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## Factors associated with viral load non-suppression in people living with HIV in Nigeria: cross-sectional analysis from 2001 to 2021

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# Factors associated with viral load non-suppression in people living with HIV in Nigeria: cross-sectional analysis from 2001 to 2021

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For peer review only

## 1 **Abstract**

2 **Objectives** Identify demographic and clinical factors associated with a non-suppressed viral load  
3 of patients on antiretroviral therapy in Nigeria.

4  
5 **Design** Cross-sectional study.

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7 **Setting** Sixteen USAID supported states in Nigeria.

8  
9 **Participants** 517,012 people living with HIV (PLHIV) on antiretroviral therapy (ART).

10  
11 **Primary outcome measures** Viral load (VL) non-suppression (defined as having a VL of at least  
12 1,000 HIV ribonucleic acid copies per mL of plasma). Chi-square testing and multivariable logistic  
13 regression were conducted on routinely collected ART program data.

14  
15 **Results** Sixty-six percent of the study population were females. The largest age groups were 35–  
16 44 and 25–34, accounting for 32% and 31%, respectively. The greatest adjusted odds for a non-  
17 suppressed VL were associated with shorter duration MMD prescriptions of 1–2 months (adjusted  
18 odds ratio [AOR]=14.05) and 3 months (AOR=3.13). Males had 8% greater odds (AOR=1.08) of  
19 being non-suppressed. The age groups below the 45–59 age group (AOR=0.84) had higher odds  
20 of having a non-suppressed VL, with the highest odds in the 0–14 age group (AOR=1.87). Clients  
21 enrolled at tertiary and secondary level facilities had the greatest odds of having a non-suppressed  
22 VL. A shorter time on ART until the last VL (1–3 years [AOR=1.14]) was associated with a higher  
23 risk of a non-suppressed VL. Clients in the North-Central (AOR=1.83) and North-East  
24 (AOR=1.49) zones had the greatest odds of viral non-suppression.

25  
26 **Conclusions** Enabling the provision of 3+ months of MMD to PLHIV and targeting younger age  
27 groups, tertiary and secondary health facilities, small and medium facilities, and the North-Central  
28 and North-East zones for interventions could lead to improvements in VL suppression in Nigeria.  
29 The independent factors associated with a non-suppressed VL can guide improvements in ART  
30 program development and VL suppression of PLHIV in Nigeria.

## 32 **Strengths and limitations of the study**

- 33 • The study uses data from over 500,000 PLHIV enrolled on ART across all geopolitical
- 34 Zones in Nigeria
- 35 • The data used is routinely collected by clinics.
- 36 • Variables such as education level and marital status/cohabiting were not available.

## 38 **Introduction**

39 In 2020, 37.7 million people were living with HIV (PLHIV) globally; currently, 27.5 million  
40 (73%) have access to antiretroviral therapy (ART) [1]. In 2020, 66% of PLHIV were virally  
41 suppressed [1]. Nigeria, a country with one of the highest global HIV infection rates, was reported  
42 to have 78% of PLHIV on ART virally suppressed, against a target of 95% [1,2]. The Nigeria  
43 National Guidelines for HIV Prevention, Treatment, and Care define virologic suppression as  
44 having a viral load (VL) below 1,000 HIV ribonucleic acid copies per mL of plasma [3] (viral load  
45 non-suppression is defined as having a VL of at least 1,000 HIV ribonucleic acid copies per mL  
46 of plasma). Given that an undetectable VL makes HIV untransmissible, suppressing the VL of  
47 95% of PLHIV on ART is key to achieving epidemic control [4,5].

48 Globally, including in some Nigerian states, factors that were found to be predictors of viral  
49 suppression were age, sex, duration on ART [6–9], current ART regimen [10], and adherence to  
50 medications [11]. This study explored whether similar associations alongside other factors such as  
51 geo-political zones and facility level existed in Nigeria using data over a period of 20 years from  
52 16 States that were not necessarily under investigation before, contributing to the body of  
53 knowledge and allowing better targeted interventions to improve HIV programs, the VL of clients,  
54 and epidemic control in the country.

55 The objective of this study was to determine which factors were associated with a non-suppressed  
56 VL in Nigeria using a large cross-sectional database of clients who received ART. We explored  
57 several variables—sex, age group, duration on ART, multi-month dispensing (MMD) defined as  
58 dispensing of 1-2 months, 3 months, or 3+ months of ART treatment, facility level, and  
59 geopolitical zone—to identify which factors were associated with viral non-suppression. The  
60 objective of this analysis is to guide HIV programs to target population groups at the highest risk.

