most affected region, is close to reaching this target and we project that 12 countries and one region,  
358 Southern Africa, will have reached that goal among adults in 2020. However, reaching 90% diagnosis  
359 coverage remains challenging and our results shed light on stark sex and age gaps in KOS. None of the  
360 12 countries projected to reach the 90% target overall are projected to do so in all age and sex groups.  
361 National HIV control programs are now contemplating how to reach the next UNAIDS target of 95%  
362 diagnostic coverage by 2030 in a context of declining positivity, declining yields of “true” new diagnoses,



363 and COVID-19 disruption. Reaching this objective will require a better understanding of retesting  
364 patterns and a focus on addressing disparities among older men and young people in KOS.

### 365 **Contributors**

366 JWE, KG, KM, LFJ, and MMG conceived the study. AJ, JWE, KM, LFJ, and MMG developed the  
367 mathematical model. KG performed the analyses. AJ, CCJ, EE, FB, FM, IW, KM, and MM contributed  
368 data and helped with result interpretation. KG and MMG wrote the initial draft. AJ, CCJ, EE, FB, FM,  
369 IW, KM, LFJ, MM, and IW provided expert input to inform background, context, and local  
370 epidemiology. All authors contributed to and approved the final manuscript.

### 371 **Declaration of interests**

372 We acknowledge funding from the *Steinberg Fund for Interdisciplinary Global Health Research* (McGill  
373 University), the *Canadian Institutes of Health Research*, and the *Bill and Melinda Gates Foundation*.  
374 MMG holds a *Canada Research Chair (Tier 2) in Population Health Modeling* and reports other from  
375 UNAIDS, other from WHO, grants from Gilead Sciences Inc., outside the submitted work; KG reports  
376 a Postdoctoral Fellowship from *Fonds de recherche du Québec – Santé*, during the conduct of the study;  
377 personal fees from UNAIDS, outside the submitted work; JWE reports grants from *Bill and Melinda*  
378 *Gates Foundation*, grants from UNAIDS, grants from UK Medical Research Council, during the conduct  
379 of the study; grants from NIH, grants from UNAIDS, grants from WHO, personal fees from WHO, grants  
380 from USAID, outside the submitted work; All other authors has nothing to disclose. The contents in this  
381 article are those of the authors and do not necessarily reflect the view of the *World Health Organization*.

