Impact of differentiated service delivery models on 12-month retention in HIV treatment in Mozambique: an interrupted time-series analysis

Dorlim A Moiana Uetela, Orvalho Augusto, James P Hughes, Onei A Uetela, Eduardo Samo Gudo, Sérgio A Chicumbe, Aleny M Couto, Irénio A Gaspar, Diogo L Chavana, Sandra E Gaveta, Marita R Zimmermann, Sarah Gimbel, Kenneth Sherr

Lancet HIV 2023; 10: e674–83

See **Comment** page e628

For the Portuguese translation of the abstract see Online for appendix 1

Instituto Nacional de Saúde, Marracuene, Mozambique (D A Moiana Uetela PhD, E Samo Gudo PhD, S A Chicumbe PhD, D L Chavana BSc, S E Gaveta MD); **Department of Global Health** (D A Moiana Uetela, O Augusto MD, O A Uetela MD, K Sherr PhD, S Gimbel PhD), **School of Public Health–Biostatistics** (Prof J P Hughes PhD), **The Comparative Health Outcomes, Policy, and Economics Institute** (M R Zimmermann PhD), **Department of Child, Family and Population Health Nursing** (S Gimbel), **Department of Epidemiology** (K Sherr), **and Department of Industrial and Systems Engineering** (K Sherr), **University of Washington, Seattle, WA, USA; Universidade Eduardo Mondlane, Maputo, Mozambique** (O Augusto); **National STI and HIV/AIDS Control Program, Ministry of Health, Maputo, Mozambique** (A M Couto MD, I A Gaspar MD)

Correspondence to: Dr Dorlim A Moiana Uetela, Instituto Nacional de Saúde, Marracuene, Mozambique **dorlim.moiana@ins.gov.mz**

Summary

Background HIV treatment has been available in Mozambique since 2004, but coverage of, and retention in, antiretroviral therapy (ART) remain suboptimal. Therefore, to increase health system efficiency and reduce HIV-associated mortality, in November, 2018, the Ministry of Health launched national guidelines on implementing eight differentiated service delivery models (DSDMs) for HIV treatment. We assessed the effect of this implementation on retention in ART 12 months after initiation, and explored the associated effects of COVID-19.

Methods In this uncontrolled interrupted time-series analysis, data were extracted from the Mozambique ART database, which contains data on individuals in ART care from 1455 health facilities providing ART in Mozambique. We included individual-level data from facilities that were providing ART at the beginning of the study period (Jan 1, 2016) and at the start of DSDM implementation (Dec 1, 2018). We compared the proportion of individuals retained in ART 12 months after initiation between the periods before (Jan 1, 2017, to Nov 30, 2018) and after (Dec 1, 2019, to June 30, 2021) implementation of the DSDMs, overall and stratified by sex and age. We applied a generalised estimating equation model with a working independence correlation and cluster-robust standard errors to account for clustering at the facility level. In a secondary analysis, we assessed the effect of COVID-19 response measures during the post-intervention period on ART retention.

Findings The study included 613 facilities and 1 131 118 individuals who started ART during the inclusion period up to June 30, 2020, of whom 79 178 (7·0%) were children (age ≤14 years), 226 224 (20·0%) were adolescents and young adults (age 15–24 years), and 825 716 (73·0%) were adults (age ≥25 years). 731 623 (64·7%) were female and 399 495 (35·3%) were male. Introduction of the DSDMs was associated with an estimated increase of 24·5 percentage points (95% CI 21·1 to 28·0) in 12-month ART retention by the end of the study period, compared with the counterfactual scenario without DSDM implementation. By age, the smallest effect was estimated in children (6·1 percentage points, 1·3 to 10·9) and the largest effect in adolescents and young adults (28·8 percentage points, 24·2 to 33·4); by sex, a larger effect was estimated in males (29·7 percentage points, 25·6 to 33·7). Our analysis showed that COVID-19 had an overall negative effect on 12-month retention in ART compared with a counterfactual scenario based on the post-intervention period without COVID-19 (–10·0 percentage points, –18·2 to –1·8).

Interpretation The implementation of eight DSDMs for HIV treatment had a positive impact on 12-month retention in ART. COVID-19 negatively influenced this outcome.

Funding None.

Copyright © 2023 Elsevier Ltd. All rights reserved.

Introduction

In 2015, 13·2% of adults in Mozambique were living with HIV.[1] Antiretroviral therapy (ART) has been available since 2004, but both coverage and retention have been suboptimal.[2,3] In 2016, Mozambique adopted the then UNAIDS 90-90-90 targets for 2020 (90% of people living with HIV diagnosed, 90% of those diagnosed on treatment, and 90% of those on treatment virologically suppressed), and the WHO test and treat strategy (initiation of ART for all, regardless of CD4 cell count), which overburdened the already limited capacity of the health system.[4,5]

For more on **DSDMs** see https://www.differentiatedservicedelivery.org/getting-started/

WHO recommends differentiated service delivery models (DSDMs) for HIV treatment[6] and their use has grown in the past decade. In November, 2018, the Mozambique Ministry of Health (MISAU) decided on the nationwide implementation of eight DSDMs for HIV treatment,[7] which had been piloted individually and implemented at smaller scales.[3] DSDMs are client-centred and focus on simplifying and adapting HIV services to better serve individual needs and reduce unnecessary burdens on the health system.

The eight DSDMs to have been implemented in Mozambique are: (1) adherence clubs, (2) community ART groups, (3) family approach, (4) fast-track, (5) one-stop shop for adolescent-friendly health services, (6) one-stop shop for maternal and child health services, (7) one-stop shop for

Research in context

Evidence before this study

WHO recommends differentiated service delivery models (DSDMs) for HIV treatment and their use has grown in the past decade. On Sep 15, 2019, when we designed this study, a PubMed search of English language articles published from database inception, using the search terms "HIV" AND "differentiated service delivery" AND "treatment", yielded 15 articles. Two of these articles discussed the effectiveness of DSDMs (a review and a commentary on the monitoring and evaluation of DSDM implementation). Additional articles were identified by manually searching the reference list of the review article. However, articles were not easily identified by our search terms, because studies focused on individual models and identified them by name and not as DSDMs. The most commonly studied models were community antiretroviral therapy groups and adherence clubs. More recently, DSDMs have been used extensively in sub-Saharan Africa and the body of literature is growing, but to our knowledge, evidence of their effectiveness remains limited. Due to previous studies focusing on different models and contexts and having inconsistent designs and outcomes, it has been difficult to assess the overall impact of the DSDMs, as a package of services, on service and client outcomes.

