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Kenyan HIV Clinics with Youth-Friendly Services and Trained Providers Have a Higher Prevalence of Viral Suppression Among Adolescents and Young Adults: Results from an Observational Study

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Abstract

Sustained viral suppression in adolescents and young adults living with HIV (AYALWH) is necessary for epidemic control. We evaluated facility and individual correlates of viral suppression using programmatic data from AYALWH between ages 10 and 24 years at 24 HIV clinics in Kenya. Binomial regression was used to evaluate correlates of viral load (VL) suppression (<1000 copies/ml). Of 5,316 AYALWH on antiretroviral therapy (ART) ≥6 months, 2,081 (39%) had VLs available in the medical record, of which 76% were virally suppressed. In multivariable analyses, ART initiation among AYALWH older than 10 years was associated with higher viral suppression than initiation under 10 years (adjusted Risk Ratio [aRR] 10–14 = 1.03, 95% CI 0.97–1.10; aRR 15–19 = 1.30, 95% CI 1.19–1.41; aRR 20–24 = 1.43, 95%CI 1.24–1.63). Facilities with both youth-friendly services (YFS) and trained providers had significantly higher VL suppression compared to facilities without YFS or trained providers (aOdds Ratio:2.07, 95%CI:1.71–2.52). Viral suppression remains sub-optimal among AYALWH. YFS and trained providers plus greater use of VL data may help increase viral suppression among AYALWH.

Keywords

adolescent and young adults; HIV; HIV care; HIV viral suppression; Kenya; observational study

In sub-Saharan Africa (SSA), major gaps remain in achieving 95% viral suppression among adolescents and young adults between the ages of 10 and 24 years who are living with HIV (AYALWH) by 2030 (Enane et al., 2018; Kariminia et al., 2018; Mokdad et al., 2016; Slogrove & Sohn, 2018). Sustained viral suppression is necessary to achieve benefits of antiretroviral therapy (ART), including improved health, survival, and reduced transmission risk. A global cohort of adolescents living with HIV reported only 65% viral suppression (Collaborative Initiative for Paediatric H.I.V.E. Research Global Cohort, et al., 2018) and viral suppression prevalence in other studies in East Africa among AYALWH varied from 40% to 80% (Mwau et al., 2018; Natukunda et al., 2019; Petersen et al., 2017).

Youth-friendly services (YFS) is one strategy to help improve ART adherence and viral suppression among AYALWH. YFS may include designated spaces, peer support groups, caregiver involvement, trained providers, and developmentally-appropriate counseling to improve engagement and viral suppression among AYALWH (WHO, 2012). While widely implemented across SSA, YFS interventions vary by setting, population, and available resources, with mixed evidence of effectiveness on viral suppression (Njuguna et al., 2020). Kenya has comprehensive national guidelines to offer YFS to all AYALWH in care, with training and job aids to help standardize implementation. Given the variation in local epidemics and clinic resources within countries (National AIDS Control Council, 2016), more information is needed about YFS implementation in routine care and the extent to which services or specific trainings may influence virologic outcomes among AYALWH.

In addition to service delivery influences, social and behavioral factors also affect viral suppression across different ages or developmental stages (Ferrand et al., 2016; Ferrand et al., 2017). Younger adolescents with vertically acquired infection have distinct barriers to attaining viral suppression, including history of incorrect drug regimens for age and weight, first-line treatment failure as children (Ferrand et al., 2016; Ferrand et al., 2017), lack of knowledge of HIV status, or difficulty coping with HIV status due to HIV-stigma (Kacanek et al., 2019). Among older adolescents, barriers to ART adherence and viral suppression may include depression (Mellins & Malee, 2013), fear of HIV-related stigma from peers (Kacanek et al., 2019), and treatment disruptions during school or transitioning to adult HIV care (Tsondai et al., 2017).

Most studies of viral suppression among AYALWH in SSA are from research cohorts and trials with limited generalizeability (Ferrand et al., 2017). The expansion of routine viral load (VL) testing and electronic medical record systems (EMRs) offers an opportunity to better characterize correlates of viral suppression and inform program improvements (Kadima et al., 2018; Mwau et al., 2018). In 2016, Kenya was among the first countries in SSA to launch national VL monitoring of all people enrolled in HIV care, with an aim to reach the 'third 95%' target by 2030 (National AIDS Control Council, 2016). However, few studies have used EMR and VL data to estimate viral suppression specific to AYALWH (Ferrand et al., 2016; Kariminia et al., 2018). To address this gap, we analyzed data from a programmatic setting to estimate viral suppression prevalence and correlates among AYALWH enrolled in HIV clinics in Kenya.