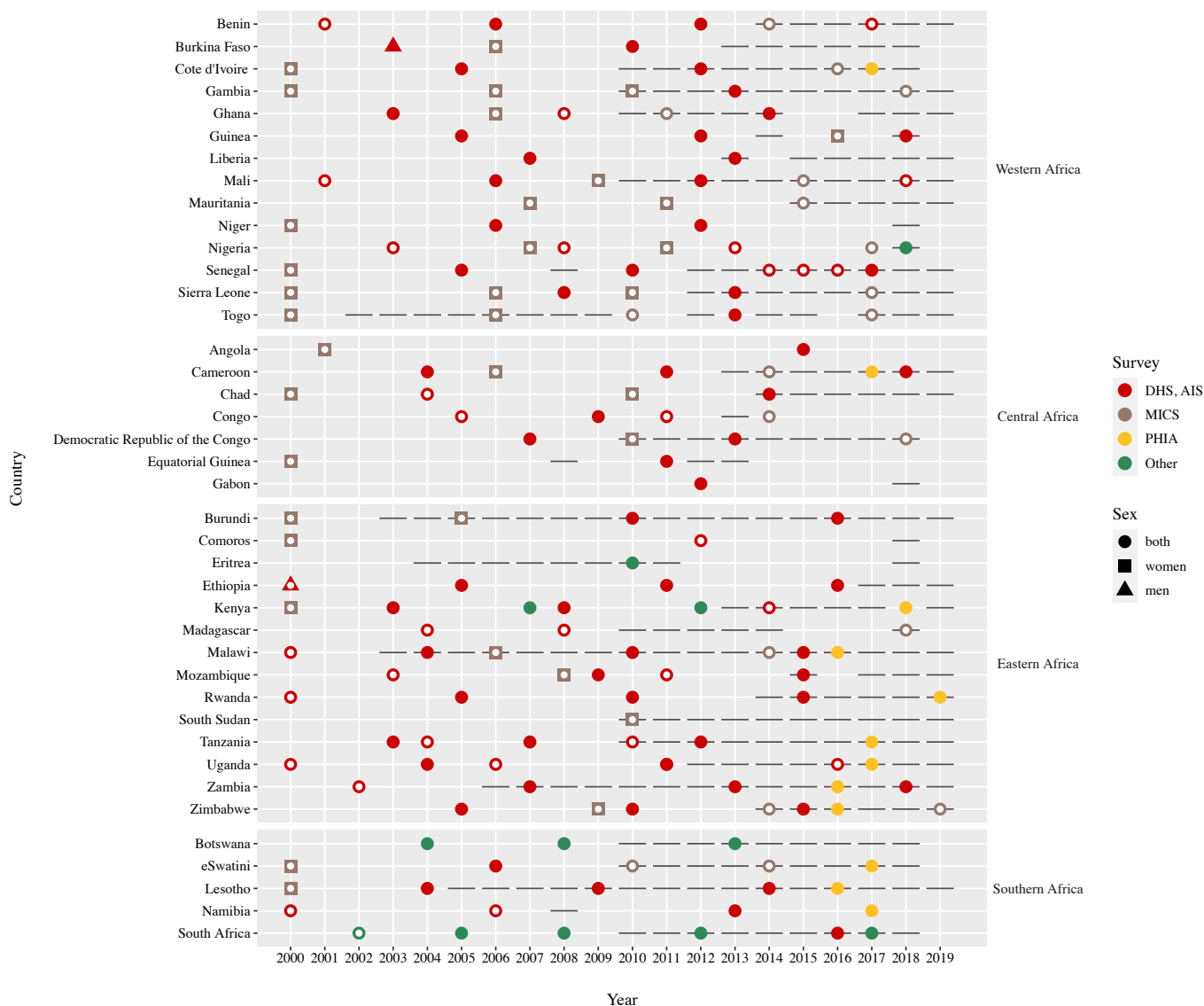


## References

1. Grinsztejn B, Hosseinipour MC, Ribaldo HJ, et al. Effects of early versus delayed initiation of antiretroviral treatment on clinical outcomes of HIV-1 infection: results from the phase 3 HPTN 052 randomised controlled trial. *Lancet Infect Dis* 2014; **14**: 281-90.
2. Tippett Barr BA, van Lettow M, van Oosterhout JJ, et al. National estimates and risk factors associated with early mother-to-child transmission of HIV after implementation of option B+: a cross-sectional analysis. *The Lancet HIV* 2018; **5**: e688-e95.
3. Cohen MS, Chen YQ, McCauley M, et al. Antiretroviral therapy for the prevention of HIV-1 transmission. *N Engl J Med* 2016; **375**: 830-9.
4. World Health Organization. Consolidated guidelines on HIV testing services. Geneva, Switzerland; 2015. Access Date:
5. UNAIDS. UNAIDS data 2020. Geneva, Switzerland; 2020. Available from: <https://www.unaids.org/en/resources/documents/2020/unaids-data>. Access Date: September 10, 2020
6. STAR Initiative, Unitaid, World Health Organization. Knowing your status - then and now: Realizing the potential of HIV self-testing. 2018. Available from: <https://unitaid.org/assets/STAR-Initiative-Report-Knowing-your-status%E2%80%93then-and-now.pdf>. Access Date: September 10, 2020
7. UNAIDS. Ending AIDS: Progress towards the 90-90-90 targets. Geneva, Switzerland; 2017. Available from: [https://www.unaids.org/en/resources/documents/2017/20170720\\_Global\\_AIDS\\_update\\_2017](https://www.unaids.org/en/resources/documents/2017/20170720_Global_AIDS_update_2017). Access Date: January 16, 2020
8. Suthar AB, Ford N, Bachanas PJ, et al. Towards universal voluntary HIV testing and counselling: a systematic review and meta-analysis of community-based approaches. *PLoS Med* 2013; **10**: e1001496.
9. Rodriguez-Garcia R, Bonnel R, Wilson D, N’Jie ND. Investing in communities achieves results: Findings from an evaluation of community responses to HIV and AIDS. Washington, D.C.: The World Bank; 2013.
10. Plate DK, Rapid HIV Test Evaluation Working Group. Evaluation and implementation of rapid HIV tests: the experience in 11 African countries. *AIDS Res Hum Retroviruses* 2007; **23**: 1491-8.
11. UNAIDS. Fast track: ending the AIDS epidemic by 2030. Geneva, Switzerland; 2014. Available from: [https://www.unaids.org/en/resources/documents/2014/fast\\_track](https://www.unaids.org/en/resources/documents/2014/fast_track). Access Date: January 16, 2020
12. Stover J, Glaubius R, Mofenson L, et al. Updates to the Spectrum/AIM model for estimating key HIV indicators at national and subnational levels. *AIDS* 2019; **33 Suppl 3**: S227-S34.
13. Maheu-Giroux M, Marsh K, Doyle C, et al. National HIV testing and diagnosis coverage in sub-Saharan Africa: a new modeling tool for estimating the “first 90” from program and survey data. *AIDS* 2019; **33**: S255–S69.
14. Jacob N, Rice B, Kalk E, et al. Utility of digitising point of care HIV test results to accurately measure, and improve performance towards, the UNAIDS 90-90-90 targets. *PLoS One* 2020; **15**: e0235471.
15. Fishel JD, Barrère B, Kishor S. Validity of data on self-reported HIV status and implications for measurement of ARV coverage in Malawi. Calverton, MD: ICF International; 2012. Access Date:
16. Kim AA, Mukui I, Young PW, et al. Undisclosed HIV infection and antiretroviral therapy use in the Kenya AIDS indicator survey 2012: relevance to national targets for HIV diagnosis and treatment. *AIDS* 2016; **30**: 2685-95.
17. Mooney AC, Campbell CK, Ratlhagana MJ, et al. Beyond social desirability bias: Investigating inconsistencies in self-reported HIV testing and treatment behaviors among HIV-positive adults in North West Province, South Africa. *AIDS Behav* 2018; **22**: 2368-79.