Added value of this study

To our knowledge, this study is the first evaluation of the effectiveness of all DSDMs being implemented in a country at the national level. Previous studies in Mozambique and other countries compared outcomes (typically retention in ART or viral suppression) among individuals enrolled in specific DSDMs and those not enrolled in DSDM. We compared 12-month retention in ART between the periods before (pre-intervention) and after (post-intervention) the implementation of eight DSDMs in Mozambique, with the post-intervention period including a combination of DSDMs along with the conventional services offered in the pre-intervention period. This approach enabled us to measure the impact both for people enrolled in DSDMs and for those not enrolled, thus generating evidence on the impact for all individuals receiving HIV treatment regardless of their enrolment in DSDMs.

Implications of all the available evidence

Findings from this study suggest that DSDMs are effective in improving retention in ART for all individuals receiving HIV treatment, regardless of whether they are enrolled in DSDMs. The results support the hypothesis that DSDMs are beneficial for both the health system and the people enrolled in HIV treatment, by optimising efficiencies in HIV services through reducing unnecessary visits and redirecting resources to those who need them the most.

tuberculosis services, and (8) 3-month antiretrovirals dispensing (table 1).[7,8] These models aim to reduce unnecessary visits for people enrolled in DSDMs by reducing visit frequency for individuals established on ART, integrate services for people not established on ART, and redirect resources to those who need them the most. These models have been expected to lead to a reduction in provider workload, resulting in increased time to dedicate to individuals who need the greatest attention, and increased client satisfaction and retention in ART, which will lead to viral suppression and, ultimately, decreased associated mortality.[7]

In the past decade, DSDMs have been used extensively in sub-Saharan Africa. The popularity of DSDMs increased during the COVID-19 pandemic, when innovative approaches were urgently needed to limit health facility visits and to deliver antiretrovirals in the community for those unable to pick them up at health facilities.[9–11]

As the use of DSDMs increases, evidence of their effectiveness is also growing. However, assessing the overall impact of DSDMs on the basis of previous studies is difficult, because of inconsistencies in study designs, outcomes, and comparison groups.[12] In general, studies have focused on a specific model, used the outcomes of retention in care and viral suppression, and reported model effectiveness to be equivalent to or better than conventional care.[13–15] To our knowledge, the effect of DSDMs at the national level for all individuals enrolled in ART, regardless of their enrolment in DSDMs, has not been studied previously.

In this study, our primary aim was to measure the effect of the DSDMs in Mozambique on retention in treatment 12 months after ART initiation, and our secondary aim was to explore the effect of COVID-19 on this outcome.

Methods

Study design

We used an uncontrolled interrupted time-series design to compare the outcome (the proportion of individuals retained in ART 12 months after initiation) before and after the nationwide implementation of the eight DSDMs (table 1). The package of service delivery in the pre-intervention period was the conventional model of care, consisting of individual one per month scheduled appointments for clinical observation and medication prescription and dispensation, and in the post-intervention period it was a combination of the conventional model (for individuals ineligible or unwilling to enrol in DSDMs) and the eight DSDMs. A 12-month roll-out period between the pre-intervention and post-intervention periods was included to account for the lag for the outcome to be observed.

For both primary and secondary aims, the pre-intervention period for DSDMs (considering the dates of

	Who (service provider)	When (frequency)	Where (place)
Adherence clubs, managed by health-care workers (group size 15–30)*			
ART adherence support	Counsellor, peer educator, or community health worker	Quarterly	Selected space in health facility
Clinical observation	Nurse	Twice a year	Selected space in health facility
ART dispensing	Nurse	Monthly or quarterly	Selected space in health facility
Sample collection for laboratory tests	Nurse	Twice a year	Selected space in health facility
Community ART groups, managed by clients (group size 3–6)†			
Peer support	Client	Monthly	Community
Clinical observation	Clinician	Variable	Observation room
ART dispensing	Pharmacist or pharmacy technician	Monthly	Pharmacy
Sample collection for laboratory tests	Laboratory technician	Twice a year	Laboratory
Family-approach, managed by health-care workers (group size varies)‡			
Clinical observation	Clinician	Variable	Observation room
ART dispensing	Pharmacist or pharmacy technician	Monthly	Pharmacy
Sample collection for laboratory tests	Laboratory technician	Twice a year	Laboratory
Fast-track (individual)§			
Clinical observation	Clinician	Twice a year	Observation room
ART dispensing	Pharmacist or pharmacy technician	Monthly or quarterly	Pharmacy
Sample collection for laboratory tests	Laboratory technician	Twice a year	Laboratory
OSS for AFHS (individual)¶			
ART adherence support	Counsellor, peer educator, or nurse	Quarterly	AFHS sector in health facility
Clinical observation	AFHS nurse	Monthly or twice a year	AFHS sector in health facility
ART dispensing	AFHS nurse	Monthly or twice a year	AFHS sector in health facility
Sample collection for laboratory tests	AFHS nurse	Twice a year	AFHS sector in health facility
OSS for MCH services (individual)||			
Clinical observation	MCH nurse	Monthly	MCH sector in the health facility
ART dispensing	MCH nurse	Monthly	MCH sector in the health facility
Sample collection for laboratory tests	MCH nurse	Monthly	MCH sector in the health facility
OSS for tuberculosis services (individual)||			
Clinical observation	Tuberculosis sector nurse	Monthly	Tuberculosis sector in the health facility
ART dispensing	Tuberculosis sector nurse	Monthly	Tuberculosis sector in the health facility
Sample collection for laboratory tests	Tuberculosis sector nurse	Twice a year	Tuberculosis sector in the health facility
3MMD (individual)**			
ART pick-up	Pharmacist or pharmacy technician	Quarterly	Pharmacy

AFHS=adolescent-friendly health services. ART=antiretroviral therapy. MCH=maternal and child health. OSS=one-stop shop. 3MMD=3-month antiretrovirals dispensing. *Requires additional staff for activities coordination and implementation; ART dispensing depends on stock in health facility. †Requires additional staff for coordination and implementation; group members take turns visiting health facility for clinical observation; all members must be observed and have laboratory tests done at least twice a year; ART for all group members dispensed monthly to member who visits the health facility. ‡All family members' appointments scheduled for same day; visits take place monthly, quarterly, or twice-yearly depending on presence and age of children and clinical condition of all family members. §Can be implemented in isolation or combined with 3MMD; ART dispensed monthly in health facilities unless combined with 3MMD. ¶Clinical observation depends on client's needs; ART dispensing depends on stock in the health facility. ||All HIV services provided by nurses. **Only in combination with fast-track.