Methods

Setting and Population

This observational study, using a retrospective cross-sectional approach, utilized pre-intervention data from 24 HIV facilities from a randomized trial to improve quality of care for AYALWH (ClinicalTrials.gov Number NCT02928900). These facilities were purposively selected from among 30 facilities in four counties in Central (Nairobi and Kiambu) and Western (Homa Bay and Kisumu) Kenya. Eligible facilities had electonric medical records systems (EMR), at least 40 AYALWH enrolled in care, and no adolescent-specific interventions. Details of this trial are descrbed elsewhere (Wilson et al., 2017).

Data Collection

The study team extracted EMRs from all AYALWH (ages 10 to 24 years) with visits between November 2015 and March 2017, including AYALWH who had acquired HIV through vertical or horizontal transmission. Separately, VL results were abstracted from the Kenyan National AIDS and STD Control Program database, covering January 2016 until March 2017, and linked to EMRs using unique study identifiers. To include facility-level data in this analysis, we used variables from study surveys administered to providers and facility managers during the same period. Pilot-tested surveys were administered to facility managers to assess facility characteristics, including the availability of YFS, any provider trainings in AYALWH care, and the Kenyan Government's Adolescent Package of Care (APOC) checklist – a job aid introduced in 2015 that providers complete for each AYALWH client during the clinic visit (Mburu et al., 2019). The study team received permission from facility managersto recruit all providers (i.e. nurses, counselors, clinical officers, medical officers)who were over age 18 and working with AYALWH at the time of the study and ask them to complete confidential, in-person surveys using electronic tablets. Participation in the surveys was 100%. Surveys assessed sociodemographics and self-reported competence and training in caring for AYALWH, as described previously (Karman et al., 2020). Due to high turnover in the health care workforce, we did not assume that a health facility offering a training meant that all providers had received training. Viral suppression was defined as most recent VL <1000 copies/ml (c/ml) among AYALWH on ART at least 6 months, which is consistent with Kenyan and WHO guidelines (Mwau et al., 2018; Organization, 2016; World Health Organization, 2016). Separately from the correlates analysis, we estimated the propotions of all AYALWH with VL suppression who had been on ART at least 12 months and on ART at least 24 months, respectively. We also estimated the proportion of AYALWH with undetectable VL, who may have the lowest risk of onward HIV transmission, using a more stringent cut off of <200 copies/ml (Bermudez et al., 2018; Cherutich et al., 2016; Ssewamala et al., 2020).

Data Analysis

Individual and facility correlates of viral suppression were evaluated based on previous studies and available data (Mwau et al., 2018; Natukunda et al., 2019; Njuguna et al., 2020; Petersen et al., 2017). Individual correlates in the EMR included age group (ages 10–14 “early adolescence”, 15–19 “middle adolescence”, 20–24 years “young adult”), childhood HIV diagnosis (<10 or ≥10 years of age), age at ART initiation (child, early, middle, young adult), months on ART, sex, and WHO stage at enrollment in clinical care (1–2 vs. 3–4). Mode of transmission was not routinely collected, although we did abstract age of HIV diagnosis. Facility-level correlates were binary variables (yes/no): availability of any YFS, clinical utilization of the APOC checklist at each encounter, and offering any provider training in AYALWH care. The number of HCWs who reported completing any previous training in AYALWH care was converted into a binary variable (any vs. no trained provider at the facility) and evaluated as a facility-level correlate. We created a categorical variable to evaluate the association between availability of both YFS and providers with training in AYALWH care and viral suppression (both YFS and trained providers, either YFS or trained providers, neither).

Viral suppression prevalence at most recent measure was estimated as a proportion with 95% Confidence Intervals (CIs). We separately computed the prevalence of VL suppression at 12 months as the total number of AYALWH who were virally suppressed among all AYALWH on ART at least 12 months. We estimated the the prevalence of VL suppression at 24 months as the total number of AYALWH who were virually suppressed among all AYALWH on ART at least 24 months.