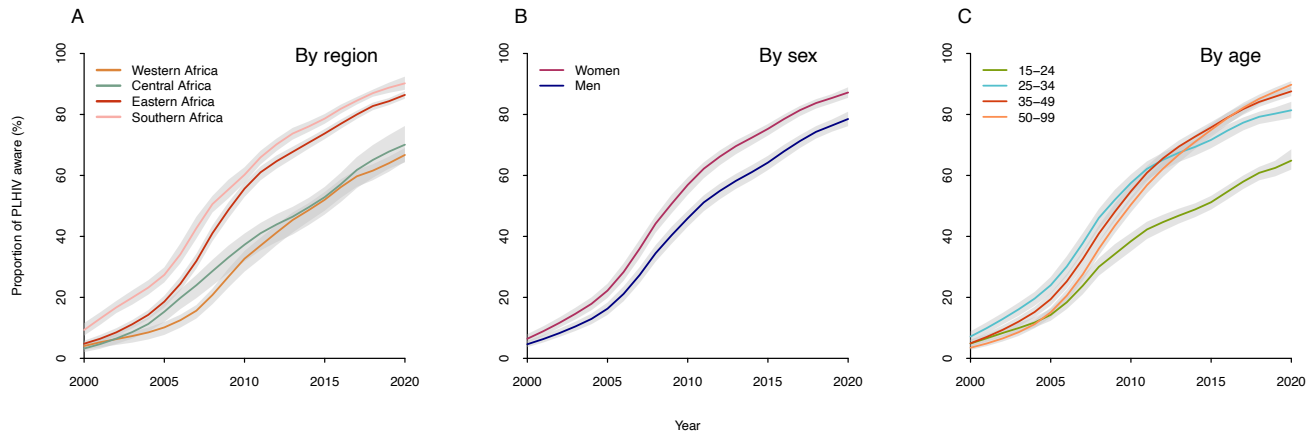
18. Nash J. Compact Numerical Methods for Computers - Linear algebra and function minimisation. . 2nd ed. Bristol, England: Adam Hilger; 1990.
19. Preston SH, Heuveline P, Guillot M. Demography: measuring and modeling population processes: Malden, MA: Balckwell Publishers; 2001.
20. Eddelbuettel D, Balamuta JJ. ExtendingRwith C++: A Brief Introduction to Rcpp. *The American Statistician* 2017; **72**: 28-36.
21. Stevens GA, Alkema L, Black RE, et al. Guidelines for Accurate and Transparent Health Estimates Reporting: the GATHER statement. *The Lancet* 2016; **388**: e19-e23.
22. World Health Organization. Consolidated guidelines on HIV prevention, diagnosis, treatment and care for key populations. Geneva, Switzerland; 2014. Access Date:
23. Stannah J, Dale E, Elmes J, et al. HIV testing and engagement with the HIV treatment cascade among men who have sex with men in Africa: a systematic review and meta-analysis. *The Lancet HIV* 2019; **6**: e769-e87.
24. Floyd S, Ayles H, Schaap A, et al. Towards 90-90: Findings after two years of the HPTN 071 (PopART) cluster-randomized trial of a universal testing-and-treatment intervention in Zambia. *PLoS One* 2018; **13**: e0197904.
25. Staveteig S, Croft TN, Kampa KT, Head SK. Reaching the 'first 90': Gaps in coverage of HIV testing among people living with HIV in 16 African countries. *PLoS One* 2017; **12**: e0186316.
26. Huerga H, Van Cutsem G, Ben Farhat J, et al. Progress towards the UNAIDS 90-90-90 goals by age and gender in a rural area of KwaZulu-Natal, South Africa: a household-based community cross-sectional survey. *BMC Public Health* 2018; **18**: 303.
27. Gaolathe T, Wirth KE, Holme MP, et al. Botswana's progress toward achieving the 2020 UNAIDS 90-90-90 antiretroviral therapy and virological suppression goals: a population-based survey. *The Lancet HIV* 2016; **3**: e221-e30.
28. Marsh K, Eaton JW, Mahy M, et al. Global, regional and country-level 90-90-90 estimates for 2018: assessing progress towards the 2020 target. *AIDS* 2019; **33 Suppl 3**: S213-S26.
29. World Health Organization. Global update on the health sector response to HIV, 2014. Geneva, Switzerland; 2014. Available from: [https://apps.who.int/iris/bitstream/handle/10665/128494/9789241507585\\_eng.pdf](https://apps.who.int/iris/bitstream/handle/10665/128494/9789241507585_eng.pdf). Access Date: January 16, 2020
30. Hawkes S, Buse K. Gender and global health: evidence, policy, and inconvenient truths. *Lancet* 2013; **381**: 1783-7.
31. Quinn C, Kadengye DT, Johnson CC, Baggaley R, Dalal S. Who are the missing men? Characterising men who never tested for HIV from population-based surveys in six sub-Saharan African countries. *J Int AIDS Soc* 2019; **22**: e25398.
32. Cohen MS, Chen YQ, McCauley M, et al. Prevention of HIV-1 infection with early antiretroviral therapy. *N Engl J Med* 2011; **365**: 493-505.
33. Insight Start Study Group. Initiation of antiretroviral therapy in early asymptomatic HIV infection. *N Engl J Med* 2015; **373**: 795-807.
34. TEMPRANO ANRS 12136 Study Group. A trial of early antiretrovirals and isoniazid preventive therapy in Africa. *N Engl J Med* 2015; **373**: 808-22.
35. Eaton JW, Johnson LF, Salomon JA, et al. HIV treatment as prevention: systematic comparison of mathematical models of the potential impact of antiretroviral therapy on HIV incidence in South Africa. *PLoS Med* 2012; **9**: e1001245.
36. World Health Organization. Global Health Sector Strategy on HIV, 2016-2021: Towards Ending AIDS. Geneva, Switzerland: World Health Organization; 2016. Access Date:
37. Angotti N, Bula A, Gaydosh L, Kimchi EZ, Thornton RL, Yeatman SE. Increasing the acceptability of HIV counseling and testing with three C's: convenience, confidentiality and credibility. *Soc Sci Med* 2009; **68**: 2263-70.

