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Three-year virological outcomes among adolescent girls and young women living with human immunodeficiency virus enrolled in vertical transmission prevention services during pregnancy and postpartum in Tanzania: A prospective cohort study

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ABSTRACT

Objectives: This large cohort study examines long-term trends and predictors of viremia among pregnant and postpartum adolescent girls and young women (AGYW) living with human immunodeficiency virus (HIV) in Tanzania.

Methods: This prospective cohort study included 7703 pregnant/postpartum AGYW with at least one viral load (VL) enrolled in routine prevention of mother-to-child transmission (PMTCT) care between 2018 and 2020 across three regions in Tanzania and followed for a minimum of 36 months. Poisson generalized linear models with a log link function were used to estimate adjusted incidence rate ratios and 95% confidence intervals for detectable viremia (VL ≥50 copies/mL) by baseline exposures.

Results: Over three years, detectable viremia was highest among the youngest age group 15-17 years (20.4%) compared with those aged 18-19 (16.7%) and 20-24 years (12.5%). Viremia declined during pregnancy but plateaued postpartum, with >10% of participants remaining viremic. Perinatally infected AGYW (HIV diagnosis at age ≤12 years) had higher rates of viremia (28.8%) than those already receiving antiretroviral therapy (ART) (11.0%) or newly initiated on ART (15.2%) who were diagnosed after childhood. Over 25% of perinatally infected AGYW remained viremic throughout the PMTCT cycle. Second-line ART and urban residence were associated with higher risk of viremia.

Conclusion: Persistently high viremia was observed over time among Tanzanian pregnant/postpartum AGYW with HIV, particularly adolescents and those with perinatally acquired infection. Tailored PMTCT interventions, including resistance-informed treatment and youth-friendly adherence support, are needed to improve maternal outcomes and accelerate elimination of vertical transmission.

Introduction

Over the past two decades, global efforts to scale up universal lifelong antiretroviral therapy (ART) for pregnant and breastfeeding women living with HIV have improved global ART coverage

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from 45% in 2010 to approximately 84% in 2024 [1], contributing to substantial reductions in new pediatric human immunodeficiency virus (HIV) infections [1]. However, recent large funding cuts for HIV programs in sub-Saharan Africa (SSA), which accounts for 83% of new pediatric HIV infections globally [1], threaten to reverse these gains [1]. Vertical transmission from mother to child remains a major public health concern, particularly among adolescent girls and young women (AGYW). Globally, AGYW account for nearly one in four pregnant and breastfeeding women living with HIV [1], yet their retention in care and virological outcomes along the prevention of mother-to-child transmission (PMTCT) care continuum are consistently poorer than those of older women [2,3]. These disparities among AGYW are driven by delays in uptake of antenatal care (ANC), HIV testing, and ART [4], as well as poor adherence and retention in care [5], and predispose them to higher risks of vertical transmission [6], HIV drug resistance, and poor maternal health outcomes [2].

Tanzania illustrates these challenges, with an overall reduction in vertical transmission from 11% in 2019 to 7.6% in 2024 [7]. However, disparities persist among AGYW, especially adolescent mothers aged <20 years, those newly diagnosed during ANC [2], and those with perinatally acquired HIV. The latter group has often been exposed to suboptimal ART during childhood and more often displays treatment fatigue and ART drug resistance, alongside structural barriers such as stigma, limited youth-friendly services, and inadequate social support [4,8], undermining viral suppression and PMTCT effectiveness [9].

Longitudinal data on viremia during pregnancy and postpartum among age-disaggregated subgroups of AGYW, including those with perinatally acquired HIV infection, are very limited. Our study addresses this gap by investigating patterns and determinants of detectable viremia (≥50 copies/mL) in a large cohort of AGYW living with HIV who are enrolled for PMTCT services across three regions of Tanzania.

Methods

Study design and setting

This prospective cohort study was based on de-identified data extracted from routinely collected demographic and clinical health care records of AGYW aged 15-24 years with HIV who were enrolled in routine PMTCT services across three regions of Dar es Salaam, Kagera, and Tabora in Tanzania between January 1, 2018, and December 31, 2020, and followed up until December 31, 2023. Dar es Salaam is predominantly urban, while Kagera and Tabora are primarily rural. Adult (≥15 years) HIV prevalence is estimated at 4.2% in Dar es Salaam, 5.7% in Kagera, and 5.6% in Tabora [10]. Each region registers about 140,000-200,000 new pregnant women in ANC annually, of whom 20-27% are AGYW, and 3-4% are living with HIV [11].

In Tanzania, PMTCT services are integrated with ANC, and 88.9% [12] of pregnant women know their HIV status at their first ANC visits. According to national PMTCT guidelines, women diagnosed with HIV should be promptly enrolled in PMTCT services and initiated on lifelong ART containing a dolutegravir-based integrase inhibitor regimen, while women already on ART are encouraged to adhere to their existing ART regimen [13]. Routine HIV/PMTCT care visits are scheduled throughout pregnancy and postpartum until the infant's HIV status is confirmed at 18 months. Infants diagnosed HIV-positive before 18 months are transitioned to a care and treatment clinic for HIV care, while HIV-exposed but negative infants remain in PMTCT follow-up until final confirmation. During PMTCT/ANC visits, women receive ART adherence counseling, are encouraged to attend with their partners for partner testing, and are provided with psychosocial support from peer mothers, who also remind them of clinic appointments and early infant diagnosis test dates. For pregnant and postpartum women living with HIV, viral load (VL) monitoring follows national treatment guidelines. For women already receiving ART, an HIV VL test is done at the first ANC visit, whereas for women newly initiated on ART, VL testing is done three months after ART initiation. Thereafter, VL monitoring occurs biannually until cessation of breastfeeding and annually thereafter.