The proportion of AYALWH with undetectable VL at most recent measure (VL <200 copies/ml [c/ml]) was estimated the same way as the primary outcome except using the more stringent threshold. Each AYALWH contributed one VL outcome to the analysis. Univariate log-binomial generalized linear regression models with robust standard errors produced risk ratios (RRs) estimates and 95% CIs, accounting for clustering by facility. Separate multivariable regression models were run for each correlate and adjusted for pre-specified confounding factors of age (continuous) and sex. Individual-level models were adjusted for age and sex, except for the models evaluating pregnancy status and sex. The model of WHO stage was adjusted for age, time on ART, and sex. Models of facility-level correlates were adjusted for facility volume and AYALWH age. Each facility-level correlate was assessed separately.To evaluate both facility- and individual-level correlates on individual-level VL, multi-level models were used to generate odds ratios (OR) and 95% CIs, with correlates as fixed effects and facility as a random effect, adjusted for AYALWH volume and age. Assuming a 75% prevalence of viral suppression in the unexposed group and 80% power, and a two-sided $\alpha = 0.05$ design effect of 2.21 for an effective sample of 905, the minimum detectable risk ratio for a correlate would be 1.10. All analyses were conducted using Stata IC 16 (College Station, TX). The study was approved by Kenyatta National Hospital Ethics/University of Nairobi Review Committee (KNH-UON ERC; P476/06/2016) and the University of Washington Human Subjects Research Committee (51926), and all providers completed informed consent.

Results

Individual Correlates of Virual Suppression

Of 7,082 AYALWH with at least one visit documented in the EMR during the observation period, 5,316 (75%) had been on ART at least 6 months, among whom 2,081 (39%) had at least one VL available after 6 months on ART. Median follow-up time for AYALWH in this dataset was 8.4 months (Interquartile range [IQR]: 4.0–12.3). AYALWH represented different age groups, from early (n = 628, 30%) and middle adolescence (n = 490, 24%) to young adults (n = 963, 46%). The majority of the sample was female (n = 1,463, 70%), diagnosed with HIV as a child (n = 1,095, 53%), in WHO stage 1 or 2 (n = 1,357, 77%), and had started ART either before age 10 (n = 646, 31%) or as young adults (n = 673, 32%; Table 1). Median time on ART was 29 months (IQR: 9–74). Among 1,472 AYALWH with data on ART regimen, most AYALWH (n = 1,442, 98%) were on first-line therapy, as recommended by the Kenyan Ministry of Health, and the remainder were on second or third line or indeterminant regimens (n = 30, 2%). More AYALWH missing VL results started ART at ages 15 or older (n = 1,846, 57% vs. n = 1,050, 51%, $p < 0.001$), were diagnosed after age 10 (n = 2,197, 68% vs. n = 1,313, 63%, $p < 0.001$), and were classified as WHO stage 1 or 2 compared to those with VL results (n = 2,445 82% vs. n = 1,357, 77%).

Overall, 76% (n = 1,581) of eligible AYALWH were virally suppressed (<1000 c/ml) at their most recent visit, and 68% (n = 1,415) had undetectable results (<200 c/ml). Viral suppression among 1,740 AYALWH on ART at least 12 months was 74% (n=1,288) and 70% (n=822) among 1,258 AYALWH on ART at least at 24 months.In univariate analyses of individual-level correlates, female sex (RR = 1.13, 95% CI [1.05, 1.21]), HIV diagnosis after age 10 (RR = 1.17, 95% CI [1.11, 1.24]), and initiation of ART in middle adolescence (RR = 1.17, 95% CI [1.09, 1.24]) or young adulthood (RR = 1.24, 95% CI [1.15, 1.34]) compared to childhood (<10 years) were associated with a significantly higher probability of viral suppression (Table 2). In multivariate models adjusted for sex and age, ART initiation as an adolescent or young adult remained associated with higher viral suppression (middle aRR = 1.30, 95% CI [1.14, 1.48]; young adult aRR = .45, 95% CI [1.21, 1.76]). Similarly, older age (middle aRR = 0.97, 95% CI [0.89, 1.06]; young adult aRR = 1.13, 95% CI [1.06, 1.20]) and female sex were associated with viral suppression (aRR = 1.08, 95% CI [1.00 – 1.15]).