38. Franse CB, Kayigamba FR, Bakker MI, et al. Linkage to HIV care before and after the introduction of provider-initiated testing and counselling in six Rwandan health facilities. *AIDS Care* 2017; **29**: 326-34.
39. Fuente-Soro L, Lopez-Varela E, Augusto O, et al. Monitoring progress towards the first UNAIDS target: understanding the impact of people living with HIV who re-test during HIV-testing campaigns in rural Mozambique. *J Int AIDS Soc* 2018; **21**: e25095.
40. Moore HA, Metcalf CA, Cassidy T, et al. Investigating the addition of oral HIV self-tests among populations with high testing coverage - Do they add value? Lessons from a study in Khayelitsha, South Africa. *PLoS One* 2019; **14**: e0215454.
41. Kulkarni S, Tymejczyk O, Gadisa T, et al. "Testing, Testing": Multiple HIV-Positive Tests among Patients Initiating Antiretroviral Therapy in Ethiopia. *J Int Assoc Provid AIDS Care* 2017; **16**: 546-54.
42. Wringe A, Moshabela M, Nyamukapa C, et al. HIV testing experiences and their implications for patient engagement with HIV care and treatment on the eve of 'test and treat': findings from a multicountry qualitative study. *Sex Transm Infect* 2017; **93**.
43. Horter S, Thabede Z, Dlamini V, et al. "Life is so easy on ART, once you accept it": Acceptance, denial and linkage to HIV care in Shiselweni, Swaziland. *Soc Sci Med* 2017; **176**: 52-9.
44. Rentsch CT, Reniers G, Machemba R, et al. Non-disclosure of HIV testing history in population-based surveys: implications for estimating a UNAIDS 90-90-90 target. *Global Health Action* 2018; **11**.
45. Xia Y, Milwid RM, Godin A, et al. Accuracy of self-reported HIV testing history and awareness of HIV-positive status among people living with HIV in four Sub-Saharan African countries. [Preprint] 2020. Available from: <https://www.medrxiv.org/content/10.1101/2020.09.16.20196105v1>. Access Date: September 21, 2020
46. Jiang H, Zhou Y, Tang W. Maintaining HIV care during the COVID-19 pandemic. *The Lancet HIV* 2020; **7**: e308-e9.
47. Nash D, Robertson M. How to evolve the response to the global HIV epidemic with new metrics and targets based on pre-treatment CD4 counts. *Curr HIV/AIDS Rep* 2019; **16**: 304-13.