Table 1: **Summary of eight differentiated service delivery models for HIV treatment implemented in Mozambique**

the outcome measurement) was from Jan 1, 2017, to Nov 30, 2018, and the roll-out period was from Dec 1, 2018, to Nov 30, 2019. For the primary analysis, the post-intervention period was from Dec 1, 2019, to June 30, 2021. For the secondary analysis of the effect of COVID-19 on the outcome, the post-intervention period included the period without COVID-19 from Dec 1, 2019, to March 31, 2020, and the period with COVID-19 from April 1, 2020 (beginning of the COVID-19 response measures in Mozambique) to June 30, 2021.

This work was approved by the Mozambique National Ethics Committee (Maputo, Mozambique; reference number 634/CNBS/20) and the University of Washington Institutional Review Board (Seattle, WA, USA; reference number FWA#00006878).

Data and procedures

Client data (sex [extracted from medical records and assigned at birth], age, dates of ART initiation, follow-up visits, medication pick-up, and treatment status) were extracted from the Mozambique ART database (MozART), which is a facility-level electronic tracking system containing individual data for individuals enrolled in HIV treatment.[16] MozART data are available for individuals on ART starting from 2012; however, in the main analysis we only included data from facilities providing ART from Jan 1, 2016 onwards, when the WHO test and treat strategy was introduced, to ensure comparable pre-intervention and post-intervention periods in terms of conventional treatment delivery other than DSDMs implementation. Additionally, we only included facilities that were providing ART at the start of DSDM implementation (Dec 1, 2018). Power calculations are presented in appendix 2 (p 1). The inclusion criteria (for the primary analysis) is health facilities using the electronic tracking system that feeds MozART and offering ART in the beginning of the study period in January, 2016. MISAU provided administrative approval to use client data (reference number 1984/GMS/002/2020); client informed consent was not required by The Mozambique National Ethics Committee as the study is a secondary analysis of routine programme data without any identifying information.

We constructed client cohorts on the basis of ART initiation month, from Jan 1, 2016, to June 30, 2020. For the primary outcome, in accordance with national guidelines, we defined clients as retained in ART if, after 12 months of ART initiation, they had not stopped treatment and were not deceased, transferred to another health facility, or lost to follow-up (ie, had not missed a clinical or antiretroviral refill visit up to and including the last scheduled visit before the end of the 12-month period).[17] A missed visit status was assigned if a client did not have contact with the health facility during a 60-day window around each visit (ie, they were at least 60 days late for a clinical visit or refill; 60 days is the period used in MISAU guidelines[18]); we did not account for clients who sought care at a new facility without filing formal transfer documentation (ie, silent transfers, treated as lost to follow-up). If the 60-day window around the last scheduled visit before the censor date for the 12-month period was not completed, the previous visit was considered to ascertain the outcome. The status deceased, transferred out, and stopped treatment were retrieved from the database.

Statistical analysis

We used descriptive statistics to summarise client demographics during the study period. For the primary and secondary analyses, we used segmented regression by fitting a generalised estimating equation (GEE) model with an independence working correlation structure and cluster-robust standard errors to account for clustering at the health facility level and for possible informative cluster size.[19,20] For the primary analysis, we assumed a change in the slope from the pre-intervention period to the roll-out period and from the roll-out period to the post-intervention period, and no immediate level change between pre-intervention and roll-out periods, but an immediate level change between the roll-out and post-intervention periods. In addition, for the secondary analysis, we assumed a slope change and an immediate level change between the post-intervention period without COVID-19 and the post-intervention period with COVID-19. Models for the primary analysis (model 1) and secondary analysis (model 2) were fitted as follows:

$$\text{Model 1: } \pi_{iht}=\beta_0+\beta_1\times(\text{time})+\beta_2\times(\text{time since roll-out}) +\beta_3\times(\text{DSDM})+\beta_4\times(\text{time since DSDM})$$

See Online for appendix 2

$$\text{Model 2: } \pi_{iht}=\beta_0+\beta_1\times(\text{time})+\beta_2\times(\text{time since roll-out}) +\beta_3\times(\text{DSDM})+\beta_4\times(\text{time since DSDM}) +\beta_5\times(\text{COVID-19})+\beta_6\times(\text{time since COVID-19})$$

In these models, π_{iht} is the proportion of individuals (i) with 12-month retention in ART at a health facility (h) at a given time (t); "time" is a continuous variable for time of outcome measurement in months starting from January, 2017; "time since roll-out" is a continuous variable for time in months with values starting from December, 2018 (beginning of the roll-out period) and a value of zero before that; "DSDM" is a dummy variable with a value of one during the implementation of DSDMs and zero before that; "time since DSDM" is a continuous variable for time in months with values starting from December, 2019 (beginning of the post-intervention period) and a value of zero before that; "COVID-19" is a dummy variable with a value of 1 during the period of the COVID-19 response measures and zero before that; "time since COVID-19" is a continuous variable for time in months with values starting from April, 2021 (beginning of the COVID-19 response measures in Mozambique) and a value of zero before that; β_0 is the estimated baseline 12-month retention in Jan 1, 2017; β_1 is the estimated monthly change (ie, the average change per month during the period, or the trend) in retention before DSDMs; β_2 is the estimated monthly change in retention during roll-out, compared with the trend in the pre-intervention period; β_3 is the estimated immediate change in level in retention from the roll-out period to post-DSDM period; β_4 is the estimated monthly change in retention in the post-intervention period, compared with the trend in the roll-out period; β_5 is the estimated immediate change in retention from the pre-COVID-19 period to the COVID-19 period; and β_6 is the estimated monthly change in retention during the post-intervention period with COVID-19, compared with the trend in the post-intervention period without COVID-19. The post-intervention trend in retention was estimated by adding the coefficients associated with time before intervention, time during roll-out, and time after intervention (ie, the sum of β_1, β_2, and β_4). The post-COVID-19 trend in retention was estimated by adding the coefficients associated with time before intervention, time during roll-out, time post-intervention without COVID-19, and time post-intervention with COVID-19 (ie, the sum of β_1, β_2, β_4, and β_6).

