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Viral Load Non-Suppression and Low-Level Viremia among adults on ART in Mozambique: analysis of the 2021 Population-Based HIV Impact Assessment (INSIDA)

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Abstract

Viral load monitoring is essential for treatment success among Mozambique's 2.5 million PLHIV and supports global epidemic control. Viral load non-suppression (≥ 1,000 copies/mL) undermines individual health and hinders national HIV control efforts. Updated clinical guidelines advocate for a viral load of < 200 copies/mL, offering additional benefits including reduced risk of virological failure. Understanding factors associated with non-suppression and low-level viremia (200–999 copies/mL) enables targeted program interventions.

We conducted a secondary analysis of viral load results for PLHIV on antiretroviral treatment (ART) from the 2021 Mozambique Population-based HIV Impact Assessment database. The results were divided into sub-groups to analyze viral load non-suppression, low-level viremia (200–999 copies/mL), and low viral load results (< 200 copies/mL) which we consider as undetectable for this analysis. We reported weighted estimates of socio-demographic and treatment indicators.

Among 1,321 PLHIV on ART, 9.9% had viral load non-suppression (VLNS) and 7.1% had low-level viremia (LLV). Longer duration of medication dispensation (≥ 3 months - aOR 0.51, 95% CI: 0.28–0.92) and older age (≥ 50 years - aOR 0.27 CI: 0.12–0.59) reduced VLNS odds. Males showed significantly higher odds of both VLNS (aOR 2.16, 95% CI: 1.29–3.62) and LLV (aOR 1.62, 95% CI: 1.08–2.43) compared to females. Though VLNS and LLV were low in the study population, this analysis found specific groups were more likely to have higher viral load results. Men, a priority population in Mozambique, are the only group which have strong association with both LLV and VLNS, providing evidence for the continued focused on male engagement in the country.

Introduction

Viral load suppression (VLS), defined by the World Health Organization (WHO) as an HIV viral load less than 1,000 copies/mL, is one of three key targets established globally for achieving HIV epidemic control by 2025 and serves as the final goal in the 95-95-95 cascade [1]. This goal is defined as 95% of people living with HIV (PLHIV) on antiretroviral treatment (ART) achieving viral suppression, equivalent to 86% of all PLHIV [1]. Viral load monitoring is a critical component of the treatment as prevention approach, as individuals who have achieved VLS have a substantially reduced risk of sexual HIV transmission, and reaching 95% suppression among PLHIV has been prioritized in the Mozambican National Strategic Plan for the HIV/AIDS Response 2021–2025 [2–4]. Viral load testing also monitors ART efficacy, with growing evidence showing that persistent viral load results ≥ 200 copies/mL are related to adverse outcomes including virologic failure [5].

Mozambique has made tremendous progress in the last ten years in the improvement of VLS among PLHIV. In 2015, 67.8% of adults aged 15–49 years on antiretrovirals achieved VLS in Mozambique, well below the 90% target for 2020 [6, 7]. Results from the 2021 Mozambique Population-based HIV Impact Assessment (INSIDA) showed marked improvements; among the same group, 88.0% achieved VLS; 90.4% among women and 87.6% among men [8]. However, when suppression is calculated based off all PLHIV, not just those on ART, only 64.1% had achieved VLS, showing that significant gaps remain in achieving population-based the 95-95-95 targets.

Advances in laboratory technologies and improved ART efficacy have lowered the viral load detection standards, allowing a more detailed analysis of treatment outcomes at viral load levels below 1,000 copies/mL. One benchmark of viral load is focused on results between 200 and 1,000 copies/mL, known as low-level viremia (LLV). Related to the risk of virologic failure, or the failure of medication to effectively suppress HIV virus replication, as well as all-cause mortality when compared to patients with undetectable viral load, LLV is an emerging concern for clinicians and policy makers [5, 9]. LLV has been associated with non-adherence, older age, and male sex, and has never been studied in a national survey in Mozambique [10, 11].

The objective of this paper is to describe the distribution of viral load results among all adult PLHIV (aged ≥ 15 years) on ART in Mozambique and to identify sociodemographic and HIV treatment factors associated with viral load non-suppression (VLNS), or vial load results > 1,000 copies/mL, and LLV using data from 2021 Mozambique Population-based HIV Impact Assessment (INSIDA). The findings can be used to inform interventions to improve viral load tracking and decrease virologic failure in patients on ART.

Methods

Overview

The INSIDA 2021 was a nationally representative household survey conducted from April 2021 to February 2022, with a four-stage cluster sampling frame of 11,375 randomly selected dwelling units from 311 enumeration areas. Eligible respondents, individuals aged 15 years and older who slept the previous night in the dwelling unit, were interviewed using an additional individual standardized questionnaire, which included questions on household composition, socio-economic status, and HIV testing, care and related risk behaviors. The interview was followed by a venous blood draw for those who consented. Of the 17,105 eligible participants interviewed (unweighted response rate 85.9%), 14,488 had blood drawn (unweighted response rate 84.7%), of whom 2,038 tested HIV-positive. Of the participants tested HIV-positive, 1,321 respondents, or the analytical population for this analysis, self-reported being on ART or had antiretroviral medications (ARV) detected in their blood sample (Fig. 1) [8]. Self-reported as aware and on ART is based on participants with no missing VL and ARV status and not previously diagnosed with HIV. Individuals who did not disclose their status were removed from this analysis due to the co-variates focus on HIV-care questions in multivariate analysis.

Procedures for HIV, Viral Load, and ARV Testing

All tests were performed at the National Institute of Health (INS) central lab. The HIV-1 viral load (HIV RNA copies per mL) of all confirmed HIV-positive participants was measured using the Roche COBAS®AmpliPrep/COBAS® TaqMan® (CAP/CTM), COBAS® 4800 (Roche Molecular Diagnostics, Branchburg, New Jersey, United States). Plasma was tested using the HIV-1 Test, (version 2.0 for CAP/CTM), and DBS was tested using the Roche Free Virus Elution assay with a separate test definition file (TDF) optimized by Roche for DBS. Confirmed positive specimens were processed into dried blood spots and plasma aliquots and sent to the INS in Maputo for viral load and CD4 testing and storage. Results allowed distinction between VLNS, LLV, and finally results below 200 copies/mL.[12] The same sample was screened for detectable amounts of atazanavir, lopinavir, efavirenz, and dolutegravir, a combination of which make up 99.9% of all antiretrovirals in health facilities with electronic medical records [13].