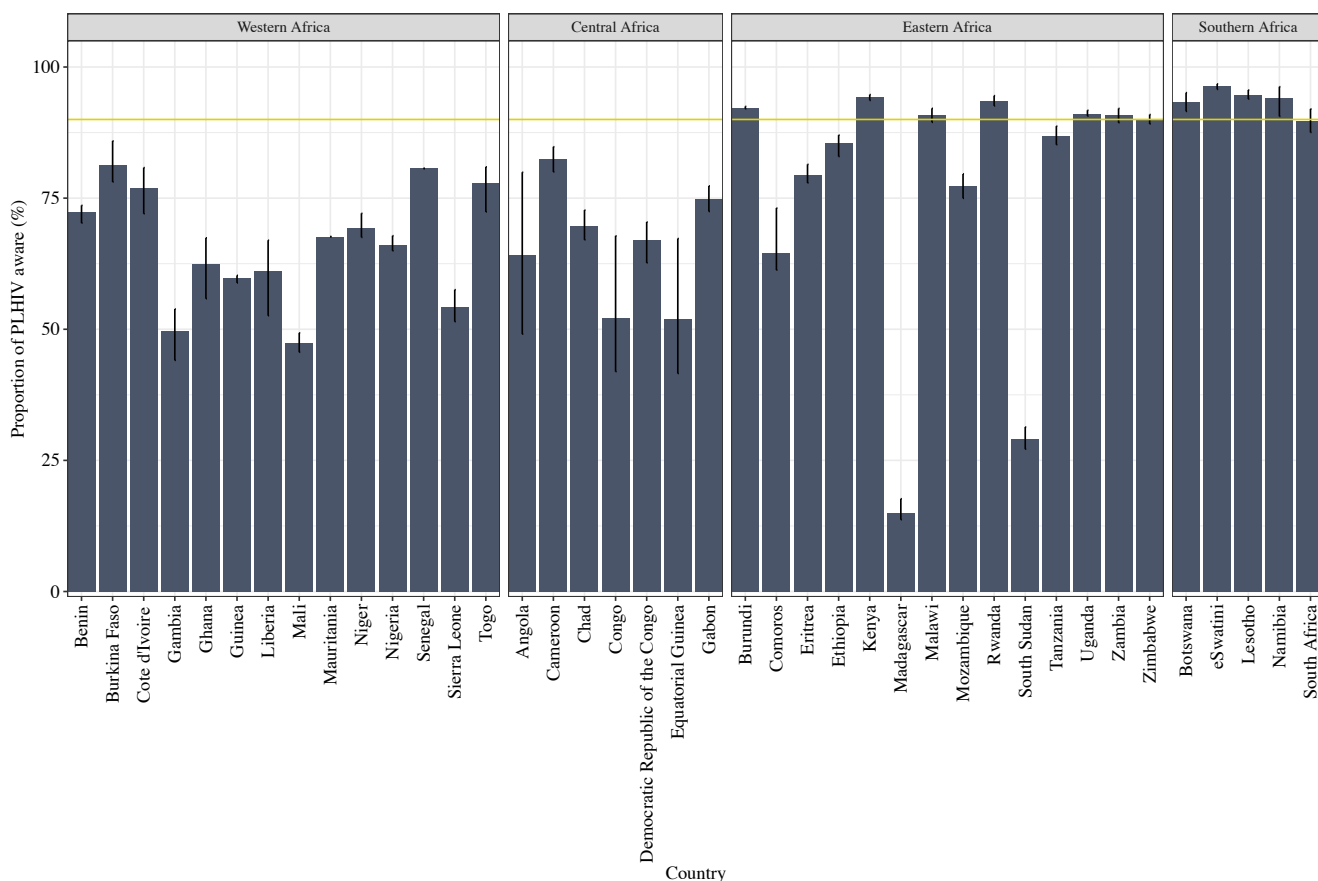
**Figure 1: Summary of included surveys and HIV testing services program data by country and year, 2000-2019**

Circles represent surveys that were conducted among both men and women, while squares and triangles represent surveys that were conducted among women or among men only, respectively. White dots indicate surveys where results on the proportion of individuals who self-report having ever been tested for HIV are not available by HIV status. Horizontal lines represent HIV testing services program data. DHS: Demographic Health Survey. AIS: AIDS Indicator Survey; MICS: Multiple Indicator Cluster Survey; PHIA: Population-based HIV Impact Assessment Survey. Other types of surveys include: Population Health Survey from Eritrea, South African National HIV Prevalence, Incidence, Behaviour and Communication Surveys, and Botswanan, Kenyan and Nigerian AIDS Indicator Surveys.