Given that we used an interrupted time-series design, the effect of the DSDMs was calculated as the percentage point difference between the estimated 12-month retention that was based on the modelled trend from the data, and the estimated 12-month retention that was based on the counterfactual trend, at the end of the study period, as recommended for time-series analysis.[21,22] We defined the counterfactual trend as the expected trend if the DSDMs had not been implemented, as: $\pi_{iht}=\beta_0+\beta_1\times(\text{time})$. 95% CIs were obtained on the basis of robust standard errors of the regression parameters. For linear combination of the coefficients the delta method was used to derive standard errors.

For the primary analysis we included sex and age groups (children, age 0–14 years; adolescents and young adults, age 15–24 years; and adults, age ≥25 years) as effect modifiers. These age categories were used in accordance with the country's age categorisation for HIV reporting.[1,2] We first added these variables as interaction terms in the main model and then stratified all the data by sex, and all the data by age.

We conducted sensitivity analyses exploring: the behaviour of the pre-intervention trend in 12-month ART retention, comparing the trend for individuals who started ART in the period before (Jan 1, 2012 to Dec 31, 2015) and after (Jan 1, 2016 to Nov 30, 2018) introduction of the test and treat strategy; modelled trends based on individuals who started ART since Jan 1, 2012; and a constant counterfactual trend at the level of the last measurement of retention (ie, the retention rate in the last month before DSDMs) in the pre-intervention period, using data for individuals starting ART from Jan 1, 2016 onwards.

All analyses were done with R statistical software (version 4.2). We considered statistical significance to be a p value of less than 0·05.

Role of the funding source

There was no funding source for this study.

Results

On Dec 1, 2018 (when DSDM implementation began), MozART contained data for 742 (51·0%) of the 1455 health facilities providing ART in Mozambique during the study period. Of these facilities, 613 (82·6%) offered ART at the beginning of the study period (Jan 1, 2016) and were included in the analysis. 276 (45·0%) facilities were in the northern region, 110 (17·9%) were in the central region, and 227 (37·0%) were in the southern region. 460 (75·0%) facilities were in rural locations as defined by the Ministry of Health. Across the 613 facilities between Jan 1, 2016, and June 30, 2020, 1131118 people initiated ART, of whom 79178 (7·0%) were children, 226224 (20·0%) were adolescents and young adults, and 825716 (73·0%) were adults at the time of starting ART. 731623 (64·7%) were female and 399495 (35·3%) were male. There was no apparent change in the distribution of sex and age at ART initiation over time (figure 1).

Modelled trends in 12-month ART retention during the study periods, overall and by sex and age, are provided in table 2. At baseline (Jan 1, 2017), the estimated 12-month retention was 67·4% (95% CI 65·8 to 68·9). There was a negative mean monthly change in mean retention rate during the pre-intervention period (–0·4 percentage points, 95% CI –0·5 to –0·4) and roll-out period (–0·7 percentage points, –0·9 to –0·6). This negative trend was followed by a positive immediate change

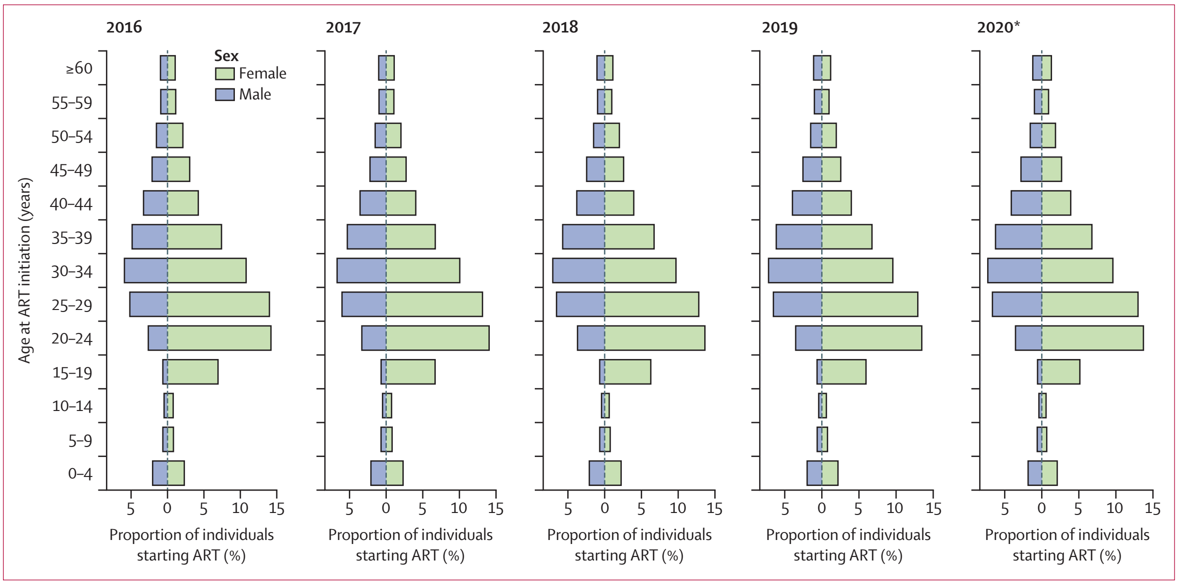

Figure 1: **Demographic characteristics of the study population**
*Including data up to Dec 31, 2020 for comparability with other years.

	January, 2017: baseline 12-month retention on ART, %	February, 2017, to November, 2018: pre-DSDMs period trend*, percentage points	December, 2018, to November, 2019: roll-out period trend*, percentage points	December, 2019: immediate change† from roll-out period to post-DSDMs period, percentage points	December, 2019, to June, 2021: post-DSDMs period trend*, percentage points
Overall	67·4% (65·8 to 68·9)	–0·4 (–0·5 to –0·4)	–0·7 (–0·9 to –0·6)	6·8 (5·5 to 8·0)	0·7 (0·6 to 0·9)
Sex					
Female	67·3% (65·7 to 68·9)	–0·4 (–0·4 to –0·3)	–0·7 (–0·9 to –0·5)	6·5 (5·3 to 7·7)	0·7 (0·6 to 0·8)
Male	67·3% (65·6 to 69·0)	–0·6 (–0·7 to –0·5)	–0·8 (–1·1 to –0·6)	7·1 (5·5 to 8·7)	0·8 (0·9 to 1·0)
Age, years					
0–14	65·7% (63·7 to 67·7)	–0·2 (–0·3 to –0·1)	–1·1 (–1·3 to –0·8)	7·1 (4·8 to 9·3)	0·3 (0·1 to 0·5)
15–24	62·7% (60·8 to 64·7)	–0·5 (–0·6 to –0·4)	–0·8 (–1·1 to –0·6)	7·1 (5·3 to 8·9)	0·9 (0·8 to 1·1)
≥25	68·8% (67·2 to 70·4)	–0·4 (–0·5 to –0·4)	–0·7 (–0·9 to –0·5)	6·7 (5·4 to 8·0)	0·7 (0·6 to 0·9)

Values in parentheses are 95% CIs. ART=antiretroviral therapy. DSDMs=differentiated service delivery models. *Slope mean change per month. †Change from the end of the previous period to the first month of the post-intervention period.