Data management and analysis

To understand the distribution of VLS and associated factors in Mozambique, viral load results were analyzed in three ways. First, results were separated into three categories to analyze distribution as seen in Table 1. Second, for bivariate and multivariate analysis, a binary variable was created to indicate VLNS, ≥ 1,000 copies/mL, among all PLHIV on ART. Third, among those suppressed (< 1,000 copies/mL), results were reclassified as < 200 copies/mL or 200–999 copies/mL, creating a LLV variable to examine determinants of virologic failure.

All analyses applied sample weights to account for complex survey design, using Stata 18 SE svy commands with Taylor Series Linearization. Estimates are weighted, while case numbers remain unweighted. Multivariate logistic regression assessed information captured from the individual interviews, including socio-demographic (sex, age, residence, region, province, wealth, education, marital status) and HIV-treatment variables (medical visits within 12 months, years on ART, supply duration, ARV regimen changes, missed doses). Multivariate models were run in two stages, sociodemographic

and treatment, each controlling for age and sex and are included in the supplemental materials (Supplemental Table 1, Supplemental Table 2). The Stata command “testparm” and F-value comparisons guided elimination of variables. This two-stage approach allows comparison of adjusted odds ratios and clarifies sociodemographic versus treatment effects on viral load outcomes.

Table 1 presents viral load distribution by covariates with 95% confidence intervals (95% CI) and CD4 categories to illustrate links between viral load and immune health. Bivariate and multivariate logistic regression results (Table 2 and 3) examine relationships between LLV, VLNS, sociodemographic factors, and treatment indicators, reporting odds ratios (ORs), adjusted ORs (aORs), and 95% CIs. In this table 10 cases were removed due to missing responses on sociodemographic covariates. Table 2 is the comparison on VLNS to VLS (N = 1,321), while Table 3 is a comparison of LLV to the undetectable sample (N = 1,211). The multivariate analysis was conducted for each table (VLNS and LLV) two times, once with all the significant variables from the bivariate analysis for both groups for ease of comparison, and finally with only the significant variables from the specific analysis. This second analysis is considered the final multivariate model for this manuscript. Full analysis output is available in the supplemental tables.

Ethics approval

The INSIDA survey protocol, consent forms, screening forms, referral forms, recruitment materials, and questionnaires were reviewed and approved by the National Health Bioethics Committee (CNBS) and the institutional review boards of Columbia University Medical Center. In addition, the study protocol was reviewed and approved by the CDC Institutional Review Board protocol #7258 (See 45 C.F.R. part 46.114; 21 C.F.R. part 56.114) and the study was conducted in accordance with the Declaration of Helsinki. Prior to the interview and blood draw, all eligible participants provided informed written consent and additional parental consent was given for respondents aged 15 to 17 years. Supplementary information on the study procedures for confidentiality can be found in the INSIDA report [8].

Results

Distribution of Viral Load by Sociodemographic Characteristics and HIV Treatment Factors

Among the 1,321 adult PLHIV on ART, 9.9% had VLNS, 7.1% had LLV, and 83.1% had a undetectable result < 200 copies/mL (Table 1). A larger proportion of adults with VLNS and LLV were male (11.9% and 9.4%), residing in the northern provinces of Cabo Delgado, Niassa, and Nampula (VLNS: 12.2%, LLV: 9.6%), and with a CD4 count of less than 200 (VLNS: 24.3%, LLV: 8.1%). VLNS was observed more often among never married adults (15.6%) and LLV among widowed adults (9.6%). Importantly, VLNS was more frequent among adults without education (12.7%) and adults between the ages of 15 and 24 years (19.6%) and LLV was more frequent for adults aged ≥ 50 years (8.6%) and those with secondary or more education (8.6%).

Within treatment indicators, more PLHIV with VLNS and LVV responded “Don’t Know” for multiple categories, including months of ARV supplied (33.2% and 13.8%, respectively), ARV regimen changed (14.9% and 10.6%), and travel duration from home at their last HIV care visit (11.5% and 12.6%). For years on ART, more adults with LLV responded “Don’t Know” (10.7%), while more adults with VLNS were on ART less than two years (12.8%). Finally, for the number of days missed taking ARVs in the last 30 days a larger share of those with VLNS responding “Don’t Know” (23.3%), while more individuals with LLV missed four days (11.3%). These differences should be considered with frequent overlapping confidence intervals due to the small sample sizes.

Table 1

Viral load non-suppression (≥ 1000 copies/mL), low-level viremia (200–999 copies/mL), and undetectable results (< 200 copies/mL) by sociodemographic and clinical characteristics, adults 15 years and older, Mozambique 2021

	Non-Suppressed VLNS (n = 110)		Low-level viremia LLV (n = 84)		Undetectable (n = 1,127)			
Table 1: Characteristic	**≥ 1,000 copies/mL**		**200–999 copies/mL**		**< 200 copies/mL**		**N**	**Chi-Sq p-value**
	Percent	**95% CI**	**Percent**	**95% CI**	**Percent**	**95% CI**		
Sex								
Male	11.9	[8.9–14.8]	9.4	[6.6–12.2]	78.7	[74.7–82.7]	389	95.69
Female	8.8	[5.9–11.8]	5.9	[4.3–7.5]	85.2	[82.0-88.4]	932	3.88
Age Group								
15–24	19.6	[10.8–28.3]	5.9	[0.4–11.5]	74.5	[65.4–83.6]	101	306.65
25–34	10.8	[7.2–14.3]	5.7	[2.8–8.6]	83.5	[79.2–87.9]	308	2.74
35–49	10.0	[7.4–12.5]	7.5	[4.1–10.9]	82.5	[78.1–87.0]	593	*
≥ 50	3.2	[0.8–5.5]	8.6	[2.6–14.6]	88.2	[82.0-94.5]	319	
Area of Residence								
Urban	9.3	[7.1–11.5]	6.8	[4.2–9.4]	83.9	[80.7–87.2]	671	6.56
Rural	10.4	[6.9–13.8]	7.4	[4.2–10.5]	82.3	[78.2–86.4]	650	0.15
Geographic Region of Residence								
North *(Cabo Delgado, Nampula, Niassa)*	12.2	[7.9–16.4]	9.6	[6.1–13.0]	78.3	[73.0-83.5]	328	172.74
Central *(Zambézia, Tete, Manica, Sofala)*	10.6	[7.6–13.5]	4.5	[2.0–7.0]	85.0	[81.5–88.4]	271	3.45
South (*Inhambane, Gaza, Maputo, Maputo Cidade*)	7.3	[4.8–9.9]	5.9	[3.9-8.0]	86.7	[84.1–89.4]	722	*
Province								
Niassa	0.0	[0.0–0.0]	7.5	[3.2–11.8]	92.5	[88.2–96.8]	43	523.07
Cabo Delgado	22.3	[0.6–43.9]	7.2	[0.7–13.8]	70.5	[49.5–91.5]	45	2.16
Nampula	17.5	[10.0–25.0]	12.2	[5.0-19.3]	70.4	[62.0-78.8]	95	**