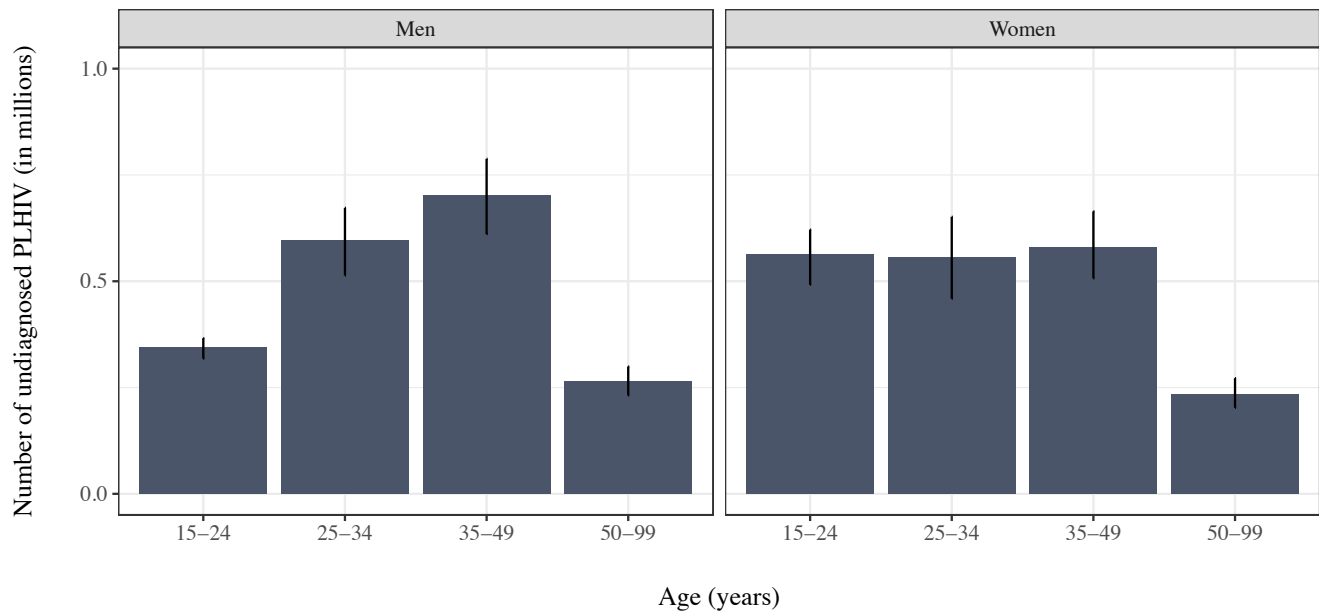
**Figure 2: Progress and disparities in knowledge of HIV status in sub-Saharan Africa, 2000-2020**

Panels A to C show trends in proportion of people living with HIV (PLHIV) who are aware of their HIV status in sub-Saharan Africa by region (A), by sex (B), or by age group (C). The shaded areas correspond to the 95% credible intervals.