61

## 62 **Methods**

### 63 **Study design, setting, and population**

64 The study was a cross-sectional analysis of clients who were enrolled on ART at 580 facilities  
65 across 16 States in Nigeria that were supported by the United States Agency for International  
66 Development (USAID). The data set covered a period of 20 years, with the first ART initiation  
67 date recorded on January 1, 2001, and the most recent ART pickup date of March 26, 2021. The  
68 study was carried out to investigate the clinical and demographic factors associated with a non-  
69 suppressed VL among more than 500,000 HIV clients who had a VL test during the period.

### 71 **Data Source and Management**

72 The data were provided by the USAID-supported implementing partners (IPs) through their  
73 quarterly data submission using the retention and audit determination tool (RADET). Each IP  
74 submission was then combined into a single data set that was used for this study.

76 The data obtained were collected by the Federal Ministry of Health (FMOH) and IPs using  
77 standardized national HIV data collection tools that recorded demographic, clinical, and treatment  
78 information about the client at each visit in the electronic medical records (EMR) system.

80 The data set received contained 867,981 non-longitudinal, cross-sectional client records. Due to  
81 missing unique client identifiers for 158,898 clients, a unique identifier was created for data  
82 deduplication using the date of birth, sex, database-provided unique identifier, and client hospital  
83 number. For clarification, unique identifiers are not provided at all facilities, in such cases a client  
84 hospital number is captured instead. Data cleaning involved removing duplicate unique identifiers  
85 (n=17,267), and missing entries for MMD (n=1) and ART regimen line (n=148). In addition, data  
86 which may have contained a typo, like records with an ART start date occurring before the date of  
87 birth or after the date of last drug pickup, or a VL result date occurring earlier than the ART start  
88 date, were removed from the sample (n=3,030). Clients with a date of birth earlier than 1940  
89 (n=961) or an ART start date earlier than 1990 (n=2) were also excluded from the analysis. An  
90 additional 2,314 clients with a VL test result date earlier than the ART start date were likewise  
91 removed. Missing values for current ART status (n=56) and sex (n=1) were excluded (Figure 1).



93 Of the 844,201 complete client records retained, 517,012 (61.2%) had a VL test (only the last one)  
94 on record, whereas the remaining 327,189 (38.8%) had no documented VL test (Figure 1). Clients  
95 without documented VL test results were removed from the study population before the logistic  
96 regression analysis was conducted.

97

98 **Figure 1. Data cleaning process, excluded data, and study population subset analysed.**

99

### 100 **Variables explored as predictors of a non-suppressed viral load**

101 The “age at last VL test” variable was generated by calculating the time difference (in years)  
102 between the date of received current VL and the date of birth of the client. The age at last VL test  
103 was reclassified into six age groups: 0–14, 15–24, 25–34, 35–44, 45–59, and 60+ years.

104 Similarly, the “duration on ART to last VL test” variable was created by calculating the time  
105 difference (in months) between the date of received current VL and the ART start date. The  
106 duration on ART was reclassified as <1 year, 2–3 years, and 3+ years, and labelled as “time to last  
107 VL.”

108 The “facility size” variable was calculated by determining the number of clients ever receiving  
109 care at the facility, then assigning the facility size group as small [0,25) percentiles, medium  
110 [25,75) percentiles, or large [75,100] percentiles.

111

112 The “facility level” variable was created by classifying the facility name provided in the data set  
113 to the nationally recognized facility levels using the Nigeria health facility registry (HFR) [12].

114 The classification resulted in three levels of facilities: primary (operate at Local Government  
115 level), secondary (operate at State level), and tertiary (operate at Federal Government level) [13].

116 Similarly, the “facility ownership” variable was created by grouping the facilities in their  
117 respective ownership type (public or private) according to their classification in the Nigeria HFR  
118 system [12].

119

120 The “geopolitical zone” variable was created by grouping the 16 USAID-supported States into  
121 their nationally recognized geopolitical zones. This resulted in five geopolitical zone groupings:  
122 North-Central (Kwara and Niger States), North-East (Adamawa, Bauchi, Borno, and Yobe States),

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3 123 North-West (Jigawa, Kano, Kebbi, Sokoto, and Zamfara States), South-South (Akwa Ibom,  
4 124 Bayelsa, Cross River, and Edo States), and South-West (Lagos).

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## 8 126 **Patient and public involvement**

9  
10 127 Patients or the public were not involved in the design, or conduct, or reporting, or dissemination  
11 128 plans of our research.