	Non-Suppressed VLNS (n = 110)		Low-level viremia LLV (n = 84)		Undetectable (n = 1,127)			
Table 1: Characteristic	**≥ 1,000 copies/mL**		**200–999 copies/mL**		**< 200 copies/mL**		**N**	**Chi-Sq p-value**
	Percent	**95% CI**	**Percent**	**95% CI**	**Percent**	**95% CI**		
Zambezia	8.4	[5.1–11.7]	9.1	[4.3–13.9]	82.5	[76.7–88.3]	145	
Tete	11.0	[4.7–17.3]	1.3	[0.0-3.3]	87.7	[81.0-94.4]	100	
Manica	4.0	[0.0-8.4]	9.5	[2.9–16.2]	86.5	[77.6–95.3]	75	
Sofala	13.7	[9.2–18.2]	4.0	[0.3–7.6]	82.3	[77.9–86.7]	96	
Inhambane	9.0	[3.2–14.8]	6.7	[0.6–12.8]	84.3	[76.4–92.2]	104	
Gaza	7.1	[2.1–12.0]	6.0	[2.0-10.1]	86.9	[80.8–93.0]	211	
Maputo Prov.	7.0	[2.2–11.8]	7.2	[3.4–11.0]	85.8	[81.8–89.8]	226	
Maputo City	7.3	[4.1–10.6]	2.8	[0.7–4.9]	89.9	[85.1–94.7]	181	
Wealth Quintile								
Lowest	12.5	[5.4–19.7]	6.3	[0.7–12.0]	81.1	[73.1–89.2]	99	132.18
Second	12.3	[6.1–18.5]	5.1	[1.0-9.1]	82.6	[75.1–90.1]	126	0.96
Middle	11.1	[6.6–15.6]	8.8	[4.2–13.5]	80.1	[74.3–85.9]	238	.
Fourth	11.2	[5.9–16.5]	7.9	[3.4–12.4]	80.9	[75.3–86.6]	385	
Highest	6.2	[3.9–8.5]	6.1	[3.3–8.9]	87.7	[84.6–90.8]	472	
Level of Education Attended								
None	12.7	[5.5–20.0]	6.0	[1.1–10.9]	81.2	[72.9–89.5]	264	58.63
Primary	8.9	[6.5–11.4]	6.7	[4.3-9.0]	84.4	[81.0-87.8]	674	0.66
Secondary or more	8.7	[6.0-11.3]	8.6	[5.2–11.9]	82.8	[78.4–87.1]	379	.
Civil Status								
Never married	15.6	[8.1–23.2]	6.1	[1.2–11.0]	78.3	[69.6–87.0]	123	172.32

	Non-Suppressed VLNS (n = 110)		Low-level viremia LLV (n = 84)		Undetectable (n = 1,127)			
Table 1: Characteristic	**≥ 1,000 copies/mL**		**200–999 copies/mL**		**< 200 copies/mL**		**N**	**Chi-Sq p-value**
	Percent	**95% CI**	**Percent**	**95% CI**	**Percent**	**95% CI**		
Married	8.6	[6.3–10.9]	7.2	[4.8–9.6]	84.2	[81.3–87.1]	769	1.73
Divorced/Separated	14.2	[8.1–20.3]	5.8	[0.7–11.0]	80.0	[72.9–87.1]	243	.
Widowed	4.5	[1.0–8.0]	9.6	[4.6–14.5]	85.9	[79.4–92.4]	181	
Medical Visit in the last 12 Months								
Yes	8.9	[6.5–11.4]	7.8	[5.9–9.7]	83.2	[80.3–86.2]	1083	98.30
No/Don't Know	14.0	[9.7–18.3]	3.7	[1.0-6.4]	82.3	[76.9–87.7]	238	3.84
Years on ART								
< 2 years	12.8	[8.9–16.8]	5.4	[2.2–8.7]	81.7	[76.9–86.6]	306	84.50
2–4	9.0	[4.9–13.0]	7.9	[4.1–11.8]	83.1	[77.4–88.8]	368	0.52
5–9	8.8	[4.9–12.8]	6.9	[3.4–10.5]	84.2	[79.5–88.9]	328	.
≥ 10	8.4	[3.8–13.0]	7.0	[0.8–13.3]	84.5	[78.0-91.1]	224	
Don't Know	8.1	[1.6–14.6]	10.7	[0.0-21.9]	81.2	[69.6–92.9]	95	
ART detected in the sample								
Yes	3.8	[2.8-5.0]	7.2	[5.7-9.0]	89.1	[87.0-90.8]	100	4429.72
No	57.6	[47.8–66.9]	6.4	[2.2–17.3]	36.0	[25.7–47.8]	100	102.36
Total	9.9	[7.9–12.2]	7.1	[5.6–8.9]	83.1	[80.5–85.4]	100	***
Months of ARV Supplied								
0–2 months	14.7	[9.3–20.2]	7.6	[4.5–10.8]	77.6	[71.8–83.5]	301	472.20
≥ 3	7.3	[5.3–9.3]	6.6	[4.5–8.7]	86.0	[83.3–88.7]	992	4.72
Don't Know	33.3	[4.5–62.2]	13.8	[0.0-31.6]	52.9	[25.5–80.3]	28	**
Have your ARVs ever been changed or modified?								