Participants and procedures

The study population consisted of pregnant and breastfeeding AGYW aged 15-24 years living with HIV who were enrolled for PMTCT care between January 1, 2018, and December 31, 2020, at 543 public and private health facilities across three regions of Tanzania supported by Management and Development for Health. Participants were identified from routinely collected PMTCT/HIV care records. AGYW included were those with at least one documented VL result during the follow-up period and comprised those newly diagnosed with HIV and initiated on ART during the index pregnancy (defined as the first recorded pregnancy during the enrollment period). We also included AGYW who were already on ART before the index pregnancy, those diagnosed with HIV in childhood (age ≤12 years; a proxy for perinatally acquired HIV infection), and those diagnosed after childhood (age >12 years). The 12-year cutoff was selected on the basis of the study by He *et al.*, which demonstrated the highest discriminatory performance, balancing sensitivity and specificity, minimizing misclassification, excluding early sexual transmission, and capturing most long-term survivors with vertically acquired HIV [14]. We excluded AGYW without any documented VL test following PMTCT enrollment. Participants were followed prospectively from the date of PMTCT enrollment for up to three years or until their last recorded clinic visit, whichever occurred first. Follow-up data were available through December 31, 2023.

Measures

Primary outcome variable

The primary outcome variable was detectable viremia, defined as ≥50 copies/mL at any time during the three-year follow-up period.

Exposure variables

Predictors of detectable viremia were assessed at baseline (PMTCT enrollment) and included sociodemographic, clinical, and laboratory characteristics. These data were extracted from patient medical records, entered into the national HIV care and treatment clinic electronic database, and categorized in accordance with classifications used in previous studies [2]. They included maternal age (15-17, 18-19, 20-24 years), ART status at enrollment and age at HIV diagnosis (already receiving ART and diagnosed with HIV at age ≤12 years; diagnosed with HIV at age >12 years and already receiving ART versus newly initiated on ART at PMTCT enrollment), marital status (single, married/cohabiting, divorced/separated), pregnancy stage (first, second, or third trimester, postpartum), advanced HIV disease status (yes vs no based on CD4 count <200 cells/μL or World Health Organization clinical stage III or IV), and ART regimen (first-line [nonnucleoside reverse transcriptase inhibitor– and integrase inhibitor–based backbone] or second-line [protease inhibitor–based backbone]). Facility-level exposure variables included facility ownership (public, private), number of AGYW in PMTCT care at the facility (low = 1-6, medium = 7-18, high = 19-152) derived from tertiles of the number of pregnant and postpartum AGYW enrolled in care, and facility location (urban, rural).

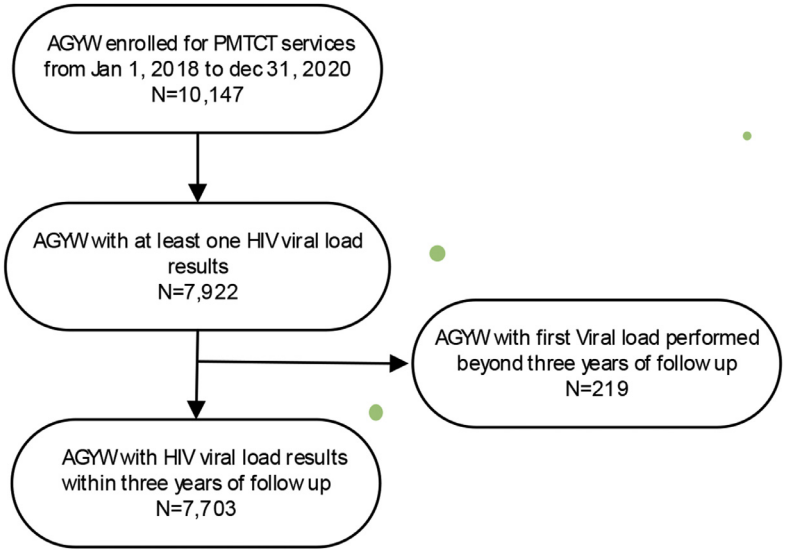

Figure 1. Study flowchart. AGYW enrolled for PMTCT services from January 2018 to December 2020 and followed up through December 2023 in three Tanzanian regions: Dar Es Salaam, Kagera, and Tabora. AGYW, adolescent girls and young women; PMTCT, prevention of mother-to-child transmission.

Statistical analysis

We summarized participants' baseline characteristics using frequencies and percentages. The proportion of missing data was 14.1% for marital status and pregnancy stage, likely due to random incomplete documentation. Quantitative variables were categorized according to clinical relevance, programmatic considerations, and consistency with previous studies. Associations between categorical variables and the outcome were assessed using the chi-squared test. To explore variations within the AGYW population, analyses were stratified by age group at PMTCT enrollment, age at HIV diagnosis ($\leq$12 years, likely perinatally acquired HIV infection vs >12 years, probably sexually acquired HIV infection), and ART status at PMTCT enrollment (already receiving ART vs newly initiated on ART).