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## 15 130 **Statistical analysis**

16  
17 131 For the population with a last VL test on record, the Pearson's chi-square test was used to examine  
18 132 the association of each variable with a non-suppressed VL at a client's last VL test date.  
19 133 Unadjusted and adjusted logistic regression models were run to explore the association of variables  
20 134 with a non-suppressed VL. Current ART status was excluded as a factor from the regression  
21 135 modelling because at the time of the VL test, all clients were active, even though they may now  
22 136 have a different status (interruption in treatment (IIT), deceased, or stopped treatment). Similarly,  
23 137 the regimen line was excluded from the regression analysis because other regimen lines, aside  
24 138 from the first-line regimen, are prescribed in the case of a non-suppressed VL. The regimen line  
25 139 was therefore dependent on the VL outcome investigated and it could not be used as an  
26 140 independent variable associated with VL non-suppression. The variables included in the models  
27 141 were sex, age group, geopolitical zone, facility level, facility size, MMD of antiretrovirals (ARVs),  
28 142 and time to last VL test. The group accounting for the most clients in each of the independent  
29 143 variables analysed was set as the reference group for the respective variable. A two-tailed P value  
30 144 of  $P < 0.000001$  was used to define statistical significance [14]. Model selection was done using  
31 145 backward elimination where the Akaike's information criterion (AIC) was used to evaluate  
32 146 variable inclusion in the final model. Multicollinearity was tested using the generalized variance  
33 147 inflation factor (GVIF) for the set of variables used in the logistic regression model, and none of  
34 148 the variables exhibited multicollinearity. All data were analysed using R software for Statistical  
35 149 Computing v4.0. [15].

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## 51 151 **Results**

52 152 Of the 517,012 clients included in the analysis, 476,218 (92%) were virologically suppressed  
53 153 whereas the remaining 8% were virologically non-suppressed (Table 1). Sixty-six percent of the

154 clients were female, with 8% of both sexes virologically non-suppressed. Clients ages 25–34 and  
 155 35–44 were the largest age groups, accounting for 31% and 32% of the total number of clients in  
 156 the analysis, respectively. Clients in the 0–14 age group had the smallest proportion who were  
 157 virally suppressed.

158  
 159 The ART status of 87% of the clients was recorded as active on treatment, with the remaining 13%  
 160 being dead (2%), had transferred out to another facility (3%), or had interrupted treatment (8%)  
 161 (Table 1). Most clients (95%) were on the adult first-line ART regimen, with 93% of them being  
 162 virally suppressed. Both the adult second-line and paediatric first-line ART regimens had 2% of  
 163 the clients, with 80% and 78% of clients on these regimens being virally suppressed, respectively.  
 164 Most clients were receiving ART at a secondary health facility (54%), followed by primary health  
 165 facilities (33%) (Table 1). Clients receiving treatment at a tertiary or secondary health facility were  
 166 more likely to be virally non-suppressed compared with clients receiving ART at a primary health  
 167 facility.

168  
 169 Ninety-four percent of the clients received ARVs from a publicly owned facility, with 92% of  
 170 them being virally suppressed (Table 1). Only 6% of the clients were receiving treatment from a  
 171 privately owned facility, with 91% of these clients virally suppressed.

173 **Table 1. Characteristics of the 517,012 clients with a viral load test on record at Nigerian**  
 174 **facilities between 2001 and 2021.**

Factors	Non-suppressed (%)	Suppressed (%)	Total (%)	p-value
<b>Sex</b>				
Female	26,558 (8)	312,401 (92)	338,959 (66)	0.042873
Male	14,236 (8)	163,817 (92)	178,053 (34)	
<b>Age group</b>				
35–44	12,045 (7)	152,752 (93)	164,797 (32)	<0.000001
25–34	12,157 (8)	149,699 (92)	161,856 (31)	
45–59	7,006 (7)	98,026 (93)	105,032 (20)	
15–24	4,535 (9)	44,231 (91)	48,766 (9)	
60+	1,278 (7)	17,985 (93)	19,263 (4)	