Table 2: **Modelled trends of 12-month retention in ART by study period**

(ie, change in level) from the roll-out period to the post-intervention period (6·8 percentage points, 5·5 to 8·0) and a positive month-to-month change during the post-intervention period (0·7 percentage points, 0·6 to 0·9). The stratified analysis shows similar trends by sex or age, although with different magnitudes.

The 12-month ART retention time series starting on Jan 1, 2017 and ending on June 30, 2021, overall and independently stratified by sex and age, are presented in figure 2. Although we observed a difference in the magnitude of changes in trends over time, all groups had a similar steady negative trend in the pre-intervention period, a positive immediate change from the roll-out period to the post-intervention period, and a steady positive trend in the post-intervention period. Stratification by sex and age combined is presented in appendix 2 (p 2).

We compared the difference in 12-month retention in ART between the model including DSDM implementation and the counterfactual model without DSDM implementation. Overall, the introduction of DSDMs was associated with an estimated increase of 24·5 percentage points (95% CI 21·1 to 28·0) in retention by the end of the study period (table 3). By age, we observed the smallest estimated effect in children (6·1 percentage points, 1·3 to 10·9) and the largest in adolescents and young adults (28·8 percentage points, 24·2 to 33·4). By sex, we observed a larger estimated effect in males (29·7 percentage points, 25·6 to 33·7).

In secondary analysis of the effect of COVID-19, the estimated baseline 12-month retention in ART and the pre-intervention trend were the same as in the primary analysis. The estimated immediate change in level from the roll-out period to the post-intervention period without COVID-19 was 3·62 percentage points (95% CI 2·44 to 4·79) and the estimated mean monthly change in retention during the post-intervention period without COVID-19 was 1·36 percentage points (0·88 to 1·84). We observed a negative immediate change in level from the post-intervention period without COVID-19 to the post-intervention period with COVID-19 (–0·28 percentage points, –1·60 to 1·05), and a positive (but lower, compared with pre-COVID-19) mean monthly change in retention during the post-intervention period with COVID-19 (0·66 percentage points, 0·49 to 0·83). Figure 3 shows the time series for 12-month retention in ART. The estimated 12-month retention in ART at the end of the study period in the presence of COVID-19 was 68·1% (95% CI 66·0 to 70·2); in the counterfactual scenario without COVID-19, this rate was 78·1 (70·1 to 86·1). Thus, the overall effect of COVID-19 on 12-month retention in ART was a decrease (–10·0 percentage points, –18·2 to –1·8).

In sensitivity analysis exploring the trend in 12-month ART retention before and after introduction of the test and treat strategy, we observed a monthly change of 0·01 percentage points (95% CI –0·01 to 0·01) before its introduction, and –0·33 percentage points (–0·42 to –0·24) after (appendix 2 p 3). Additionally, compared with the primary analysis, we observed a smaller magnitude of the overall effect of DSDMs on 12-month ART retention with the inclusion of client data since 2012 (10·8 percentage points, 8·2 to 13·5), and with the assumption of a constant counterfactual trend at the level of the last measurement of retention in the pre-intervention period and using client data since 2016 (11·3 percentage points, –9·3 to 13·4; appendix 2 p 4).

Discussion

Our analysis of data from 613 health facilities across Mozambique indicated a positive impact of DSDM implementation on 12-month ART retention (24·5 percentage point increase) compared with the pre-implementation trend.

These findings support results from previous studies of individual DSDMs in Mozambique that reported decreases in loss to follow-up among individuals enrolled in community ART groups and adherence clubs.[3,23,24]