We applied a generalized linear model (GLM) for repeated measures to account for within-individual correlation over time. To examine patterns in detectable viremia since PMTCT enrollment, all available VL results collected during the follow-up period were included in the analysis. VL results were categorized into clinically relevant periods: 0-6 months (during pregnancy), 7-12 months (around delivery), 13-24 months (mid-postpartum), and $\geq$25 months (late postpartum). These intervals approximately correspond to phases of pregnancy and the postpartum period. However, VL measurements were obtained as part of routine care and not at standardized time points across individuals. GLMs with a Poisson distribution and log link function were used to estimate adjusted incidence rate ratios (aIRR) and corresponding 95% confidence intervals (CIs) for detectable viremia in relation to baseline exposures. To account for between-participant variability and within-participant correlation due to repeated VL measurements from the same individual at different time points, clustered robust standard errors were applied at the individual level. All analyses were performed using Stata, version 18 (StataCorp, College Station, TX).

Results

Sample characteristics

Between January 1, 2018, and December 31, 2020, a total of 10,147 AGYW were enrolled for PMTCT services at the study facilities and followed up for three years until December 31, 2023. Of these, 7922 (78.1%) had at least one recorded VL result. We excluded 219 (2.8%) AGYW whose first VL test was performed beyond three years of follow-up. In total, 7703 AGYW with at least one VL result within the follow-up period were included in the present analysis (Figure 1).

The mean age at PMTCT enrollment was 21.5 years (standard deviation 2.2 years), comprising 376 (4.9%) adolescents aged 15-17 years, 1167 (15.1%) aged 18-19 years, and 6160 (80.0%) young women aged 20-24 years (Table 1). At PMTCT enrollment, 3405 (44.2%) AGYW were newly diagnosed and initiating ART, while the remaining (n=4298) were already receiving ART; among these, 303 (3.9%) AGYW had been diagnosed with HIV in childhood, and 3995 (51.9%) AGYW were diagnosed after childhood. HIV diagnosis in childhood was most common among adolescents aged 15-17 years (83; 22.1%). Across all age groups, the majority (>80%) of the AGYW enrolled in PMTCT care late (in the second/third trimester or postpartum), and about half received care in rural settings (Table 1).

Patterns in VL during the three-year follow-up period

Over the three-year follow-up from PMTCT enrollment, a total of 32,442 VL tests were performed among the 7703 AGYW included in the analysis, with a median of five tests per woman (interquartile range 3-7). Overall, the proportion with detectable viremia was 13.5% (95% CI: 13.1-13.9%), which was higher among adolescents aged 15-17 years (20.4%; CI: 18.5-22.5%) than those aged 18-19 years (16.7%; CI: 15.7-17.8%) and young women aged 20-24 years (12.5%; CI: 12.1-12.9%). Across the three age groups, the proportion with viremia declined by almost half from peak levels during pregnancy to the time of delivery; however, it remained consistently >10% throughout the postpartum period (Figure 2).

When analysis was stratified by ART status at PMTCT enrollment and age at HIV diagnosis (indicating perinatal versus sexual HIV acquisition), AGYW diagnosed with HIV in childhood (and already receiving ART) had the highest proportion of viremia, with an average of 28.8% (CI: 26.5-31.3%) remaining viremic for a minimum of 36 months of follow-up across the pregnancy and postpartum periods (Figure 3).

In contrast, the proportion of AGYW with viremia was lower among AGYW diagnosed with HIV after childhood, including both

Table 1
Baseline characteristics of 7703 AGYW at enrollment into PMTCT services across three regions of Tanzania, by age group.

Characteristics	Total N = 7703 n (column %)	15-17 years N = 376 n (column %)	18-19 years N = 1167 n (column %)	20-24 years N = 6160 n (column %)	*P*-value
ART status and age at HIV diagnosis					0.001
Already receiving ART, diagnosed during childhood[a]	303 (3.9%)	83 (22.1%)	93 (8.0%)	127 (2.1%)	
Already receiving ART, diagnosed after childhood[a]	3995 (51.9%)	122 (32.4%)	460 (39.4%)	3413 (55.4%)	
Newly initiated on ART	3405 (44.2%)	171 (45.5%)	614 (52.6%)	2620 (42.5%)	
Marital status					0.001
Single	2098 (27.2%)	187 (49.7%)	363 (31.1%)	1548 (25.1%)	
Married/Cohabiting	4195 (54.5%)	134 (35.6%)	605 (51.8%)	3456 (56.1%)	
Divorced/Separated	326 (4.2%)	8 (2.1%)	44 (3.8%)	274 (4.4%)	
Missing	1084 (14.1%)	47 (12.5%)	155 (13.3%)	882 (14.3%)	
Pregnancy stage					0.093
First trimester	1219 (15.8%)	46 (12.2%)	187 (16.0%)	986 (16.0%)	
Second trimester	3468 (45.0%)	164 (43.6%)	555 (47.6%)	2749 (44.6%)	
Third trimester	888 (11.5%)	53 (14.1%)	124 (10.6%)	711 (11.5%)	
Postpartum	1043 (13.5%)	50 (13.3%)	139 (11.9%)	854 (13.9%)	
Missing	1085 (14.1%)	63 (16.8%)	162 (13.9%)	860 (14.0%)	
Advanced HIV disease					0.001
No	6520 (84.6%)	288 (76.6%)	996 (85.3%)	5236 (85.0%)	
Yes	1183 (15.4%)	88 (23.4%)	171 (14.7%)	924 (15.0%)	
ART regimen core					0.001
NNRTI or INSTI (first line)	7603 (98.7%)	363 (96.5%)	1148 (98.4%)	6092 (98.9%)	
PI (second line)	100 (1.3%)	13 (3.5%)	19 (1.6%)	68 (1.1%)	
Facility volume of AGYW in PMTCT care[b]					0.027
Low	440 (5.7%)	26 (6.9%)	67 (5.7%)	347 (5.6%)	
Middle	1670 (21.7%)	78 (20.7%)	293 (25.1%)	1299 (21.1%)	
High	5593 (72.6%)	272 (72.3%)	807 (69.2%)	4514 (73.3%)	
Facility ownership					0.039
Public	7496 (97.3%)	369 (98.1%)	1,147 (98.3%)	5980 (97.1%)	
Private	207 (2.7%)	7 (1.9%)	20 (1.7%)	180 (2.9%)	
Facility location					0.001
Urban	3786 (49.1%)	173 (46.0%)	512 (43.9%)	3101 (50.3%)	
Rural	3917 (50.9%)	203 (54.0%)	655 (56.1%)	3059 (49.7%)	