0–14	3,773 (22)	13,525 (78)	17,298 (3)	
<b>Current ART status</b>				
Active	22,786 (5)	428,619 (95)	451,405 (87)	<0.000001
IIT	10,370 (26)	29,132 (74)	39,502 (8)	
Transferred out	3,834 (24)	12,014 (76)	15,848 (3)	
Dead	3,104 (38)	5,024 (62)	8,128 (2)	
Stopped	700 (33)	1,429 (67)	2,129 (0)	
<b>Current regimen line</b>				
Adult 1st line	35,558 (7)	456,863 (93)	492,421 (95)	<0.000001
Pediatric 1st line	2,706 (22)	9,695 (78)	12,401 (2)	
Adult 2nd line	2,389 (20)	9,438 (80)	11,827 (2)	
Pediatric 2nd line	123 (40)	182 (60)	305 (0)	
Adult 3rd line	10 (29)	24 (71)	34 (0)	
Salvage	8 (33)	16 (67)	24 (0)	
<b>Facility level</b>				
Secondary	25,233 (9)	254,063 (91)	279,296 (54)	<0.000001
Primary	8,067 (5)	163,076 (95)	171,143 (33)	
Tertiary	7,494 (11)	59,079 (89)	66,573 (13)	
<b>Facility Ownership</b>				
Public	38,124 (8)	448,514 (92)	486,638 (94)	<0.000001
Private	2,670 (9)	27,704 (91)	30,374 (6)	
<b>Facility size</b>				
Large	32,055 (7)	400,824 (93)	432,879 (84)	<0.000001
Medium	8,337 (11)	70,774 (89)	79,111 (15)	
Small	402 (8)	4,620 (92)	5,022 (1)	
<b>MMD</b>				
3+	10,419 (3)	308,307 (97)	318,726 (62)	<0.000001
3	15,094 (10)	135,703 (90)	150,797 (29)	
1–2	15,281 (32)	32,208 (68)	47,489 (9)	
<b>Time to last VL</b>				
3+ years	18,994 (9)	200,513 (91)	219,507 (42)	<0.000001

	<1 year	11,031 (6)	166,782 (94)	177,813 (34)	
	1–3 year	10,769 (9)	108,923 (91)	119,692 (23)	
	<b>Zone</b>				
	South-South	16,985 (6)	264,688 (94)	281,673 (54)	<0.000001
	North-East	8,137 (10)	71,155 (90)	79,292 (15)	
	North-West	6,065 (10)	57,112 (90)	63,177 (12)	
	South-West	4,981 (9)	49,052 (91)	54,033 (10)	
	North-Central	4,626 (12)	34,211 (88)	38,837 (8)	

175

176 A greater proportion of ART clients received treatment from a large volume facility (84%), with  
 177 93% of these clients being virally suppressed (Table 1). ART clients at the medium volume  
 178 facilities comprised 15% of the total clients, with 89% of them being virally suppressed.  
 179 MMD of more than three months (62%) and three months (29%) of ARVs were the majority (Table  
 180 1). These two groups had the highest proportions of virally suppressed clients on treatment, at 97%  
 181 and 90%, respectively.

182

183 Forty-two percent of the clients had been on ART for more than three years and 34% had been on  
 184 treatment for less than one year (Table 1). Clients who were on ART for less than one year had a  
 185 higher proportion of being virally suppressed (94%) than those who had been on ART for one to  
 186 three years or more than three years (both 91%). The South-South zone had the largest proportion  
 187 of clients (54%) in the sample and had the highest proportion of virally suppressed clients (94%)  
 188 (Table 1).

189

190 A multivariable logistic regression model was run using the Sex, age group, facility level, facility  
 191 size, time to last VL, MMD and Zone. All variables were significant, except for “Facility  
 192 Ownership” (p-value =0.64925). The AIC for this model did not change when ownership was  
 193 included (AIC= 243,815), therefore it was removed from the model. Backward elimination of  
 194 variables produced the lowest AIC—243,815 with all variables combined—that is, sex, time to  
 195 last VL, facility level, facility size, age group, geopolitical zone, and MMD. The logistic regression  
 196 model assessing the relationship between predictor variables and a non-suppressed VL among  
 197 ART clients is summarized in Table 2. All factors used in the adjusted logistic regression model

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198 were statistically significant, with a p-value of <0.000001, except for the <1 year time to last VL,  
199 which had a p-value of 0.18893, and small facility size, with a p-value of 0.00029.

201 Males (adjusted odds ratio [AOR]=1.08, 95% CI: 1.05–1.10, P<0.000001) were found to have 8%  
202 higher odds of being virally non-suppressed than females (Table 2). Univariable and multivariable  
203 logistic regression indicated with statistical significance that young people ages 0–24 were  
204 associated with higher odds of viral non-suppression compared with the 35–44 age group. Younger  
205 clients ages 0–14 years had the highest adjusted odds (AOR = 1.87, 95% CI: 1.79–1.95,  
206 P<0.000001).