	Non-Suppressed VLNS (n = 110)		Low-level viremia LLV (n = 84)		Undetectable (n = 1,127)			
Table 1: Characteristic	**≥ 1,000 copies/mL**		**200–999 copies/mL**		**< 200 copies/mL**		**N**	**Chi-Sq p-value**
	Percent	**95% CI**	**Percent**	**95% CI**	**Percent**	**95% CI**		
Yes	7.3	[4.7–9.9]	8.3	[5.3–11.3]	84.5	[80.8–88.1]	661	138.41
No	11.9	[8.1–15.6]	5.6	[3.6–7.5]	82.6	[78.7–86.4]	606	1.87
Don't Know	14.9	[5.7–24.1]	10.6	[0.0-22.5]	74.5	[61.7–87.3]	54	.
Number of days missed taking ARVs in the last 30 days								
0–1 days	8.5	[6.6–10.4]	6.5	[4.6–8.5]	84.9	[82.5–87.4]	1123	257.47
2–3	11.9	[4.7–19.1]	9.4	[3.3–15.5]	78.7	[69.6–87.9]	127	2.16
4	22.9	[1.9–43.8]	11.3	[1.7–20.9]	65.8	[46.1–85.5]	36	.
Don't Know	23.3	[12.2–34.3]	9.7	[-6.9-26.4]	67.0	[46.1–87.9]	35	
Travel duration from home at last HIV care visit								
< 30 min	8.9	[5.3–12.4]	6.5	[2.5–10.6]	84.6	[80.4–88.8]	434	48.09
30–59 min	10.3	[5.9–14.8]	6.2	[3.9–8.6]	83.4	[78.8–88.1]	416	0.36
1 + hrs.	10.1	[6.7–13.5]	7.6	[4.3–10.8]	82.3	[78.4–86.3]	414	.
Don't Know	11.5	[2.3–20.7]	12.6	[0.0-29.6]	76.0	[61.7–90.3]	57	
CD4 Category								
<200	24.3	[14.2–34.4]	8.1	[0.0-16.6]	67.6	[55.3–79.8]	66	596.82
200–349	18.2	[11.1–25.4]	7.3	[3.1–11.6]	74.4	[67.6–81.2]	205	5.88
350–499	13.3	[8.8–17.8]	7.9	[3.7–12.1]	78.8	[72.3–85.2]	290	***
≥ 500	5.0	[3.0–7.0]	6.6	[3.9–9.4]	88.4	[85.0-91.8]	756	
Total	9.9	[7.8–12.0]	7.1	[5.4–8.7]	83.1	[80.6–85.5]	1321	

CI = Confidence Interval, N = number; Note: Percents may not add up to 100.0 due to rounding

	Non-Suppressed VLNS (n = 110)		Low-level viremia LLV (n = 84)		Undetectable (n = 1,127)			
Table 1: Characteristic	**≥ 1,000 copies/mL**		**200–999 copies/mL**		**< 200 copies/mL**		**N**	**Chi-Sq p-value**
	Percent	**95% CI**	**Percent**	**95% CI**	**Percent**	**95% CI**		
Percentages and confidence intervals are weighted and adjusted to account for the survey design. Wealth quintile (1); education level attend (4); martial status (5) and CD4 category (4) had missing cases involving a combined total of 11 cases which were excluded from Chi-square calculations.								
*** p < 0.01, ** p < 0.05, * p < 0.1								

Viral Load Non-Suppression

Age group, civil status, medical visit in the last 12 months, months of ART distributed, and the number of missed days of ARVs all had significant differences in the bivariate analysis for VLNS (Table 2). Of these, age group (≥ 50 years - OR: 0.30; 95%CI; 0.13–0.66) and ≥ 3 months medication distribution (OR: 0.48; 95%CI; 0.27–0.86) were negatively associated with VLNS, increasing the odds of VLS. The remaining significant variables including age, civil status, and absence of medical visit, were found to be positively associated with VLNS, increasing the odds of non-suppression.

In the final multivariate model, men had twice the odds of VLNS (aOR: 2.18; 95%CI: 1.32–3.59) compared to women. Divorced or separated adults (aOR: 2.27; 95%CI: 1.36–3.80) had at least twice the odds of VLNS compared to married adults in the same model. Those without a medical visit in the last 12 months, or who did not remember their last visit, had greater odds of VLNS (aOR: 1.62; 95%CI: 1.06–2.49) compared to those with a medical visit in the final multivariate model. Some attributes decreased the likelihood of VLNS in the final model, including older age and the number of months of ART supplied at last clinic visit. Those aged ≥ 50 years had 73% lower odds of VLNS (aOR: 0.27; 95%CI: 0.12–0.59) compared to adults 35–49 years, and adults who received three or more months of ART had 50% lower odds of VLNS (aOR: 0.51; 95%CI: 0.28–0.92) compared to adults who received two months or less of ART.

Table 2
Logistic Regression on Viral Load Non-Suppression (≥ 1000 copies/mL) among PLHIV adults 15 years and older on ART, Mozambique 2021

	Viral Load Non-Suppression among HIV+ adults on ART (Odds Ratios) (N = 1,321)								
	Bivariate Model			Comparison Model			Final Model		
Table 2: Characteristic	**OR (VLNS)**	**95% CI**	**P-value**	**aOR (VLNS)**	**95% CI**	**P-value**	**aOR (VLNS)**	**95% CI**	**P-value**
Sex									
Male	1.43	0.88–2.33	0.147	**2.16*** **	1.29–3.62	**0.004**	**2.18*** **	1.32–3.59	**0.003**
Female	(ref)								
Age Group									
15–24	1.99*	1.00–3.98	0.050	1.91*	0.94–3.88	0.073	**1.97** **	1.00–3.86	**0.049**
25–34	1.09	0.68–1.73	0.725	1.10	0.68–1.77	0.700	1.12	0.70–1.78	0.645
35–49	(ref)								
≥ 50	**0.30*** **	0.13–0.66	**0.003**	**0.27*** **	0.12–0.59	**0.001**	**0.27*** **	0.12–0.59	**0.001**
Area of Residence									
Rural	1.18	0.73–1.89	0.498						
Urban	(ref)								
Geographic Region of Residence									
North	1.67*	0.96–2.90	0.067	1.19	0.69–2.06	0.523			
Central	1.48	0.91–2.40	0.115	1.40	0.83–2.36	0.212			
South	(ref)								
Wealth Quintile									
Lowest	1.25	0.52–3.05	0.615						
Second	1.25	0.55–2.80	0.594						
Third	(ref)								
Fourth	1.11	0.51–2.37	0.797						
Highest	0.58*	0.31–1.07	0.083						
Level of Education Attended									