Data are presented as n (%).
Abbreviations: AGYW, adolescent girls and young women; ART, antiretroviral treatment; HIV, human immunodeficiency virus; INSTI, integrase strand transfer inhibitor; NNRTI, non-nucleoside reverse transcriptase inhibitor; PI, protease inhibitor; PMTCT, prevention of mother-to-child transmission.
[a] After childhood=age >12 years.
[b] Facility volume was defined on the basis of the number of pregnant AGYW enrolled per facility from 2018 to 2020. The cutoff (low, middle, and high) was generated in Stata to provide an approximately equal number of AGYW per group.

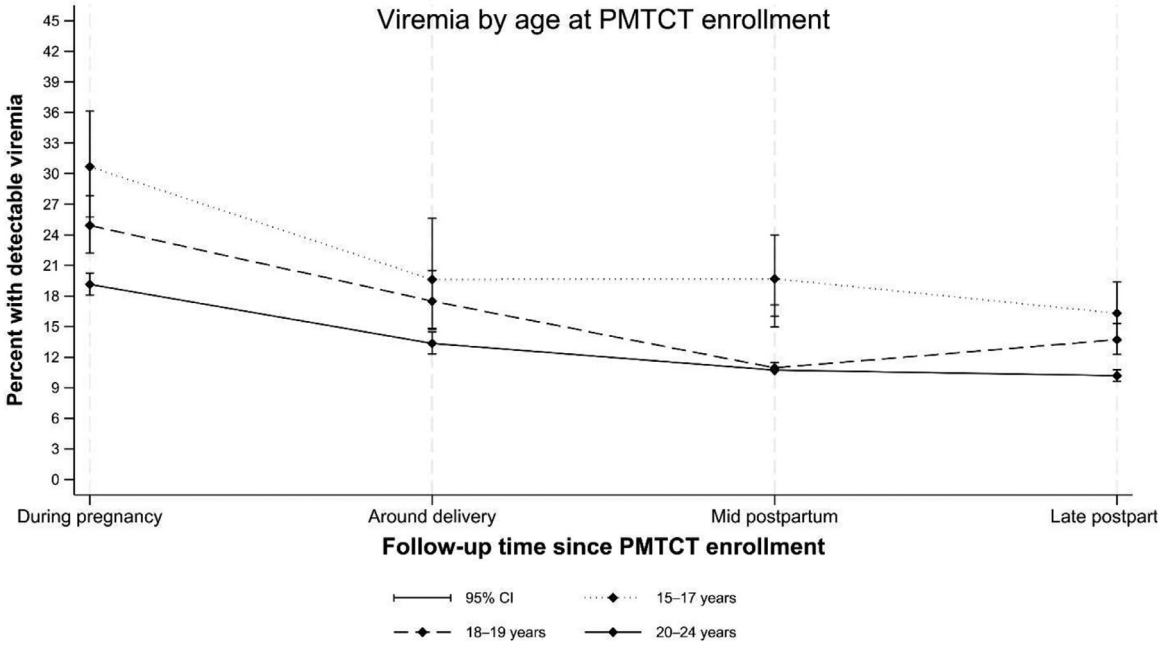

Figure 2. Trends in detectable viremia for 7703 AGYW enrolled for PMTCT services in three regions in Tanzania during pregnancy and postpartum from January 2018 to December 2020, with follow-up through December 2023, stratified by age at PMTCT enrollment. AGYW, adolescent girls and young women; CI, confidence interval; PMTCT, prevention of mother-to-child transmission.