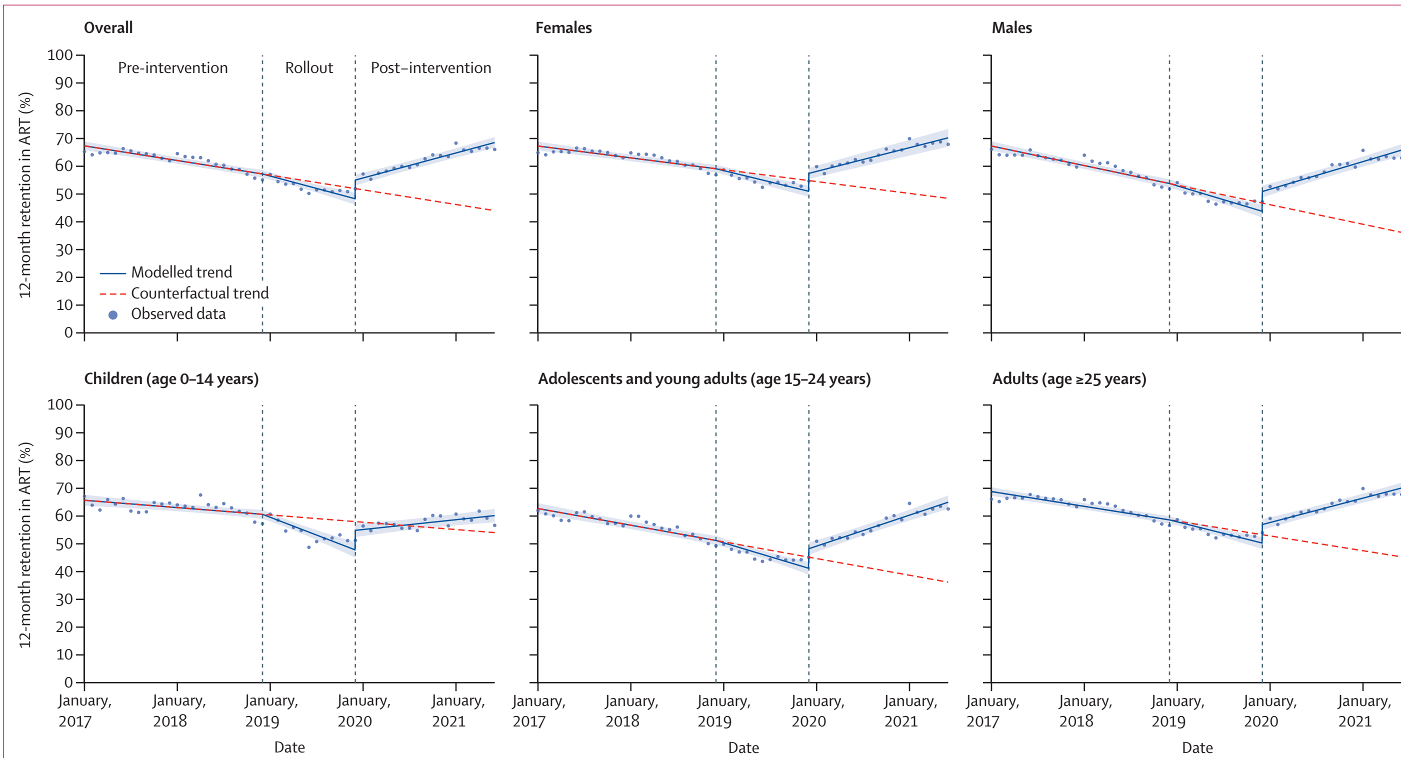

Figure 2: **Interrupted time-series analysis of 12-month retention in ART with time, overall and by sex and age, to study the effect of DSDMs**
The trend in 12-month ART retention was assessed before (pre-intervention) and after (post-intervention) the introduction of eight DSDMs in Mozambique, with an intermediary 12-month roll-out period. The counterfactual trend was defined as the expected trend if the DSDMs had not been implemented. The shaded regions around the trend line is the 95% CI. ART=antiretroviral therapy. DSDM=differentiated service delivery model.

	Estimated modelled 12-month retention by the end of the study period*, %	Estimated counterfactual 12-month retention by the end of the study period*†, %	Overall effect of the DSDMs on 12-month retention, percentage points
Overall	68·6% (66·6–70·6)	44·0% (40·8–47·3)	24·5 (21·1–28·0)
Sex			
Female	70·3% (68·3–72·2)	48·5% (45·3–51·7)	21·8 (18·4–25·2)
Male	65·8% (63·7–68·0)	36·2% (32·4–40·0)	29·7 (25·6–33·7)
Age, years			
0–14	60·2% (57·7–62·6)	54·0% (49·7–58·4)	6·1 (1·3–10·9)
15–24	65·0% (62·5–67·5)	36·2% (32·0–40·3)	28·8 (24·2–33·4)
≥24	70·1% (68·2–72·1)	45·3% (42·0–48·6)	24·8 (21·4–28·2)

Values in parentheses are 95% CIs. ART=antiretroviral therapy. DSDMs=differentiated service delivery models. *By June 30, 2021. †The counterfactual trend was defined as the expected trend if the intervention had not been implemented.

Table 3: **Overall effect of DSDMs on 12-month retention in ART**

Other studies reporting on specific models compared with conventional treatment delivery in Africa found retention in care with DSDMs to be generally within 5% of that in conventional care.[13] However, studies in Kenya and South Africa reported high loss to follow-up in adherence clubs.[12] In our study, DSDMs were not studied individually but as an intervention package including the eight DSDMs; therefore, our results are not discriminated by model.

The effect of DSDMs was modified by sex and age. The male population had greater improvements in retention than the female population, which might be because adult males had worse baseline ART retention and DSDMs address challenges that are greater among adult males (such as engagement in outside work that results in missed visits).[25,26] In addition to the advantageous treatment schedule of DSDMs, adherence clubs and community ART groups provide an opportunity to interact with peers in an empowering environment, which affirm masculinity.[27] Our estimates showed a lower effect on children compared with adolescents and adults. Children are less likely to be diagnosed with HIV and enrolled in ART, and are less likely to achieve viral suppression, and they have lower engagement in DSDMs,[28,29] which could explain the lower estimated effect we observed in this age group, and highlights the need to develop and implement DSDMs for children.[28,29]

COVID-19 had an immediate and sustained negative effect on 12-month retention in ART. Although there was no change in the reporting system due to COVID-19, MISAU reported an abrupt increase in the number of missed visits for individuals enrolled in ART early in the COVID-19 pandemic,[30] when epidemic control measures were implemented (including temporarily interrupting the group models of adherence clubs and community

ART groups, and loosening eligibility criteria for enrolment in fast-track and 3-month antiretrovirals dispensing models to reduce visit frequency, aiming to limit COVID-19 transmission in health facilities). The changes in DSDMs enrolment, and both the fear of being exposed to COVID-19 and the misconception that compliance with the government's stay-at-home mandate included not visiting the health facility for scheduled visits, might explain the observed decrease in 12-month retention. Nevertheless, for individuals who missed visits, alternative antiretroviral delivery models were offered, including mobile brigades and community dispensing, but there are no data on which individuals benefited from these models.[2,8] Finally, the analysis of COVID-19 impact was exploratory, and the counterfactual scenario for impact calculation was estimated on the basis of only four measurements in the post-intervention period without COVID-19 (from December, 2019, to March, 2020), which are insufficient to confidently estimate a trend in an interrupted time series.

Strengths of our study include the large amount of data from both rural and urban public health facilities from all 11 provinces of the country (which is likely to adequately reflect the national experience with HIV treatment in Mozambique), and the large number of timepoint measurements that enabled us to confidently estimate underlying trends in ART retention before and after the intervention.

To our knowledge, the study design we applied was the best option to conduct this post-nationwide implementation evaluation, aiming to measure the impact for all individuals enrolled in ART. A controlled interrupted time-series design could not be used because, firstly, individuals not enrolled in DSDMs could not be used as a control group because they were part of the group of interest, given that we meant to measure the impact for all people enrolled in ART, and, secondly, all health facilities were supposed to introduce DSDMs and facilities that did not introduce DSDMs (due to logistical reasons) were systematically different from implementing facilities, given that they were not ready to start the implementaton of DSDMs. An uncontrolled interrupted time-series design has inherent challenges in accurately estimating the counterfactual trend as it is influenced by measurement points and secular events. We addressed these challenges by including sufficient measurement points to improve the precision of the estimated trend and by limiting our analysis to a period when secular events were expected to have been minor. Nevertheless, it is still possible that our counterfactual does not reflect what would happen in the absence of the DSDMs. We therefore conducted sensitivity analyses. Firstly, we explored the outcome pattern before and after introduction of the WHO test and treat strategy, to exclude the possibility of an underlying improvement in retention before DSDM implementation. Secondly, we used an extension of the data measurement period to estimate the counterfactual.