	Viral Load Non-Suppression among HIV+ adults on ART (Odds Ratios) (N = 1,321)								
	Bivariate Model			Comparison Model			Final Model		
Table 2: Characteristic	**OR (VLNS)**	**95% CI**	**P-value**	**aOR (VLNS)**	**95% CI**	**P-value**	**aOR (VLNS)**	**95% CI**	**P-value**
None	1.48	0.70–3.13	0.299	1.75*	0.97–3.16	0.061	1.79*	0.97–3.31	0.062
Primary	(ref)								
Secondary and above	0.97	0.61–1.52	0.879	0.76	0.46–1.26	0.286	0.76	0.46–1.26	0.291
Civil Status									
Never married	**2.03****	1.02–4.05	**0.045**	1.87*	0.95–3.69	0.072	1.82*	0.92–3.62	0.087
Married	(ref)								
Divorced/Separated	**1.81****	1.06–3.10	**0.030**	**2.35*****	1.41–3.92	**0.001**	**2.27*****	1.36–3.80	**0.002**
Widowed	0.53	0.22–1.25	0.144	0.94	0.36–2.42	0.893	0.93	0.36–2.37	0.876
Medical Visit in the last 12 months									
Yes	(ref)								
No/Don't know	**1.71****	1.07–2.73	**0.025**	**1.58****	1.02–2.47	**0.042**	**1.62****	1.06–2.49	**0.027**
Time on ART									
< 2 years	1.43	0.77–2.66	0.252						
2–4 years	1.01	0.49–2.09	0.972						
5 to 9 years	(ref)								
≥ 10 years	0.94	0.45–1.99	0.871						
Don't Know	0.93	0.33–2.64	0.890						
ART detected in the sample									
Yes	(ref)								
No	33.39***	20.34–54.81	0.000						
Months of ART supplied									
0–2	(ref)								
≥ 3	**0.48****	0.27–0.86	**0.013**	**0.50****	0.28–0.92	**0.027**	**0.51****	0.28–0.92	**0.026**

	Viral Load Non-Suppression among HIV+ adults on ART (Odds Ratios) (N = 1,321)								
	Bivariate Model			Comparison Model			Final Model		
Table 2: Characteristic	**OR (VLNS)**	**95% CI**	**P-value**	**aOR (VLNS)**	**95% CI**	**P-value**	**aOR (VLNS)**	**95% CI**	**P-value**
Don't Know	3.04	0.74–12.55	0.124	2.17	0.63–7.50	0.219	2.26	0.66–7.71	0.190
Have your ARVs ever been changed or modified?									
Yes	0.61*	0.35–1.06	0.081						
No	(ref)								
Don't Know	1.34	0.56–3.25	0.51						
Number of days missed taking ARVs in the last 30 days									
0–1	(ref)								
2–3	1.49	0.69–3.20	0.305						
4	3.25**	1.04–10.11	0.042						
Don't Know	3.32***	1.63–6.76	0.001						
Travel duration from home at last HIV care visit									
< 30 min	(ref)								
30–59 min	1.27	0.72–2.24	0.407						
≥ 1 hrs.	1.24	0.69–2.23	0.466						
Don't Know	1.46	0.52–4.13	0.474						
*** p < 0.01, ** p < 0.05, * p < 0.1									

Low-level Viremia among Virally Suppression

Among adults 15 years and older with VLS < 1000 copies/mL, LLV was not significantly associated with most treatment and demographic indicators in either bivariate or multivariate models (Table 3). In the bivariate model, there was an slight association (p-value < 0.1) with both missing 4 days of ARVs (OR 2.22, 95%CI 0.89–5.51) and for medical visits in the last 12 months; those who did not have a visit or did not know the date of their last visit had decreased odds of LLV (OR: 0.49, 95%CI 0.21–1.10), though only the medical visit continues with the similar level of significance in the multivariate models. Men had greater odds of LLV in the final multivariate model (aOR: 1.66, 95%CI: 1.15–2.40) compared to women. PLHIV on ART in the northern provinces of Cabo Delgado, Niassa, and Nampula had nearly double the odds of LLV than residents of the southern region provinces of Maputo City, Maputo Province, Gaza and Inhambane (OR: 1.78, 95%CI: 1.04–3.07) in the bivariate model, an association that strengthened slightly when controlling for other

characteristics in the comparison multivariate model (aOR: 1.90, 95%CI: 1.07–3.38) however decreased in the final multivariate model (aOR FINAL: 1.67, 95%CI: 0.97–2.88).

Table 3
Logistic Regression on Low-level Viremia (200–999 copies/mL) among PLHIV adults 15 years and older on ART with Viral Load Suppression (< 1000 copies/mL), Mozambique 2021

	Low-level Viremia among HIV+ adults with VLS on ART (Odds Ratios) (N = 1,211)								
	Bivariate Model			Comparison Model			Final Model		
Table 3: Characteristic	**OR (LLV)**	**95% CI**	**P-value**	**aOR (LLV)**	**95% CI**	**P-value**	**aOR (LLV)**	**95% CI**	**P-value**
Sex									
Male	**1.73*** **	1.19–2.51	**0.005**	**1.60** **	1.05–2.45	**0.031**	**1.66*** **	1.15–2.40	**0.008**
Female									
Age Group									
15–24	0.88	0.25–3.07	0.842	0.72	0.21–2.47	0.600			
25–34	0.75	0.41–1.40	0.364	0.69	0.36–1.32	0.259			
35–49	(ref)								
≥ 50	1.08	0.35–3.32	0.891	1.05	0.37–2.96	0.925			
Area of Residence									
Rural	1.11	0.54–2.30	0.778						
Urban	(ref)								
Geographic Region of Residence									
North	**1.78** **	1.04–3.07	**0.037**	**1.90** **	1.07–3.38	**0.028**	1.67*	0.97–2.88	0.063
Central	0.76	0.38–1.52	0.437	0.79	0.41–1.56	0.498	0.80	0.41–1.55	0.500
South	(ref)								
Wealth Quintile									
Lowest	0.70	0.25–1.99	0.503						
Second	0.56	0.20–1.55	0.261						
Third	(ref)								
Fourth	0.88	0.32–2.41	0.806						
Highest	0.63	0.34–1.17	0.140						
Level of Education Attended									