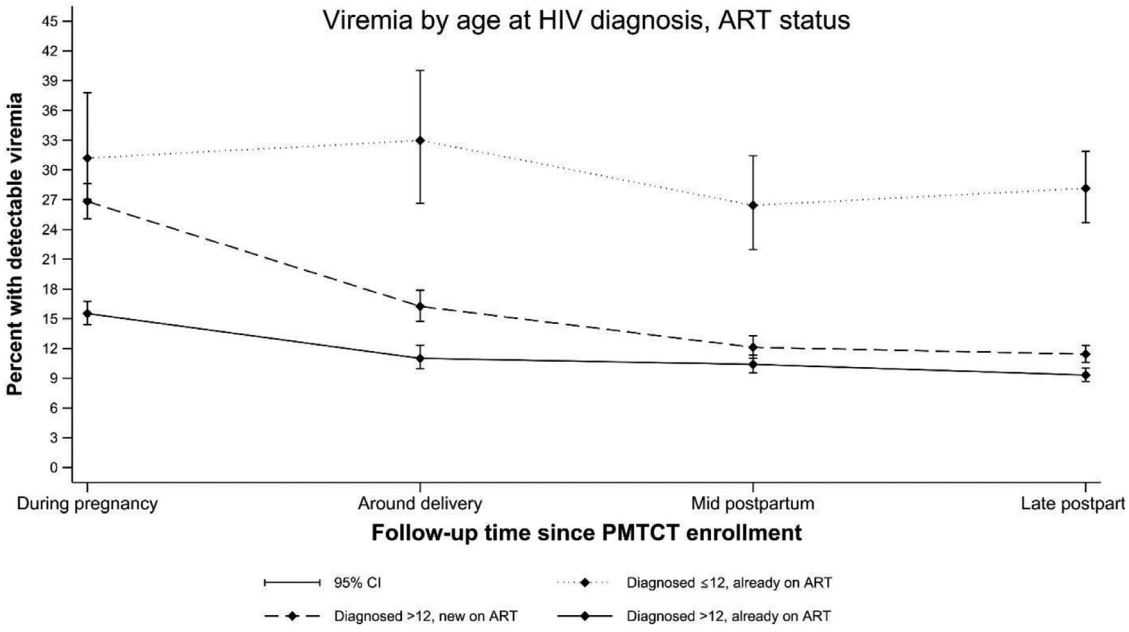

Figure 3. Trend in detectable viremia among 7703 AGYW enrolled in PMTCT services across three regions in Tanzania during pregnancy and postpartum from January 2018 to December 2020, with follow-up through December 2023, stratified by age at HIV diagnosis (indicating perinatally vs sexually acquired HIV) and ART status at PMTCT enrollment. AGYW, adolescent girls and young women; ART, antiretroviral therapy; CI, confidence interval; HIV, human immunodeficiency virus; PMTCT, prevention of mother-to-child transmission.

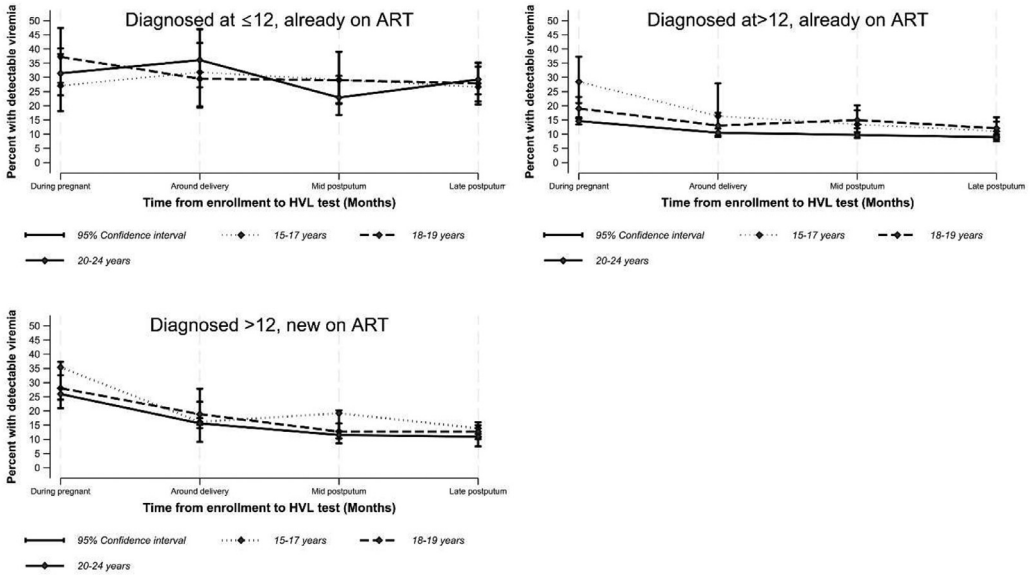

Figure 4. Trend in detectable viremia among 7703 AGYW enrolled in PMTCT services across three regions in Tanzania during pregnancy and postpartum from January 2018 to December 2020, with follow-up through December 2023, stratified by age at HIV diagnosis, ART status, and age at PMTCT enrollment. AGYW, adolescent girls and young women; ART, antiretroviral therapy; HIV, human immunodeficiency virus; HVL, HIV viral load; PMTCT, prevention of mother-to-child transmission.

those already receiving ART (mean viremic proportion 11.0%; CI: 10.6-11.5%) and those newly initiated on ART at PMTCT enrollment (15.2%; CI: 14.6-15.8%). Over the PMTCT cycle, the proportion with viremia declined by the time of delivery among those diagnosed after childhood by approximately 40% in AGYW already receiving ART and by 58% among AGYW newly initiated on ART; however, after delivery, it stagnated at 10% among AGYW who did not achieve viral suppression.