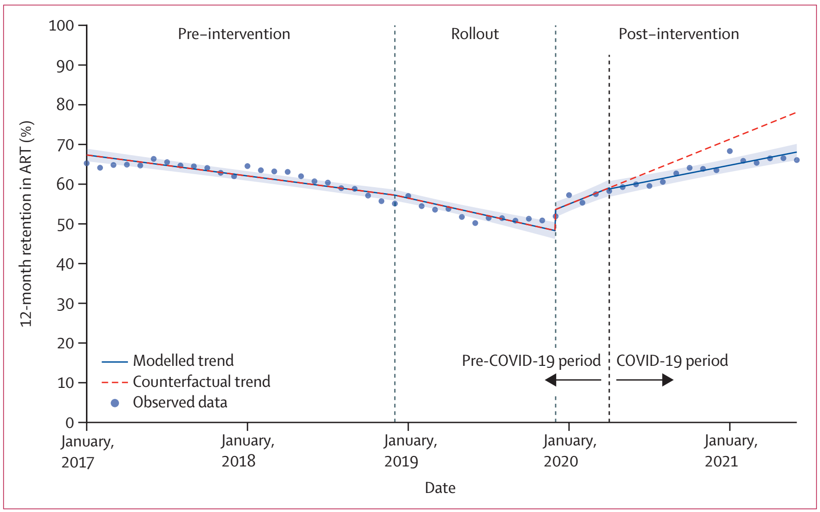

Figure 3: **Interrupted time-series analysis of 12-month retention in ART with time to study the effect of COVID-19**

COVID-19 response measures were implemented in Mozambique from April 1, 2020, during the post-intervention phase of the eight differentiated service delivery models in Mozambique. The shaded areas are 95% CIs. The counterfactual line post-roll-out is an extension of the estimated model before the COVID-19 period. ART=antiretroviral therapy.

Finally, we assumed no change in the counterfactual from the last pre-DSDM measurement point. Including client data since 2012 (before test and treat) in the counterfactual, or assuming no change in the counterfactual over time, led to a smaller magnitude of the estimated effect of DSDMs compared with the primary analysis, which is explained by the positive trend in ART retention before the test and treat period, and the fact that we did not allow the outcome to worsen over time, respectively. Nevertheless, the estimated impact in these two sensitivity analyses was an increase of at least 10 percentage points in 12-month ART retention. The reason as to why the retention trend turned negative after the introduction of test and treat (appendix 2 p 3) should be explored in the context of studying the test and treat strategy.

Other challenges include silent transfers and different visit spacing between conventional care and some DSDMs. Given that we could not identify silent transfers, they were treated as loss to follow-up and new enrolments in the health facility of origin and destination, respectively; however, we did not expect this non-differential misclassification to affect the results. Regarding visit spacing, the adherence clubs, fast-track, and 3-month antiretrovirals dispensing models are the ones with fewer scheduled visits and might result in less missing visits (the purpose of these models). Our approach to retention ascertainment relied on visit schedule compliance (rather than visit frequency), which we believe will have reduced bias in the results.

Finally, an important limitation of our study is the limited data availability, which has previously been identified as a challenge for evaluating the impact of DSDMs in sub-Saharan Africa.[31] When this study was done, there was a weak DSDMs reporting system in the country, which undermined the possibility to stratify results by DSDM enrolment status. Nevertheless, the data were adequate to assess the overall impact of DSDMs on ART retention for all individuals enrolled in ART in participating facilities in Mozambique.

In conclusion, our models indicated that the implementation of eight DSDMs positively impacted 12-month retention in ART in Mozambique, and that COVID-19 negatively influenced retention. Although these findings contribute to closing the knowledge gap on the impact of DSDMs in sub-Saharan Africa, care should be taken in generalising results to other country contexts.

Contributors

DAMU designed the study. DLC managed the database. DAMU, OA, and JPH accessed and verified the data. DAMU drafted the manuscript. OA, JPH, OAU, ESG, SAC, AMC, IAG, DLC, SEG, MRZ, SG, and KS reviewed the manuscript. DAMU, DLC, OA, and JPH had full access to all the data in the study. DAMU, OA, JPH, and KS had final responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

Data sharing

De-identified client data underlying the results reported in this Article and the respective data dictionary will be made available at the request of investigators whose proposed use of the data has been approved by an independent review committee identified for this purpose. Request submissions should be sent online at https://ins.gov.mz/institucional/unidade-organicas/direccoes/direccao-de-inqueritos-e-observacao-de-saude/bases-de-dados/, and a data access agreement will need to be signed per the procedures of Instituto Nacional de Saúde.

Acknowledgments

We acknowledge Hélder Macul from the National STI and HIV/AIDS Control Program of the Mozambique Ministry of Health, and Yao He and Hong Xiao from the University of Washington Department of Global Health. DAMU was supported by the Doris Duke Charitable Foundation African Health Initiative. KS and OA were supported by the Implementation Science Core of the University of Washington/Fred Hutch Center for AIDS Research, a programme funded by the US National Institutes of Health (NIH) under award number AI027757, which is supported by the following NIH Institutes: National Institute of Allergy and Infectious Diseases, National Cancer Institute, National Institute of Mental Health, National Institute on Drug Abuse, National Institute of Child Health and Human Development, National Heart, Lung, and Blood Institute, National Institute on Aging, National Institute of General Medical Sciences, and National Institute of Diabetes and Digestive and Kidney Diseases.

References

1 Ministério da Saúde, Instituto Nacional de Estatística, and ICF. Inquérito de indicadores de imunização, malária e HIV/SIDA em Moçambique, 2015. 2018. https://dhsprogram.com/publications/publication-ais12-ais-final-reports.cfm (accessed June 6, 2022).

2 Ministério da Saúde. Relatório anual 2020. Relatório anual das actividades relacionadas ao HIV/SIDA. 2021. https://pesquisa.bvsalud.org/portal/resource/pt/biblio-1344371 (accessed June 6, 2022).

3 Auld AF, Shiraishi RW, Couto A, et al. A decade of antiretroviral therapy scale-up in Mozambique: evaluation of outcome trends and new models of service delivery among more than 300,000 patients enrolled during 2004–2013. *J Acquir Immune Defic Syndr* 2016; **73:** e11–22.