208 **Table 2. Factors associated with a non-suppressed viral load presented as unadjusted odds**  
209 **ratio and adjusted odds ratio derived using logistic regression.**

Factors	Unadjusted OR		Adjusted OR	
	OR [95% CI]	p-value	AOR [95% CI]	p-value
<b>Sex</b>				
Female	1 [ref]		1 [ref]	
Male	1.02 [1.00–1.04]	0.042321	1.08 [1.05–1.1]	<0.000001
<b>Age group</b>				
35–44	1 [ref]		1 [ref]	
0–14	3.54 [3.40–3.68]	<0.000001	1.87 [1.79–1.95]	<0.000001
15–24	1.30 [1.25–1.35]	<0.000001	1.4 [1.35–1.45]	<0.000001
25–34	1.03 [1.00–1.06]	0.027536	1.1 [1.07–1.13]	<0.000001
45–59	0.91 [0.88–0.93]	<0.000001	0.83 [0.81–0.86]	<0.000001
60+	0.90 [0.85–0.96]	0.000633	0.78 [0.73–0.83]	<0.000001
<b>Facility level</b>				
Secondary	1 [ref]		1 [ref]	
Primary	0.5 [0.49–0.51]	<0.000001	0.74 [0.72–0.76]	<0.000001
Tertiary	1.28 [1.24–1.31]	<0.000001	1.16 [1.12–1.19]	<0.000001
<b>Facility size</b>				
Large	1 [ref]		1 [ref]	
Medium	1.47 [1.44–1.51]	<0.000001	1.42 [1.38–1.46]	<0.000001

Small	1.09 [0.98–1.21]	0.106851	1.22 [1.1–1.36]	0.00029
<b>Time to last VL</b>				
3+ years	1 [ref]		1 [ref]	
<1 year	0.70 [0.68–0.72]	<0.000001	0.98 [0.95–1.01]	0.18893
1–3 years	1.04 [1.02–1.07]	0.000709	1.14 [1.11–1.18]	<0.000001
<b>MMD</b>				
3+ months	1 [ref]		1 [ref]	
1–2 months	14.04 [13.66–14.43]	<0.000001	14.05 [13.64–14.48]	<0.000001
3 months	3.29 [3.21–3.38]	<0.000001	3.13 [3.05–3.22]	<0.000001
<b>Zone</b>				
South-South	1 [ref]		1 [ref]	
North-Central	2.11 [2.04–2.18]	<0.000001	1.83 [1.76–1.9]	<0.000001
North-East	1.78 [1.73–1.83]	<0.000001	1.49 [1.45–1.54]	<0.000001
North-West	1.65 [1.60–1.71]	<0.000001	0.89 [0.86–0.93]	<0.000001
South-West	1.58 [1.53–1.64]	<0.000001	0.74 [0.72–0.77]	<0.000001

210

211 Compared with the South-South zone, clients in the North-Central (AOR = 1.83, 95% CI: 1.76–

212 1.9) and North-East (AOR = 1.49, 95% CI: 1.45–1.54) zones had greater odds of VL non-

213 suppression (P<0.000001) (Table 2). Clients in the South-West zone had the lowest odds for VL

214 non-suppression (AOR = 0.74, 95% CI: 0.72–0.77).

215 Clients receiving ARVs at the tertiary health facilities were 16% more likely to be virally non-

216 suppressed (AOR=1.16, 95% CI: 1.12 –1.19) whereas primary health facilities were the most

217 protected (AOR = 0.74, 95% CI: 0.72–0.76) (Table 2). Moreover, small (AOR=1.22, 95% CI: 1.1–

218 1.36, P= 0.00029) and medium (AOR=1.42, 95% CI: 1.38–1.46, P<0.000001) facilities were found

219 to have the highest odds for viral non-suppression compared with large facilities.

220

221 The MMD was significantly associated with viral non-suppression. ART clients on 1–2 MMD had

222 the highest odds of viral non-suppression rates (AOR= 14.05, 95% CI: 13.64–14.48) in the

223 adjusted logistic regression model.