Figure 4 shows viremia trends by age at PMTCT enrollment, stratified by whether AGYW were diagnosed in childhood (and already receiving ART), diagnosed after childhood and already receiving ART, or newly diagnosed and initiated on ART during the index pregnancy. We found that AGYW diagnosed in childhood (and receiving ART) were those most at risk of persistent viremia throughout follow-up, particularly those aged 18-19 and 20-24 years (29.8% [CI: 25.5-34.5%] and 29.4% [CI: 25.9-33.2%], respectively). In contrast, among AGYW diagnosed after childhood, the youngest age group (15-17 years) had the highest proportion of detectable viremia at enrollment. This was true for both those already receiving ART and those newly initiated on ART. Although

Table 2
Predictors of detectable viremia (≥50 copies/mL) among 7703 AGYW enrolled in PMTCT care during pregnancy/postpartum and followed up for at least three years.

Characteristics	15-17 years (n = 326)		18-19 years (n = 93)		20-24 years (n = 4499)	
	Crude IRR (95% CI)	Adjusted IRR (95% CI)	Crude IRR (95% CI)	Adjusted IRR (95% CI)	Crude IRR (95% CI)	Adjusted IRR (95% CI)
ART status and age at HIV diagnosis						
Already receiving ART, diagnosed during childhood	1.75 (1.14-2.69)	1.37 (0.86-2.19)	2.13 (1.58-2.87)	1.45 (1.03-2.04)	2.90 (2.29-3.69)	1.65 (1.20-2.26)
Already receiving ART, diagnosed after childhood	1 [referent][a]	1 [referent]	1 [referent][a]	1 [referent][a]	1 [referent][a]	1 [referent][a]
Newly initiated on ART	1.24 (0.85-1.80)	1.42 (1.00-2.02)	1.14 (0.93-1.41)	1.20 (0.97-1.49)	1.44 (1.31-1.57)	1.45 (1.30-1.62)
Marital status						
Single	1 [referent]		1 [referent][a]	1 [referent]	1 [referent][a]	1 [referent]
Married/cohabiting	0.78 (0.54-1.12)		0.71 (0.59-0.86)	0.88 (0.71-1.09)	0.79 (0.72-0.86)	0.94 (0.85-1.04)
Divorce/separated	0.52 (0.20-1.40)		0.62 (0.37-1.03)	0.87 (0.52-1.46)	0.66 (0.51-0.85)	0.92 (0.70-1.20)
Pregnancy stage						
First trimester	1 [referent]		1 [referent]		1 [referent]	1 [referent]
Second trimester	1.30 (0.77-2.20)		0.98 (0.75-1.28)		1.17 (1.02-1.34)	1.11 (0.97-1.27)
Third trimester	1.59 (0.84-3.02)		0.94 (0.65-1.34)		1.06 (0.89-1.26)	1.12 (0.94-1.32)
Postpartum	1.37 (0.72-2.59)		1.01 (0.71-1.44)		0.91 (0.77-1.09)	1.08 (0.91-1.27)
Advanced HIV disease						
No	1 [referent]	1 [referent]	1 [referent] [a]	1 [referent]	1 [referent] [a]	1 [referent]
Yes	1.34 (0.93-1.91)	1.09 (0·72-1·65)	1.51 (1.18-1.93)	1·13 (0·85-1.51)	1.14 (1.00-1.30)	1.03 (0.89-1.20)
ART regimen core						
NNRTI or INSTI (first line)	1 [referent][a]	1 [referent][a]	1 [referent][a]	1 [referent][a]	1 [referent][a]	1 [referent][a]
PI (second line)	2.89 (1.93-4.33)	1.96 (1.23-3.13)	3.42 (2.43-4.82)	2.34 (1.53-3.58)	3.92 (3.18-4.83)	2.64 (1.85-3.78)
Facility ownership						
Public	1 [referent]		1 [referent]		1 [referent]	1 [referent]
Private	1.27 (0.53-3.02)		1.14 (0.51-2.52)		1.24 (0.96-1.59)	1.17 (0.91-1.50)
Facility location						
Urban	1 [referent][a]	1 [referent][a]	1 [referent][a]	1 [referent][a]	1 [referent][a]	1 [referent][a]
Rural	0.39 (0.28-0.55)	0·42 (0·30-0·61)	0.60 (0.49-0.72)	0·67 (0·55-0·81)	0.60 (0.54-0.66)	0.61 (0.55-0.68)

Abbreviations: AGYW, adolescent girls and young women; ART, antiretroviral treatment; CI, confidence interval; HIV, human immunodeficiency virus; INSTI, integrase strand transfer inhibitor; IRR, incidence rate ratio; NNRTI, non-nucleoside reverse transcriptase inhibitor; PI, protease inhibitor; PMTCT, prevention of mother-to-child transmission.
[a] Indicates statistically significant *P*-values.

the proportion of AGYW with viremia declined over time across all age groups, it plateaued at approximately 10% after delivery.