Facility-Level Correlates of Viral Suppression

The proportion of AYALWH with viral suppression <1000 c/ml varied by facility, from 50% to 93%. Facilities with YFS (n = 6, 26% vs. n = 5, 19% without YFS, $p < 0.001$), and any AYALWH training for providers (n = 8, 32% vs. n = 6, 27% without this training, $p < 0.001$) had higher proportions of non-missing VL results compared to facilities without those services. Overall, 20% (n = 5) of facilities reported any YFS or use of the APOC checklist; 33% (n = 8) reported ever offering provider training in AYALWH care; and 42% (n = 10) of facilities had at least one provider currently on staff who had received this training. Among the 142 HCW survey respondents, 71% were female (n = 101). The provider types included nurses (n = 40, 28%), counselors (n = 57, 40%), or clinical/medical officers (n = 45, 32%). Among all the providers, there was a median of 3 years caring for AYALWH (IQR: 1–6), and the majority (n =85, 60%) saw more than 10 AYALWH clients per week. We provide additional HCW characteristics elsewhere (Karman et al., 2020). Forty-two percent of facilities (n = 10) currently had at least one provider with AYALWH training.

A higher proportion of AYALWH were virally suppressed at facilities that reported any YFS (number and percent of AYALWH with VL suppression at facilities with any YFS = 423, 79% vs. number and percent of AYALWH with VL suppression and at at facility with no YFS = 1,158, 75%), use of the APOC (n = 304, 77% vs. n = 1,277, 76%), any training in AYALWH care (n = 521, 79% vs. n = 1,060, 75%), had at least one current HCW trained in AYALWH care (n = 877, 78% vs. n = 704, 74%), or had both services and trained staff compared to only one or none (n = 132, 84% vs. n = 998, 77% vs. n = 451, 74%; Table 2). While none of the facility characteristics were separately associated with VL suppression among AYALWH, a significantly higher proportion of AYALWH were virally suppressed at facilities that had both YFS and any providers trained in AYALWH care compared to facilities with neither characteristic (aOR:2.07, 95% CI [1.71, 2.52]), after adjusting for AYALWH individual age and facility volume. When age at ART initiation was included in this model, facilities with YFS and trained providers and older age at ART initiation both remained independently associated with individual-level viral suppression.

Discussion

In this study, using data routinely collected in the provision of care to AYALWH, 76% of AYALWH were found to be virally suppressed (<1000 c/ml); and viral suppressionwas significantly lower among adolescents who initiated ART in childhood compared to during adolescence. The prevalence we observed in this sample of large public HIV clinics in Kenya falls within range of VL suppression estimates of 50% to 80% that are reported in prior studies among AYALWH in SSA that used similar outcomes definitions (Mburu et al., 2019; Mwau et al., 2018) and far below the 2030 target for epidemic control. Importantly, we found that AYALWH attending facilities with both YFS and providers trained in AYALWH care had significantly higher probability of viral suppression compared to AYALWH at facilities with neither characteristic.

Our study supports results from one prior study by Njuguna et al. (2020) that was conducted in a separate sample of 99 clinics in Kenya, which found that younger age, male sex, and longer time on ART were associated with viral non-suppression. The finding that AYALWH who initiated ART at a younger age were less likely to be suppressed than older youth may be a marker for differences in behavioral, clinical, or service factors affecting ART adherence, including lack of awareness of HIV status, ART side effects, or inadequate treatment monitoring (Nichols et al., 2017; Njuguna et al., 2020; Sithole et al., 2018). Service interventions to improve regimen monitoring and counseling to address disclosure and adherence challenges may especially benefit younger AYALWH currently in care (Kouamou et al., 2019). Higher observed viral suppression among older adolecents and young adults may reflect a population who were infected horiztonally and who were otherwise healthy at the time of HIV diagnosis.

Viral suppression among AYALWH also varied across facilities ranging from 50% to 93%, with significantly higher prevalence at facilities that had both YFS and providers trained in AYALWH care. This result extends findings from other studies that found youth-friendly spaces (Njuguna et al., 2020) and adolescent friendly clinic days (Mburu et al., 2019) were associated with higher levels of viral suppression among AYALWH. Other research has shown that provider characteristics including kindness, listening, and non-judgemental communication have been shown to improve adolescent engagement in HIV care, enabling better monitoring of adherence and viral load (Cluver et al., 2018; Wilson et al., 2019). Our study provides further evidence that facility- and individual-level factors both contribute to viral suppression among AYALWH, with the new finding that a combination of YFS and trained providers has a stronger association than either of these factors alone.