224



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3 225 Compared with clients who had been on ART for more than three years, those who had been on  
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5 226 treatment between 1 and 3 years were 14% more likely to be virally non-suppressed (AOR=1.14,  
6  
7 227 95% CI: 1.11–1.18), whereas clients on ART for less than one year were found to be 2% less likely  
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9 228 to be virally non-suppressed (AOR=0.98, 95% CI: 0.98–1.01).  
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11 229

## 12 230 **Discussion**

13  
14 231 Our study found that clients in younger age groups and those on MMD of 1-2 months had the  
15  
16 232 highest association with VL non-suppression. We also found that males, clients who received  
17  
18 233 treatment at tertiary health facilities, at small or medium facilities, or in the North-Central or North-  
19  
20 234 East zones were associated with a higher risk of VL non-suppression. Other studies have found  
21  
22 235 similar results for the risk of viral non-suppression in younger age groups in Cambodia, Uganda,  
23  
24 236 and South Carolina (USA) [6,8,16], and among males [17–19].  
25  
26 237

27 238 The increased odds of viral non-suppression among ART clients who received treatment at tertiary  
28  
29 239 health facilities were unlike the higher odds reported for primary health facilities in Ethiopia [20].  
30  
31 240 Small and medium facilities were identified as having greater odds for viral non-suppression; this  
32  
33 241 was consistent with findings that clients were more likely to miss consecutive visits at lower  
34  
35 242 volume facilities [21].  
36  
37 243

38 244 ART clients who had their last VL test conducted within less than 1 year on treatment were less  
39  
40 245 likely to be virally non-suppressed compared with clients who had their VL tested conducted  
41  
42 246 within 1 to 3 years of being on ART. Our finding was consistent with the Center for Disease  
43  
44 247 Control and Prevention's finding that PLHIV on ART could be virally suppressed within six  
45  
46 248 months of initiation, provided that they adhered to their medication [22]. Moreover, a greater  
47  
48 249 likelihood of viral suppression was found among PLHIV who were initiated on treatment for less  
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50 250 than one year compared with those on ART for more than one year [23]. However, contrary to this,  
51  
52 251 a shorter time on ART was identified as a factor associated with a non-suppressed VL in South  
53  
54 252 Africa [24]. The contradictory findings in the literature could speak to the specific adherence  
55  
56 253 patterns of the populations investigated and models that may be specific to the study settings. Also,  
57  
58 254 elucidating that clients more engaged in care can have more opportunities for non-suppressed viral  
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1  
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3 255 load test results, though this does not necessarily mean that this population is more likely to be  
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5 256 non-suppressed.

6 257  
7  
8 258 Short duration MMD of 1 to 3 months was identified as having the highest odds for a non-  
9  
10 259 suppressed VL in both the univariable and multivariable models. This is interesting because shorter  
11  
12 260 MMD is also associated with non-adherence [25]. Shorter MMD is initially prescribed to new  
13  
14 261 clients and longer MMD is prescribed to virally stable clients to reduce the number of clinic visits  
15  
16 262 [26]. Because of non-adherence, clients may become virally non-suppressed and be placed on  
17  
18 263 shorter duration treatment, requiring more frequent check-ups and clinical support to become  
19  
20 264 stable. It is apparent that MMD is dependent on the VL status of clients; however, that is not  
21  
22 265 necessarily the case for new clients. The logistic regression model built here suggested that a  
23  
24 266 shorter MMD was associated with a non-suppressed VL. In this case, the MMD was a confounding  
25  
26 267 factor that possibly represented some degree of IIT because it was not the actual length of the  
27  
28 268 prescription that can affect the VL, rather its misadministration. We found value in retaining the  
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30 269 confounding factor in the analysis because we cannot use a factor like IIT instead, because, at the  
31  
32 270 time of the VL test, the client was active on treatment. In the absence of longitudinal data that can  
33  
34 271 identify IIT as a precedent to non-suppressed VL, we chose to include MMD in the analysis as a  
35  
36 272 proxy indicator. In doing so, the recommendation of enrolling patients on 3+ MMD to support  
37  
38 273 viral suppression is still valid, even if the improvement in VL suppression is caused by correct  
39  
40 274 adherence to treatment, not by the actual length of MMD.

41 275 A possible explanation for the North-Central zone having the highest odds of viral non-suppression  
42  
43 276 could be linked to health-seeking behaviour such as non-use of the service, poor adherence to  
44  
45 277 treatment, and possibly religious affiliation (for example Islamic religion predominant in norther  
46  
47 278 Nigeria) where in certain circumstances women require permission to leave the premises of a  
48  
49 279 household which can reduce access to healthcare [27,28].

50 280 One of the limitations of our study was the inaccessibility of the longitudinal data set, leaving us  
51  
52 281 unable to conduct a longitudinal study to explore the factors affecting viral non-suppression over  
53  
54 282 time. We were therefore restricted to conducting a cross-sectional study. The inclusion of MMD  
55  
56 283 as an independent variable is a limitation of the study because a shorter MMD can be applied based  
57  
58 284 on a non-suppressed VL, in which case MMD would be a proxy for IIT.