Predictors of detectable viremia among pregnant and postpartum AGYW living with HIV

Table 2 shows predictors of detectable viremia stratified by age group and adjusted for duration of ART at PMTCT enrollment, marital status, pregnancy stage, advanced HIV disease, ART regimen, facility volume and ownership, and residence. Patterns were broadly consistent across age groups, with some variation in effect sizes and additional age-specific associations. Compared with AGYW who were diagnosed after childhood and already receiving ART at PMTCT enrollment, the risk of viremia was higher among AGYW who were diagnosed in childhood and receiving ART (aIRR: 1.45 [CI: 1.03-2.04] for ages 18-19 and 1.65 [CI: 1.20-2.26] for ages 20-24), as well as AGYW newly initiated on ART at PMTCT enrollment (1.42 [CI: 1.00-2.02] for ages 18-19 and 1.45 [CI: 1.30-1.62] for ages 20-24).

Receipt of a second-line regimen (with a protease inhibitor backbone) was associated with higher risk of viremia, and this association increased with age (aIRR: 1.96 [CI: 1.23-3.13] for ages 15-17, 2.34 [CI: 1.53-3.58] for ages 18-19, and 2.64 [CI: 1.83-3.78] for ages 20-24), indicating increasing resistance despite young age and receipt of PMTCT counseling (Table 2).

We also found significant differences by residential setting, with rural AGYW having a lower risk of detectable viremia compared with urban AGYW across age groups (aIRR: 0.42 [CI: 0.30-0.61] for ages 15-17, 0.67 [CI: 0.55-0.81] for ages 18-19, and 0.61 [CI: 0.55-0.68] for ages 20-24). This association was consistent regardless of ART status at enrollment, including among those diagnosed in childhood (Table 2).

Discussion

In this large cohort of >7000 pregnant and postpartum AGYW living with HIV enrolled in PMTCT services in Tanzania, we observed persistently high levels of detectable viremia in >10% of participants throughout the three years of PMTCT follow-up, averaging at 13.5%. We observed substantial heterogeneity by age and ART status at enrollment and age at HIV diagnosis, with younger age and HIV diagnosis in childhood associated with the highest risks of viremia over the three years of PMTCT follow-up. These high proportions of viremic AGYW threaten progress toward elimination of vertical HIV transmission and ending acquired immunodeficiency syndrome in children [15], underscoring a persistent gap in virological control and adequate support for AGYW.

Adolescents aged 15-17 and 18-19 years exhibited consistently high risks of detectable viremia throughout pregnancy and postpartum, despite enhanced counseling as part of PMTCT care. The observed age disparity in the risk of viremia is consistent with findings from other settings [16,17], indicating persistent adherence challenges in these young mothers, not thoroughly addressed by the current PMTCT care. Poor virological outcomes among adolescents are well documented and associated with increased risks of disease progression, drug resistance, and onward HIV transmission to both infants and sexual partners [18,19]. Multiple structural and individual factors contribute to these disparities, including delayed ANC engagement, limited decision-making power, fear of HIV disclosure and partner reaction, heightened risk of intimate partner violence, low male partner involvement in PMTCT, and limited access to adolescent-friendly health services [20–22]. Addressing gender inequality and ensuring equitable access to care are critical to improving ART adherence, enhancing virological outcomes, and promoting better health among AGYW living with HIV.

AGYW diagnosed with HIV in childhood and presumed to have acquired the infection perinatally had the highest and most persistent burden of viremia. This burden remained consistently above 25% throughout pregnancy and postpartum. This pattern likely reflects treatment fatigue, cumulative adherence challenges, and possibly drug resistance mutations among these AGYW with perinatally acquired HIV and long-term ART exposure, as reported in other SSA settings [23]. These findings highlight the need for better-tailored care for this growing population of AGYW entering pregnancy with longstanding HIV infection and often suboptimal ART experiences. PMTCT care should include nonjudgmental sexual and reproductive health services, integrated mental health care, adolescent-friendly PMTCT services, strengthened adherence and psychosocial peer support programs, and resistance-informed treatment strategies [24–26]. In contrast, AGYW diagnosed after childhood and those newly initiated on ART at PMTCT enrollment had notable declines in viremia risk from pregnancy to the time of delivery, indicating some positive response to PMTCT care during pregnancy [27]. Nevertheless, viremia plateaued at 10% in the late postpartum period. Similar patterns have been reported in South Africa and Malawi, where adolescents who initiated ART during pregnancy achieved viral suppression but continued to have poorer outcomes than older women [28,29].

Second-line ART use was also strongly associated with a 2-3 times higher risk of detectable viremia across all age groups, consistent with findings in previous studies. This indicates that the problems leading to the switch from first-line regimens [30–32], such as adherence difficulties, treatment fatigue, and drug resistance mutations following prolonged ART exposure, have not been adequately addressed [8,33]. This finding highlights the importance of early and proactive identification of treatment failure and possible drug resistance, as well as intensified adherence support for AGYW with prolonged ART exposure and a history of failure to the first-line treatment regimen.

The finding that AGYW residing in rural settings were 33-58% less likely to be viremic compared with their urban counterparts is consistent with another Tanzanian PMTCT study [34] and may reflect stronger social networks, community support, lower patient volumes, or closer follow-up by community and facility health care workers at rural health facilities. By contrast, AGYW in urban informal settlements may face greater economic pressures, higher mobility, limited access to social support, and competing everyday survival demands compromising ART adherence.