**Figure 3: National estimates of knowledge of HIV status in sub-Saharan Africa, 2020**

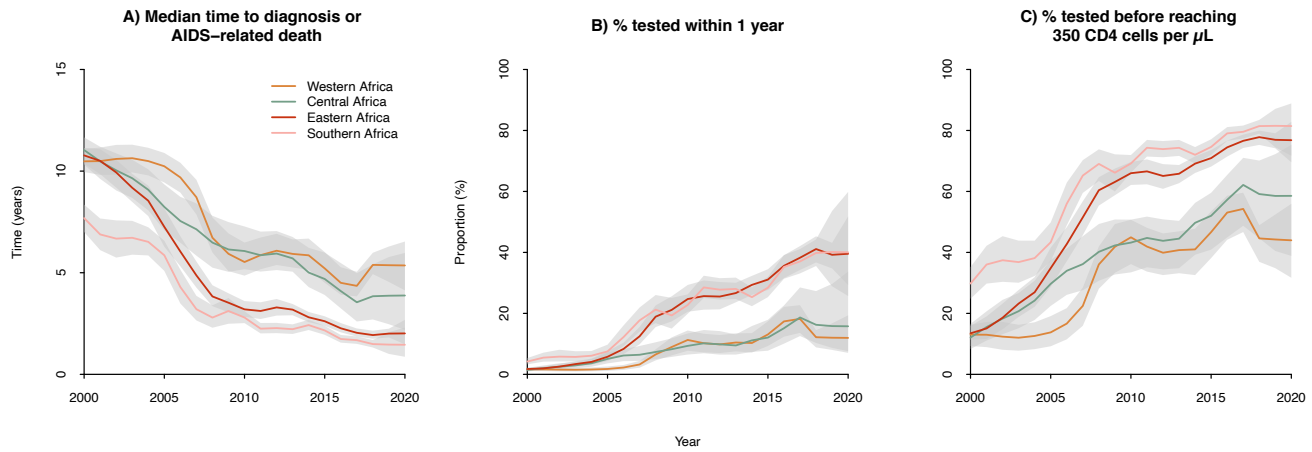
Proportion of PLHIV who know their HIV status. The horizontal yellow line represents a threshold of 90% and vertical lines correspond to the 95% credible intervals.



**Figure 4: Absolute diagnosis gaps in sub-Saharan Africa, 2020**

Each bar shows the total number of undiagnosed people living with HIV (PLHIV) by sex- and age-stratification. Vertical lines correspond to the 95% credible intervals.





**Figure 5: Progress in timeliness of HIV diagnosis in sub-Saharan Africa, 2000-2020**

Regional trends in median time to diagnosis or AIDS-related death (A), in the probability to get tested within one year (B) or before reaching a CD4 count threshold lower than 350 cells per  $\mu$ L (C) were assessed through period life-table analyses. The shaded areas correspond to the 95% credible intervals.

**Table 1: Regional progress in HIV testing related outcomes among adults 15 years and older in sub-Saharan Africa, 2000-2020**