4 UNAIDS. 90–90–90: an ambitious treatment target to help end the AIDS epidemic. Jan 1, 2017. http://www.unaids.org/en/resources/documents/2014/90-90-90 (accessed June 6, 2022).

5 WHO. Guideline on when to start antiretroviral therapy and on pre-exposure prophylaxis for HIV. 2015. https://apps.who.int/iris/handle/10665/186275 (accessed June 6, 2022).

6 WHO. Updated recommendations on service delivery for the treatment and care of people living with HIV. 2021. https://www.who.int/publications-detail-redirect/9789240023581 (accessed Sept 13, 2023).

7 Ministério da Saúde. Guião orientador sobre modelos diferenciados de serviços em Moçambique. 2018. https://comitetarvmisau.co.mz/docs/orientacoes_nacionais/Guiao_Modelos_diferenciados_2018.pdf (accessed June 6, 2022).

8 Moiana Uetela D, Gimbel S, Inguane C, et al. Managers' and providers' perspectives on barriers and facilitators for the implementation of differentiated service delivery models for HIV treatment in Mozambique: a qualitative study. *J Int AIDS Soc* 2023; **26:** e26076.

9 Grimsrud A, Wilkinson L. Acceleration of differentiated service delivery for HIV treatment in sub-Saharan Africa during COVID-19. *J Int AIDS Soc* 2021; **24:** e25704.

10 Vrazo AC, Golin R, Fernando NB, et al. Adapting HIV services for pregnant and breastfeeding women, infants, children, adolescents and families in resource-constrained settings during the COVID-19 pandemic. *J Int AIDS Soc* 2020; **23:** e25622.

11 Jo Y, Rosen S, Sy KTL, et al. Changes in HIV treatment differentiated care uptake during the COVID-19 pandemic in Zambia: interrupted time series analysis. *J Int AIDS Soc* 2021; **24** (suppl 6): e25808.

12 Roy M, Bolton Moore C, Sikazwe I, Holmes CB. A review of differentiated service delivery for HIV treatment: effectiveness, mechanisms, targeting, and scale. *Curr HIV/AIDS Rep* 2019; **16:** 324–34.

13 Long L, Kuchukhidze S, Pascoe S, et al. Retention in care and viral suppression in differentiated service delivery models for HIV treatment delivery in sub-Saharan Africa: a rapid systematic review. *J Int AIDS Soc* 2020; **23:** e25640.

14 Limbada M, Zijlstra G, Macleod D, Ayles H, Fidler S. A systematic review of the effectiveness of non-health facility based care delivery of antiretroviral therapy for people living with HIV in sub-Saharan Africa measured by viral suppression, mortality and retention on ART. *BMC Public Health* 2021; **21:** 1110.

15 Muhula S, Gachohi J, Kombe Y, Karanja S. Interventions to improve early retention of patients in antiretroviral therapy programmes in sub-Saharan Africa: a systematic review. *PLoS One* 2022; **17:** e0263663.

16 Fataha NVFA, Gaveta S, Langa JC, et al. Evaluation of the Mozambique antiretroviral therapy (MozART) database as an antiretroviral therapy patient surveillance system, 2017–2018. *Pan Afr Med J* 2022; **42:** 137.

17 Lafort Y, Couto A, Sunderbrink U, et al. Validity of reported retention in antiretroviral therapy after roll-out to peripheral facilities in Mozambique: results of a retrospective national cohort analysis. *PLoS One* 2018; **13:** e0198916.

18 Ministério da Saúde. Livro de folha de contagem e normas de preenchimento. Maputo: Ministério da Saúde, 2019.

19 Ballinger GA. Using generalized estimating equations for longitudinal data analysis. *Organ Res Methods* 2004; **7:** 127–50.

20 Kahan BC, Li F, Copas AJ, Harhay MO. Estimands in cluster-randomized trials: choosing analyses that answer the right question. *Int J Epidemiol* 2023; 52: 107–18.

21 Wagner AK, Soumerai SB, Zhang F, Ross-Degnan D. Segmented regression analysis of interrupted time series studies in medication use research. *J Clin Pharm Ther* 2002; **27:** 299–309.

22 Lopez Bernal J, Soumerai S, Gasparrini A. A methodological framework for model selection in interrupted time series studies. *J Clin Epidemiol* 2018; **103:** 82–91.

23 Jobarteh K, Shiraishi RW, Malimane I, et al. Community ART support groups in Mozambique: the potential of patients as partners in care. *PLoS One* 2016; **11:** e0166444.

24 Finci I, Flores A, Gutierrez Zamudio AG, et al. Outcomes of patients on second- and third-line ART enrolled in ART adherence clubs in Maputo, Mozambique. *Trop Med Int Health* 2020; **25:** 1496–502.

25 Nicol E, Basera W, Mukumbang FC, et al. Linkage to HIV care and early retention in care rates in the universal test-and-treat era: a population-based prospective study in KwaZulu-Natal, South Africa. *AIDS Behav* 2023; **27:** 1068–81.

26 Wiginton JM, Mathur S, Gottert A, Pilgrim N, Pulerwitz J. Hearing from men living with HIV: experiences with HIV testing, treatment, and viral load suppression in four high-prevalence countries in sub-Saharan Africa. *Front Public Health* 2022; **10:** 861431.

27 Mukumbang FC. Leaving no man behind: how differentiated service delivery models increase men's engagement in HIV care. *Int J Health Policy Manag* 2021; **10:** 129–40.

28 Abelman R, Alons C, Stockman J, et al. Implementation of differentiated service delivery for paediatric HIV care and treatment: opportunities, challenges and experience from seven sub-Saharan African countries. *Fam Med Community Health* 2020; **8:** e000393.

29 Wilkinson L, Siberry GK, Golin R, et al. Children and their families are entitled to the benefits of differentiated ART delivery. *J Int AIDS Soc* 2020; **23:** e25482.

30 Ministério da Saúde. Programa Nacional de Controlo de ITS-HIV/SIDA. Relatório anual das actividades relacionadas ao HIV/SIDA—2020. 2021. https://www.misau.gov.mz/index.php/relatorios-anuais (accessed June 6, 2022).

31 Huber A, Pascoe S, Nichols B, et al. Differentiated service delivery models for HIV treatment in Malawi, South Africa, and Zambia: a landscape analysis. *Glob Health Sci Pract* 2021; **9:** 296–307.