59 285

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3 286 It is likely that some of the nearly 40% of client records (eliminated from analysis) without a VL  
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5 287 test on record are a consequence of poor adherence to treatment which could lead to viral load  
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7 288 non-suppression that is not tested/recorded. Investigating the factors that are associated with an  
8  
9 289 untested viral load could provide useful insight. At the same time, longitudinal studies into both  
10  
11 290 viral load non-testing and viral load non-suppression may ultimately be of greatest use. Additional  
12  
13 291 variables relating to the capacity of clinical facilities to conduct testing would reveal whether the  
14  
15 292 lack of viral load testing is also affected by a low capacity.

16 293  
17 294 Other unavailable variables that could be explored in future studies to identify their association  
18  
19 295 with viral suppression are tuberculosis status, adherence level, ART drug regimen, marital status,  
20  
21 296 and education level. The absence of VL suppression data for adolescents and recently initiated  
22  
23 297 clients may have also had an impact on the study, suggesting that these findings may not  
24  
25 298 necessarily apply to those sub population groups.

26 299  
27 300 **Conclusions**  
28  
29 301 Enabling the provision of 3+ months of MMD to PLHIV and targeting younger age groups (below  
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31 302 35), tertiary health facility, small and medium facilities, and the North-Central and North-East  
32  
33 303 geopolitical zones for interventions could lead to improvements in VL suppression in Nigeria. The  
34  
35 304 independent factors associated here with a non-suppressed VL can guide the improvement of ART  
36  
37 305 program development and VL suppression of PLHIV in Nigeria.

38 306  
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40 308  
41 309 **Author contributions:** Study Design: ST, TC, JA, FA, CC, CWK, PP; Data collection: JA, DSD,  
42  
43 310 EO; Data analysis: ST, TC, JA; Funding acquisition: DSD, FA, PP; Data Interpretation: All  
44  
45 311 authors; Writing – original draft: ST, TC, JA; Writing – review and editing: All authors. All authors  
46  
47 312 read and approved the final manuscript.

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50  
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52  
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8  
9 320 including bilateral support through USAID Nigeria's Data for Implementation (Data.FI)  
10  
11 321 mechanism under the terms of Cooperative Agreement 7200AA19CA0004 to Palladium and Right  
12  
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16  
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18  
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20  
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22  
23 327  
24 328 **Data Statement:** The data that support the findings of this study are owned by the Government of  
25  
26 329 Nigeria and were used under license for the current study. Access to these data is subject to  
27  
28 330 restrictions owing to privacy and ethics policies set by the Government of Nigeria so are not  
29  
30 331 publicly available. Requests to access these data should be directed to  
31  
32 332 Dauda.Sulaiman@thepalladiumgroup.com.

### 33 334 **List of abbreviations**

34 335	AIC:	Akaike information criterion
35 336	AOR:	Adjusted odds ratio
36 337	ART:	Antiretroviral therapy
37 338	ARV:	Antiretroviral
38 339	CI:	Confidence interval
39 340	Data.FI:	Data for Implementation
40 341	EMR:	Electronic medical records
41 342	FMOH:	Federal Ministry of health
42 343	HFR:	Health facility registry
43 344	HIV:	Human immunodeficiency virus
44 345	IIT:	Interruption in treatment
45 346	IP:	Implementing partner
46 347	MMD:	Multi-month dispensing

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3 348 PEPFAR: United States President's Emergency Plan for AIDS Relief  
4  
5 349 PLHIV: People living with HIV  
6  
7 350 RADET: Retention audit determination tool  
8  
9 351 UNAIDS: Joint United Nations Programme on HIV/AIDS  
10  
11 352 USAID: United States Agency for International Development  
12  
13 353 VL: Viral load  
14  
15 354

### 15 355 **Ethics approval**

16  
17 356 Ethical approvals for this study were obtained in Nigeria and the United States. Informed consent  
18  
19 357 was waived from all subjects or, if subjects are under 18, from a parent and/or legal guardian by  
20  
21 358 the expedited institutional review board (IRB) approvals granted by both the National Health  
22  
23 359 Research Ethics Committee of Nigeria (NHREC), reference number NHREC/01/01/2007, and the  
24  
25 360 HML IRB in the United States, reference number 772EQH20. Data were anonymised and handled  
26  
27 361 confidentially during all phases of the research. All methods were carried out in accordance with  
28  
29 362 relevant guidelines and regulations. All experimental protocols were granted approval by the  
30  
31 363 institutional review board (IRB) of the National Health Research Ethics Committee of Nigeria  
32  
33 364 (NHREC), reference number NHREC/01/01/2007, and the HML IRB in the United States,  
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35 365 reference number 772EQH20.