	Low-level Viremia among HIV+ adults with VLS on ART (Odds Ratios) (N = 1,211)								
	Bivariate Model			Comparison Model			Final Model		
Table 3: Characteristic	**OR (LLV)**	**95% CI**	**P-value**	**aOR (LLV)**	**95% CI**	**P-value**	**aOR (LLV)**	**95% CI**	**P-value**
None	0.94	0.36–2.47	0.893	0.95	0.38–2.36	0.903			
Primary	(ref)								
Secondary and above	1.31	0.77–2.24	0.316	1.46	0.80–2.67	0.212			
Civil Status									
Never married	0.91	0.39–2.09	0.816	1.02	0.48–2.38	0.963			
Married	(ref)								
Divorced/Separated	0.85	0.29–2.52	0.765	1.01	0.34–2.98	0.990			
Widowed	1.31	0.66–2.59	0.433	1.92	0.79–4.65	0.148			
Medical Visit in the last 12 months									
Yes	(ref)								
No/Don't know	**0.49***	0.22–1.10	**0.084**	**0.49***	0.22–1.09	**0.079**	0.51*	0.23–1.13	0.096
Time on ART									
< 2 years	0.80	0.30–2.14	0.661						
2–4 years	1.15	0.57–2.32	0.690						
5 to 9 years	(ref)								
≥ 10 years	1.00	0.38–2.65	0.999						
Don't Know	1.64	0.40–6.69	0.489						
ART detected in the sample									
Yes	(ref)								
No	2.19	0.62–7.74	0.223						
Months of ART supplied									
0–2	(ref)								
≥ 3	0.78	0.45–1.36	0.380	0.67	0.36–1.26	0.212			

	Low-level Viremia among HIV+ adults with VLS on ART (Odds Ratios) (N = 1,211)								
	Bivariate Model			Comparison Model			Final Model		
Table 3: Characteristic	**OR (LLV)**	**95% CI**	**P-value**	**aOR (LLV)**	**95% CI**	**P-value**	**aOR (LLV)**	**95% CI**	**P-value**
Don't Know	2.62	0.56–12.31	0.220	2.56	0.61–10.79	0.199			
Have your ARVs ever been changed or modified?									
Yes	1.46	0.85–2.50	0.170						
No	(ref)								
Don't Know	2.10	0.59–7.48	0.251						
Number of days missed taking ARVs in the last 30 days									
0–1	(ref)								
2–3	1.55	0.67–3.59	0.307						
4	2.22*	0.89–5.51	0.087						
Don't Know	1.87	0.22–15.65	0.559						
Travel duration from home at last HIV care visit									
< 30 min	(ref)								
30–59 min	0.97	0.44–2.14	0.932						
≥ 1 hrs.	1.19	0.59–2.40	0.632						
Don't Know	2.18	0.29–16.61	0.448						
*** p < 0.01, ** p < 0.05, * p < 0.1									

Discussion

In this analysis 9.9% of PLHIV had VLNS, while 90.1% achieved viral suppression (< 1,000 copies/mL), slightly below the global target of 95%. The high proportion with viral load < 200 copies/mL (83.1%) reflects the efficacy of the current first-line dolutegravir-containing ART regimen. Persistent viral loads of 200–999 copies/mL carries double the risk of virologic failure compared to undetectable VL, underscoring the need to monitor the 7.1% with LLV [5, 14]. Despite making up only 17% of the total, over 30% of respondents with criteria for diagnosis with Advanced HIV Disease (< 200 CD4 counts) had either LLV or VLNS, clearly showcasing the detrimental effect of VLNS and LLV on long-term health [15].

Adults receiving three or more months of medication had roughly 50% reduced odds of VLNS, supporting implementation of Mozambique's Differentiated Service Delivery Guidelines, which require sustained VLS for multi-month dispensing [16]. Eligibility for multi-month dispensing also requires clinical stability, the definition of which includes a

defined time on ART, the absence of WHO stage III/IV conditions, and CD4 levels ≥ 200, which have all been linked to viral suppression [16–19]. Our results showed that missing medical visits for more than 12 months was associated with higher VLNS, also reinforcing the national guidelines requiring a clinical visit at least once a year [20]. Treatment adherence, including medical visits, has been prioritized in Mozambique's recent national policy documents [4, 21].

Poor health literacy and limited engagement could be a contributing factor to higher viral load results. Among the six clinical questions, PLHIV with LLV or VLNS more often answered "Don't Know", suggesting that some individuals with VLNS or LLV are either not engaged in their HIV care or were not comfortable discussing their HIV status and care and treatment. Social marginalization is a common fear among PLHIV in Mozambique, and further research on healthcare engagement, the anticipated or real effects of HIV status revelation, and their link to treatment success is warranted [22, 23].

Age was associated with VLNS, belonging to an older age group decreased the odds of being non-suppressed by 73% among adults at least 50 years of age. This is encouraging, as Mozambique's 50 + HIV population is projected to rise from 258,000 in 2017 to 478,000 in 2025 (59% increase), outpacing the projected overall growth of the 50 + population (40%) [24, 25]. Despite improved viral suppression, older PLHIV show higher occurrence of LLV than younger age groups, raising potential concerns for therapeutic failure and other adverse outcomes from long-term ART use. Ensuring quality HIV care across all stages of life remains critical.