Strengths of our study include using available EMR and VL data from AYALWH representing different ages and developmental stages and local epidemics. Use of routine EMR and national VL data is more generalizable to a routine care population than traditional research cohorts that sample among people in care (Wagenaar et al., 2016). Few programmatic analyses report VL results of AYALWH by age group or time on ART, which limits application in clinical practice (Ferrand et al., 2016). We analyzed results disaggregated by age and time on ART and included questions about YFS and provider training that are not routinely collected. Limitations of this study include quality of available EMR data, cross-sectional design, a non-random sample of clinics in the study, and assessment of facility characteristics by self-report. We assessed YFS and provider training using single questions, which may have contributed to measurement error. We were unable to evaluate other factors that may negatively affect viral suppression, including drug resistance, stigma, and disclosure of HIV status (Ferrand et al., 2017; Kacanek et al., 2019). Selection bias is possible due to missing data. Only 39% of AYALWH on ART for at least 6 months had VL data that could be linked to the EMR. Differences in AYALWH who lacked VL data could elevate the true VL suppression estimate.

Conclusion

In summary, viral suppression among AYALWH in routine care falls short of the global 95% target for 2030, especially among adolescents who start ART as children. Increased access to YFS delivered by skilled providers with greater availabily of routine VL data may improve HIV care services and ultimately help to accelerate progress toward epidemic control in this important population.

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Key Considerations

- Sustained viral suppression in adolescents and young adults living with HIV (AYALWH) is necessary for individual health and for epidemic control.
- In this study using routine clinic and viral load data among 2,081 adolescents and young adults living with HIV (AYALWH) in Kenya, viral suppression (<1000 c/ml) was lower than it should be to stay on track towards HIV elimination by 2030.
- AYALWH at facilities that had both youth-friendly services (YFS) and any providers trained in AYALWH care had a significantly higher prevalence of viral suppression compared to facilities with neither of these characteristics.
- Increased access to YFS delivered by skilled providers with greater availabily of routine viral load data may improve HIV care services, and ultimately help to optimize viral suppression among AYALWH.

Table 1.

AYALWH Characteristics at First Viral Load Measure at 24 SPEED Facilities

Adolescent characteristics	*N* = 2,081 *n* (%)
Age at first eligible viral load in sample (years)	
Early adolescence 10–14	628 (30.2)
Middle adolescence 15–19	490 (23.6)
Young adult 20–24.9	963 (46.3)
Sex	
Female	1,463 (70.3)
Male	618 (29.7)
Pregnant, (*n* = 1,097 females)[a]	106 (9.6)
Age at HIV diagnosis	
Child (<10 years of age)	768 (36.9)
Early adolescence (10 to 14 years of age)	327 (15.7)
Middle adolescence (15 to 19 years of age)	392 (18.8)
Young adult (20 to 24.9 years of age)	594 (28.5)
Age group at ART initiation	
Child (<10 years of age)	646 (31.0)
Early adolescence (10 to 14 years of age)	385 (18.5)
Middle adolescence (15 to 19 years of age)	377 (18.1)
Young adult (20 to 24.9 years of age)	673 (32.3)
Months on ART overall, by age group, expressed as median (IQR)	29.3 (9.4–73.9)
Early adolescence (10 to 14 years of age)	59.0 (26.9–88.1)
Middle adolescence (15 to 19 years of age)	55.7 (15.8–93.6)
Young adult (20 to 24.9 years of age)	13.6 (3.6–32.3)
WHO stage 1 or 2 at enrollment in care (*n* = 1,773)	1,357 (76.5)

Note. ART, antiretroviral therapy; AYALWH, Adolescent and Young Adults Living with HIV; IQR, Interquartile range

[a]Column totals may not add to 2,081 due to missing data. The variable specific denominators are in parentheses

Table 2.

Individual and facility correlates associated with AYALWH viral suppression at 24 health facilities in Kenya