Outcome	Year	Sub-Saharan Africa		Western Africa		Central Africa		Eastern Africa		Southern Africa	
Proportion of individuals (≥15 years old) ever tested for HIV among overall population (%)	2000	3.6	(3.0 to 4.4)	3.1	(2.6 to 3.8)	1.9	(1.3 to 2.6)	3.3	(2.8 to 3.9)	10	(8.3 to 13)
	2005	11	(10 to 12)	7.2	(6.6 to 7.8)	7.8	(6.6 to 9.2)	13	(12 to 14)	30	(29 to 32)
	2010	30	(29 to 32)	19	(18 to 19)	19	(17 to 22)	41	(39 to 42)	59	(58 to 61)
	2015	41	(40 to 42)	28	(27 to 29)	29	(28 to 30)	53	(52 to 54)	75	(74 to 75)
	2020	51	(49 to 54)	36	(34 to 39)	42	(39 to 48)	64	(62 to 66)	85	(83 to 88)
Proportion of PLHIV who know their HIV status (%)	2000	5.7	(4.6 to 7.0)	4.0	(2.8 to 5.2)	3.2	(2.0 to 4.6)	4.8	(4.0 to 5.8)	9.3	(7.5 to 12)
	2005	20	(18 to 22)	10	(7.7 to 12)	15	(12 to 18)	19	(17 to 21)	27	(25 to 30)
	2010	53	(50 to 55)	33	(28 to 35)	37	(32 to 41)	56	(53 to 58)	60	(58 to 63)
	2015	71	(69 to 73)	52	(48 to 55)	53	(47 to 56)	74	(72 to 75)	79	(77 to 80)
	2020	84	(82 to 86)	67	(65 to 69)	70	(64 to 76)	86	(85 to 88)	90	(88 to 92)
Time to diagnosis or AIDS-related death, median (year)	2000	9.6	(9.1 to 10)	11	(10 to 11)	11	(10 to 12)	11	(10 to 11)	7.7	(7.0 to 8.4)
	2005	7.2	(6.3 to 8.0)	10	(9.4 to 11)	8.2	(7.1 to 9.3)	7.3	(6.3 to 8.2)	5.9	(5.1 to 6.6)
	2010	3.6	(3.2 to 4.1)	5.5	(4.9 to 6.5)	6.1	(5.2 to 7.3)	3.2	(2.8 to 3.6)	2.8	(2.5 to 3.1)
	2015	3.0	(2.7 to 3.4)	5.2	(4.5 to 6.0)	4.7	(3.9 to 6.0)	2.6	(2.4 to 2.9)	2.2	(1.9 to 2.4)
	2020	2.6	(1.8 to 3.5)	5.4	(4.1 to 6.5)	3.9	(2.2 to 6.0)	2.0	(1.5 to 2.7)	1.5	(0.9 to 2.3)
Probability of getting tested within 1 year following infection (%)	2000	2.6	(2.1 to 3.3)	1.6	(1.1 to 2.1)	1.5	(1.0 to 2.1)	1.7	(1.4 to 2.1)	4.2	(3.3 to 5.3)
	2005	5.9	(4.5 to 7.7)	1.8	(1.1 to 2.6)	5.1	(3.6 to 7.1)	5.8	(4.4 to 7.6)	7.5	(5.8 to 9.7)
	2010	21	(18 to 25)	11	(7.7 to 14)	9.3	(6.5 to 13)	25	(21 to 29)	23	(20 to 26)
	2015	26	(23 to 30)	13	(9.3 to 17)	12	(7.8 to 18)	31	(28 to 35)	28	(25 to 32)
	2020	33	(23 to 46)	12	(7.0 to 19)	16	(7.6 to 34)	40	(29 to 52)	40	(26 to 60)
Probability of getting tested before reaching a CD4 count lower than 350 cells/μL (%)	2000	19	(16 to 23)	13	(9.3 to 16)	12	(8.3 to 17)	14	(11 to 16)	30	(25 to 35)
	2005	35	(29 to 42)	14	(9.2 to 19)	30	(22 to 38)	35	(29 to 42)	43	(37 to 50)
	2010	63	(58 to 66)	45	(36 to 51)	43	(34 to 51)	66	(62 to 70)	69	(66 to 72)
	2015	67	(63 to 70)	47	(38 to 53)	52	(41 to 60)	71	(68 to 74)	75	(72 to 77)
	2020	71	(62 to 79)	44	(32 to 56)	59	(39 to 75)	77	(70 to 83)	81	(72 to 89)
Positivity (% of positive tests among all tests)	2000	9.0	(7.7 to 10)	3.0	(2.1 to 3.5)	4.6	(3.5 to 5.2)	11	(9.6 to 12)	15	(13 to 19)
	2005	11	(9.2 to 14)	4.0	(3.3 to 4.5)	5.4	(4.2 to 6.7)	10	(9.1 to 12)	20	(16 to 26)
	2010	5.9	(4.3 to 8.3)	2.6	(2.0 to 3.2)	5.0	(3.6 to 6.9)	5.6	(4.2 to 7.5)	13	(9.0 to 22)
	2015	4.3	(3.5 to 5.2)	2.2	(1.7 to 2.7)	3.4	(2.4 to 4.7)	4.0	(3.5 to 4.6)	9.2	(7.1 to 13)
	2020	2.8	(2.1 to 3.9)	1.9	(1.3 to 2.7)	2.2	(1.4 to 3.3)	2.5	(1.9 to 3.3)	5.5	(3.8 to 8.4)
Diagnosis yield (% of new diagnoses among all tests)	2000	7.9	(7.0 to 8.6)	2.6	(1.8 to 2.9)	4.2	(3.2 to 4.7)	9.7	(8.8 to 11)	13	(12 to 14)
	2005	7.8	(7.0 to 8.4)	3.2	(2.7 to 3.6)	3.8	(3.1 to 4.3)	7.6	(7.0 to 8.1)	14	(12 to 15)
	2010	2.8	(2.4 to 3.3)	1.5	(1.2 to 1.7)	2.6	(2.1 to 3.0)	2.4	(2.1 to 2.9)	6.9	(6.2 to 7.5)
	2015	1.9	(1.7 to 2.1)	1.1	(0.9 to 1.3)	1.6	(1.2 to 1.8)	1.7	(1.6 to 1.8)	4.4	(4.1 to 4.6)
	2020	1.2	(0.9 to 1.5)	1.0	(0.7 to 1.5)	0.9	(0.6 to 1.3)	1.0	(0.8 to 1.3)	2.2	(1.6 to 2.9)
Proportion of new HIV diagnoses among all positive tests (%)	2000	89	(77 to 96)	86	(79 to 94)	93	(85 to 97)	91	(85 to 95)	87	(70 to 97)
	2005	72	(55 to 86)	79	(71 to 90)	71	(55 to 86)	74	(61 to 84)	70	(48 to 87)
	2010	48	(33 to 65)	56	(46 to 73)	52	(36 to 71)	44	(32 to 59)	53	(31 to 76)
	2015	44	(37 to 53)	48	(38 to 61)	46	(33 to 59)	42	(37 to 48)	47	(34 to 60)
	2020	42	(30 to 55)	52	(38 to 68)	42	(24 to 57)	41	(30 to 52)	39	(25 to 55)

PLHIV: people living with HIV, HTS: HIV testing services. Numbers in parentheses correspond to 95% credible intervals