Finally, this is the first LLV analysis conducted among a nationally representative sample in Mozambique, and the findings of this study contribute significantly to identifying gaps in achieving viral load results < 200 copies/mL. This analysis found large variations in the associated clinical and demographic attributes between VLNS and LLV, potentially limiting interventions from positively impacting both VLNS and LLV. For example, variables such as age group, medical visit, civil status, and months of treatment distributed were not found significant in both multivariate analyses. In the final multivariate models, only sex was found to be significant between VLNS and LLV after controlling for confounders, and interventions targeting males in Mozambique should be encouraged.

Despite the insights into LLV gained from this study, limitations should be considered. Social desirability bias may have influenced some participants' self-reported response, such as attending a medical visit in the last 12 months or missing ARV medication. Due to the standardized questionnaire and the design of the INSIDA survey, detailed clinical histories were not available and, thus, examining or verifying clinical factors, such as treatment duration or consistency of VL results was not possible. Even with national coverage, the survey results may not reflect specific circumstances in some provinces and thus may not be generalizable to all settings in Mozambique.

Conclusion

This study provides the first national analysis of low-level viremia in Mozambique, highlighting its significant public health implications. The nuances in clinical histories and demographic characteristics between PLHIV with VLNS and LLV are major findings from this paper and deserve additional investigation. To achieve the 95-95-95 cascade for all PLHIV by the end of 2025, strengthening efforts to maximize viral suppression is essential. This could include the expansion of routine viral load monitoring to identify and provide follow-up of results > 200 copies/mL, an approach that is currently only implemented nationally for pregnant women. Public health policies should prioritize groups with LLV or VLNS through tailored interventions, particularly men and PLHIV in the northern provinces of Cabo Delgado, Nampula and Niassa. These could include enhanced adherence support, targeted health education, and expanded access to mental health services. By aligning clinical monitoring with differentiated, patient-centered care, Mozambique can accelerate progress toward sustained viral suppression and improved health outcomes for all PLHIV.

Declarations

Competing interests:

All authors declared no competing interests.

Supporting Information

Supplemental file 1: Supplemental file 1 contains two excel tables which show the analytical steps of the model for the selection of sociodemographic and treatment indicators that make up the final model in table 2 and 3 included in this manuscript.

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Author Contribution

A.M.C, O.F.T., A.A, S.C, and S.M conceived the study. S.M conducted the analysis, O.F.T drafted the introduction, discussion, and limitations with support from S.C. A.A and S.M drafted the methods; and A.M.C, O.F.T and A.A drafted the results and public health recommendations. All authors contributed to critical review of the manuscript.

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Data Availability

The 2021 INSIDA public release datasets and files are available at the ICAP PHIA website (https://phia-data.icap.columbia.edu/datasets?country_id=15). Survey manuals, data, and documentation are available for download.

References

1. UNAIDS. *Political Declaration on HIV and AIDS: Ending Inequalities and Getting on Track to End AIDS by 2030* (Geneva, 2021).
2. Cohen, M. S. et al. Antiretroviral Therapy for the Prevention of HIV-1 Transmission. *N Engl. J. Med.* **375** (9), 830–839. 10.1056/nejmoa1600693 (2016).
3. Broyles, L. N., Luo, R., Boeras, D. & Vojnov, L. The risk of sexual transmission of HIV in individuals with low-level HIV viraemia: a systematic review. *Lancet* **402** (10400), 464–471. 10.1016/s0140-6736(23)00877-2 (2023).

4. Plano Estratégico Nacional de Resposta ao HIV e SIDA - PEN V (National Strategic Plan for the HIV/AIDS Repose). Maputo: Conselho Nacional de Combate ao HIV/SIDA; (2021).
5. Esber, A. et al. Persistent Low-level Viremia Predicts Subsequent Virologic Failure: Is It Time to Change the Third 90? *Clin. Infect. Dis.* **69** (5), 805–812. 10.1093/cid/ciy989 (2019).
6. Inquérito de Indicadores de Imunização. *Malária e HIV/SIDA (The National Malaria and HIV Indicator Survey)* (Instituto Nacional de Saúde, 2015).
7. UNAIDS. *90-90-90: An ambitious treatment target to help end the AIDS epidemic* (UNAIDS, 2014).
8. Instituto Nacional de Saúde, editor. Mozambique Population-based HIV Impact Assessment, INSIDA 2021 Final Report. Maputo, Mozambique: Instituto Nacional de Saúde; 2021.
9. Zhao, S. et al. The prevalence of low-level viraemia and its association with virological failure in people living with HIV: a systematic review and meta-analysis. *Emerg. Microbes Infect.* **14** (1), 2447613. 10.1080/22221751.2024.2447613 (2025). PubMed PMID: 39727007; PubMed Central PMCID: PMC11722027.
10. Gaifer, Z. & Boulassel, M. R. Low-Level Viremia Predicts Virological Failure in HIV-Infected Omani Patients Receiving Antiretroviral Therapy. *J. Int. Assoc. Provid AIDS Care JIAPAC*. **19**, 2325958220979817 (2020). doi:10.1177/2325958220979817 PubMed PMID: 33372823.
11. Fleming, J. et al. Low-level viremia and virologic failure in persons with HIV infection treated with antiretroviral therapy. AIDS [Internet]. ;33(13). (2019). Available from: https://journals.lww.com/aidsonline/fulltext/2019/11010/low_level_viremia_and_virologic_failure_in_persons.6.aspx
12. Hanners, E. K., Benitez-Burke, J. & Badowski, M. E. HIV: how to manage low-level viraemia in people living with HIV. *Drugs Context*. **11**, 1–26. 10.7573/dic.2021-8-13 (2022).
13. Center for Diseaese Control Mozambique, editor. *Relatório Trimestral do MozART (Quarterly MozART Report)* (Maputo, Mozambique; Centers for Disease Control and Prevention, 2024).
14. Nanyeenya, N. et al. Low-level viraemia: An emerging concern among people living with HIV in Uganda and across sub-Saharan Africa. *Afr. J. Lab. Med.* **11** (1). 10.4102/ajlm.v11i1.1899 (2022).
15. Guião de manejo. *do paciente com doença avançada por HIV (Management guide for patients with advanced HIV disease)* (Programa Nacional de Controle de ITS e HIV/SIDA, Ministério de Saúde, 2022).
16. Direcção Nacional de Saúde Pública, editor. *Orientação para a implementação do novo pacote de Modelos Diferenciados de Serviços para o HIV/SIDA (Guidance for the implementation of the new package of Differentiated Service Models for HIV/AIDS)* (Programa Nacional de Controle de ITS e HIV/SIDA, Ministério de Saúde, 2023).
17. World Health, O. *WHO case definitions of HIV for surveillance and revised clinical staging and immunological classification of HIV-related disease in adults and children* (World Health Organization, 2007).
18. Gordon, T. P., Talbert, M., Mugisha, M. K. & Herbert, A. E. Factors associated with HIV viral suppression among adolescents in Kabale district, South Western Uganda. *PLoS ONE*. **17** (8), e0270855. 10.1371/journal.pone.0270855 (2022).
19. Maina, E. K. et al. Incidences and factors associated with viral suppression or rebound among HIV patients on combination antiretroviral therapy from three counties in Kenya. *Int. J. Infect. Dis.* **97**, 151–158. 10.1016/j.ijid.2020.05.097 (2020).
20. Programa Nacional de Controlo das ITS HIV e SIDA. Direcção Nacional de Saúde Pública. Guião Orientador Sobre Modelos Diferenciados de Serviços para o HIV/SIDA em Moçambique – 2023. (2023).
21. Programa Nacional de Controle de ITS e HIV/SIDA M. in *Segundo Plano de Aceleração da Resposta ao HIV e SIDA em Moçambique, 2024–2026 (Second Plan to Accelerate the Response to HIV and AIDS in Mozambique)*. (eds de S) (Ministério da Saúde, 2024).