Overall, our results raise an overarching concern that, while Tanzania has successfully expanded ART coverage in PMTCT services, certain subgroups of AGYW remain unable to achieve viral suppression [35]. Recent cuts in global HIV funding threaten to further widen these gaps by potentially limiting access to essential services and support 1. There is therefore an urgent need for innovative, tailored, and intensified care engagement, adherence support, and effective follow-up for these vulnerable subgroups of underserved AGYW to achieve long-term virological control and minimize the risk of vertical transmission [36].

Strengths and limitations

A key strength of this study is our access to prospective data from one of the world's largest cohorts of AGYW in routine PMTCT care, which enhances the generalizability of the findings. We included all available data, and 76% of participants had multiple VL measurements, allowing for the assessment of longitudinal virological outcomes and real-time estimates of detectable viremia over at least three years. Analyses stratified by ART status at PMTCT enrollment and age (enabling comparison between pregnant adolescents and slightly older young women) and the classification of perinatal versus sexual HIV acquisition provide valuable insights into particularly vulnerable subgroups of AGYW who require greater attention and support. Furthermore, the inclusion of 543 health facilities across the country is likely to capture variations in awareness, social norms, social support, and access to services among rural and urban AGYW, further strengthening the representativeness and applicability of the results.

Limitations include the exclusion of AGYW without documented VL results, which may have introduced selection bias. While available baseline characteristics were largely comparable, unmeasured factors (*e.g.*, those leading to poorer uptake of services) could mean that our results are overly optimistic. Use of a cutoff at age 12 to distinguish between perinatal and heterosexual HIV acquisition was based on He *et al.* [14]. However, this approach may result in misclassification, as some perinatally acquired infections, particularly among long-term non-progressors, may be diagnosed later in adolescence. The absence of data on maternal ART history limited more precise classification. Additionally, pregnancy may unmask immunological decline among adolescents newly initiated on ART. Any misclassification would likely attenuate observed differences between the groups. Furthermore, we lacked data on factors not routinely collected in health care settings that influence ART adherence and virological outcomes among AGYW, such as HIV status disclosure, stigma, family support, peer mother support, mental health, and socioeconomic factors, all of which could bias our results toward the null hypothesis of no difference between comparison groups. Finally, given the observational nature of our study and reliance on routinely collected data, causal inference could not be made, and the observed associations may be influenced by unmeasured confounding factors not captured in routine health records.

Conclusion

Nearly 15 years after the rollout of universal ART for pregnant and postpartum women living with HIV in Eastern Africa, effective control of viral replication among AGYW in PMTCT services remains inadequate, particularly among younger adolescents, those with perinatally acquired HIV, those receiving second-line treatment, and AGYW in urban settings. Persistent viremia in these AGYW jeopardizes their health and their infants' HIV-free survival. The disparities observed across subgroups in this Tanzanian cohort (including young adolescents, perinatally infected AGYW, those receiving second-line ART, and urban dwellers) highlight the need for differentiated, adolescent-responsive PMTCT interventions, including adolescent-friendly services, integrated mental health support, intensified adherence interventions, and resistance-informed ART management, to improve maternal outcomes and accelerate progress toward the elimination of vertical HIV transmission.

Declaration of competing interest

The authors have no competing interests to declare.

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Ethical approval

Ethical approval was granted by the Tanzania National Health Research Ethics Committee at the National Institute for Medical Research (NIMR/HQ/R.8a/Vol.IX/4637), and informed consent was waived because of the use of de-identified data from routine electronic health care records. Ethical approval for data analysis was also granted by the Swedish Ethical Review Authority (2024-05745-01).

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Author contributions

RFU contributed to the literature search, study design and methods, project administration, data extraction, data analysis, data interpretation, writing, tables and figures, and review and editing of the manuscript. CF and AM contributed to the study design and methods, data extraction, data analysis, data interpretation, writing, tables and figures, and review and editing of the manuscript. DM, BS, HS, WM, LM, AK, and MS contributed to the project administration, data abstraction, data analysis, data interpretation, and review and editing of the manuscript. EL, HN, GB, CK, AEK, AME, and GWL contributed to the literature search, study design and methods, data analysis, data interpretation, and review and editing of the manuscript. AEK, AME, GWL, and HN contributed extensive edits and senior guidance to the manuscript. RFU, CF, AM, and GWL had access to and verified the underlying data. AEK and AME are joint senior authors. All authors had full access to all study data and had final responsibility for the decision to submit for publication.

Disclaimer

The findings and conclusions of this study are those of the authors and do not necessarily represent the official position of the funding agencies.

Data sharing

We used data extracted from routine clinical care records for patients with HIV stored in the Tanzanian national HIV care and treatment clinic database. Individual de-identified participant data used for this study, a data dictionary defining each field in the set, and the study protocol will be made available upon request via email to the corresponding author's institution (mdh@mdh.or.tz). The data can be accessed from the date of publication until September 30, 2025, with investigator support after submitting a data request form, a study proposal with ethical approval and a copy of an ethical clearance certificate from the Tanzanian National Institute for Medical Research (https://www.nimr.or.tz/), and a permission letter from the Permanent Secretary of the Tanzanian Ministry of Health, Community Development, Gender, Elders and Children (via https://www.moh.go.tz/en/), which is the primary custodian of these data.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijid.2026.108749.

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