Correlate	Denominator (N = 2,081)	VL <1,000 c/ml n (%) or median (IQR) n = 1,581	RR 95% CI, p-value	aRR 95% CI, p-value	aRR 95% CI, p-value[f]
Individual Level [a]					
Age					
10–14 Early	628	440 (70.1)	Ref	Ref	--
15–19 Middle	490	336 (68.6)	0.98 (0.89–1.07)	0.97 (0.89–1.06)	
20–24.9 Young adult	963	805 (83.6)	1.19 (1.13–1.26), <0.001[b]	1.13 (1.06–1.20), <0.001[b]	
Male	618	431 (69.7)	Ref		
Female	1,463	1,150 (78.6)	1.13 (1.05–1.21), 0.001	1.08 (1.01–1.15), 0.03	--
HIV diagnosis <10 yo	1,313	528 (68.8)	Ref	Ref	--
HIV diagnosis ≥10 yo	768	1,053 (80.2)	1.167 (1.10–1.24), <0.001	0.98 (0.91–1.05), 0.56	
Age at ART initiation					
<10	646	448 (69.4)	Ref	Ref	Ref
10–14 Early	386	248 (64.4)	0.93 (0.87–1.00)	0.98 (0.89–1.07)	1.023 (0.947–1.1006)
15–19 Middle	377	305 (80.9)	1.17 (1.09–1.24)	1.30 (1.14–1.48)	1.2530 (1.159–1.3641)
20–24.9 Young adult	676	583 (86.2)	1.24 (1.15–1.34), <0.001[b]	1.45 (1.21–;1.76), <0.001[b]	1.39, (1.22–1.58), <0.001[b]
Not pregnant [c]	990	779 (78.5)	Ref	Ref	-
Pregnant	106	90 (84.0)	1.07 (0.98–1.17), 0.13	1.00 (0.92–1.09), 0.99[b]	
WHO stage 1 or 2[d]	1,357	1,064 (78.4)	Ref	Ref	
WHO stage 3 or 4	416	290 (69.7)	0.89 (0.84–0.94), 0.001	0.98 (0.92–1.04), 0.51	
Time on ART (months)	VL≥1000 VL<1000	50.6 (20.9–83.5) 22.0 (7.6–67.8)	1.00 (0.99–1.00),0.001	1.00 (0.99–1.00), 0.001	
Facility level [e]					
Facility offers training on AYALWH					
No	1,417	1,060 (74.8)	Ref	Ref	--
Yes	664	521 (78.5)	1.17 (0.83–1.64), 0.38	1.15 (0.80–1.66), 0.46	
Facility has YFS					

Correlate	Denominator (N = 2,081)	VL <1,000 c/ml n (%) or median (IQR) n = 1,581	RR 95% CI, p-value	aRR 95% CI, p-value	aRR 95% CI, p-value[f]
No	1,547	1,158 (74.9)	Ref	Ref	--
Yes	534	423 (79.2)	1.22 (0.82–1.81), 0.31	1.22 (0.81–1.84), 0.33	
Facility has APOC Checklist					
No	1,684	1,277 (75.8)	Ref	Ref	--
Yes	397	304 (76.6)	0.98 (0.65–1.47), 0.92	0.99 (0.64–1.53), 0.97	
No HCWs trained	952	704 (74.0)	Ref	Ref	
At least 1 HCW trained	1,129	877 (77.7)	1.24 (0.90–1.71), 0.18	1.28 (0.93–1.76), 0.14	--
No YFS or trained					
HCWs	612	451 (73.7)	Ref	Ref	Ref
YFS or trained HCWs	1,311	998 (76.1)	1.11 (0.78–1.59)	1.11 (0.79–1.56)	1.00 (0.73–1.28)
Both	158	132 (83.5)	1.73 (1.27–2.36), 0.001[b]	1.91 (1.43–2.53), <0.001[b]	2.07 (1.71–2.52), <0.001[b]

Note. AYALWH, Adolescent and Young Adults Living with HIV; ART, Antiretroviral therapy; APOC, Adolescent Package of Care Checklist; YFS, Youth Friendly Services; HCW, healthcare worker; WHO, World Health Organization

[a]Individual-level models adjusted for age (mean centered) and sex, unless otherwise specified. The models of sex and pregnancy status adjusted for time on ART and age. The model of age at ART initiation adjusted for age and sex only. The model of WHO stage adjusted for age, time on ART, and sex.

[b]P-values from Global Wald test

[c]Among 1,097 females with any data about pregnancy

[d]Among 1,773 with non-missing WHO stage at enrollment in care.

[e]Final multi-level models were adjusted for AYALWH age (individual median centered) and AYALWH clinic volume. All models included 2,081 records with individual-level binary outcomes of AYALWH viral suppression.

[f]Multi-level model that included both individual-level age at ART initiation and facility-level presence of both YFS and trained HCW, adjusted for individual AYALWH age and facility volume. Time on ART was collinear with age at ART initiation and dropped from the model. Sex was not included since it was not plausibly associated with YFS or provider training.