22. Viisainen, K., Baumgart Dos Santos, M., Sunderbrink, U. & Couto, A. Gender and stigma in antiretroviral treatment adherence in Mozambique: A qualitative study. *PLOS Glob Public. Health*. **4** (7), e0003166. 10.1371/journal.pgph.0003166 (2024).
23. Ha, J. H. et al. Gendered relationship between HIV stigma and HIV testing among men and women in Mozambique: a cross-sectional study to inform a stigma reduction and male-targeted HIV testing intervention. *BMJ Open.* **9** (10), e029748. 10.1136/bmjopen-2019-029748 (2019).
24. UNAIDS. Spectrum v6.36 [Internet]. 2023 [cited 2024 Apr 20]. Available from: https://hivtools.unaids.org/spectrum-file-request/
25. Projecções da *População 2017–2050 (Population Projections)* (Instituto Nacional de Estatistica, 2019).

Figures

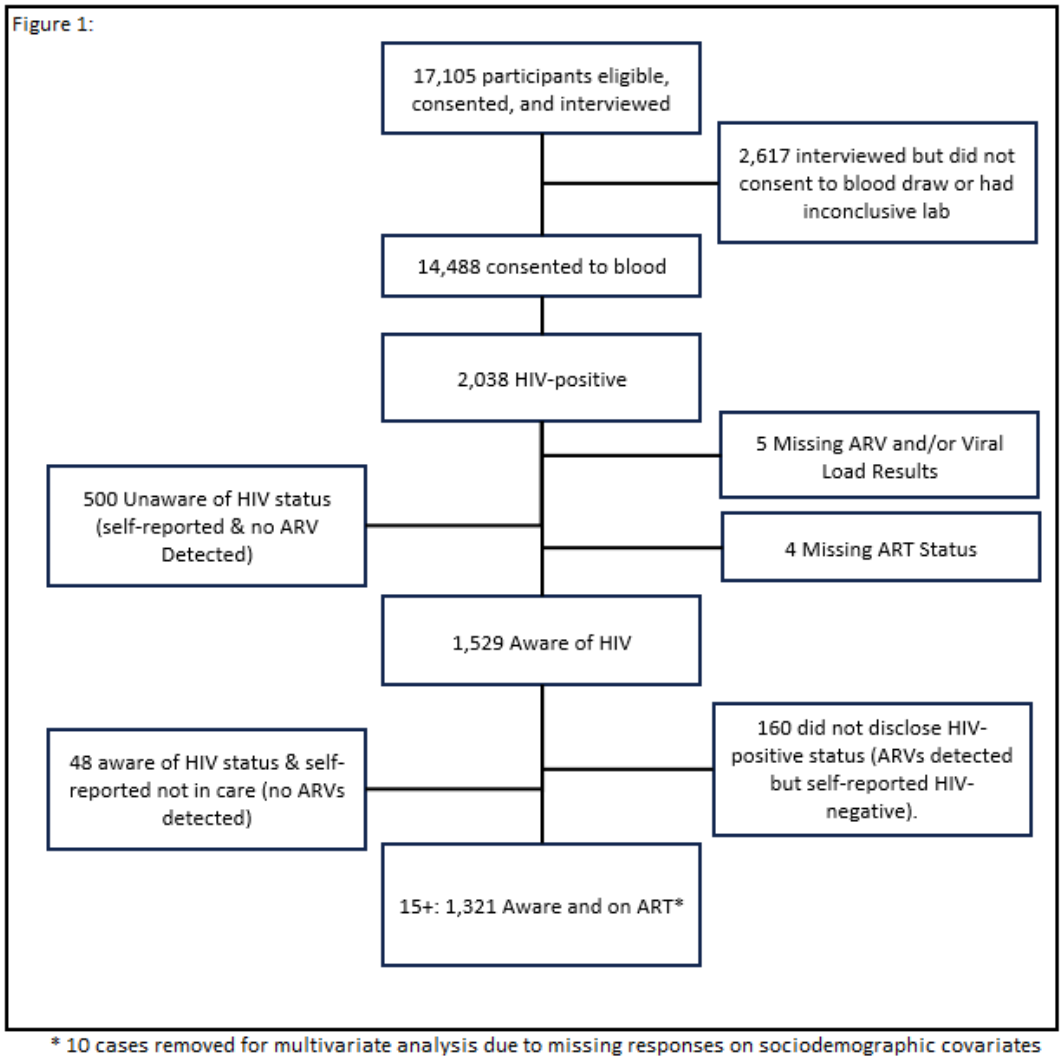

Figure 1

Flow chart of participants who interviewed, completed blood draw, had laboratory results and responded to HIV care questions in INSIDA, adults 15 years and older, Mozambique 2021

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- MozVLSSuplimentalTables25032026CLEAN.xlsx