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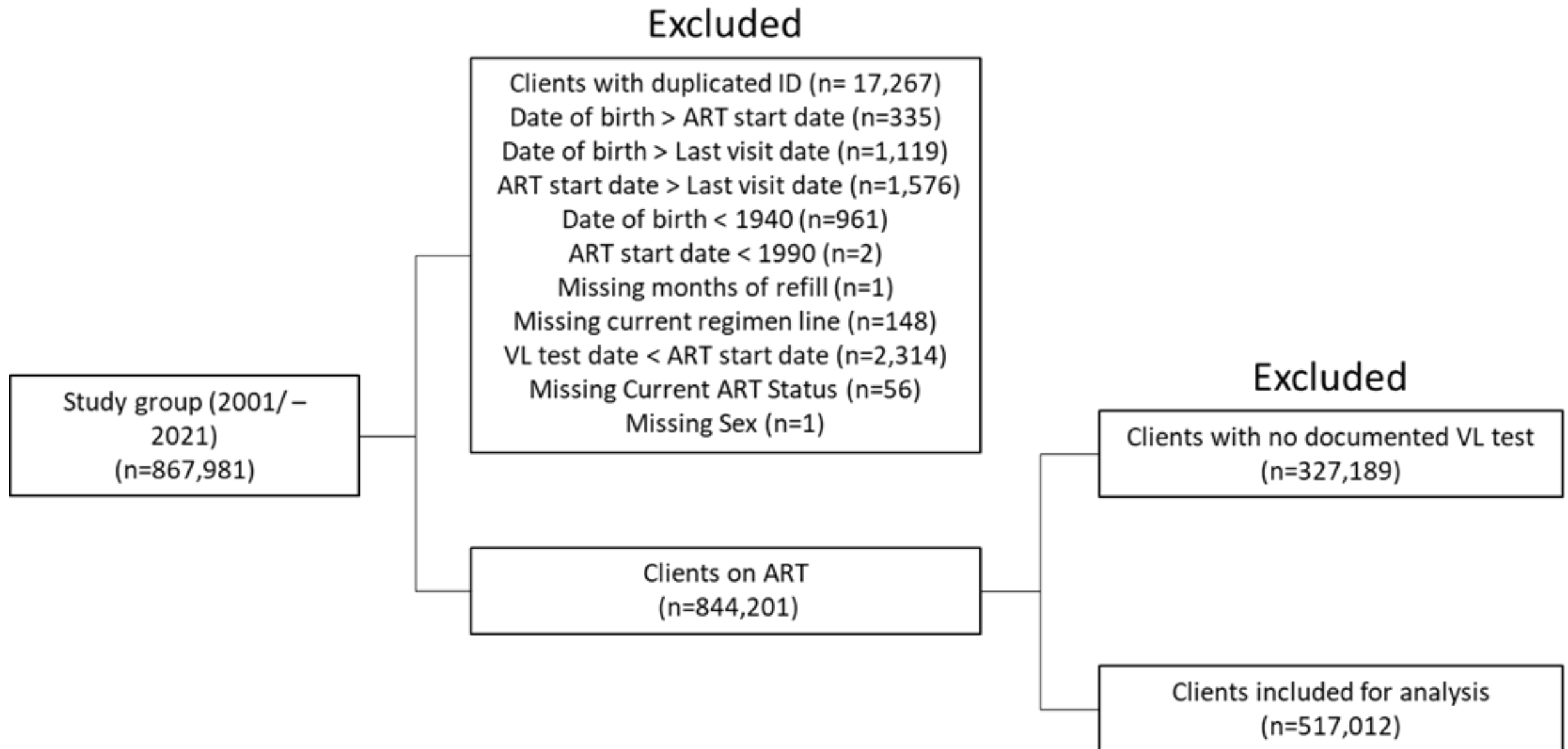
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# Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

## Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

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von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

			Page Number
<b>Title and abstract</b>			
Title	<a href="#">#1a</a>	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	<a href="#">#1b</a>	Provide in the abstract an informative and balanced summary of what was done and what was found	3
<b>Introduction</b>			
Background / rationale	<a href="#">#2</a>	Explain the scientific background and rationale for the investigation being reported	4
Objectives	<a href="#">#3</a>	State specific objectives, including any prespecified hypotheses	4
<b>Methods</b>			
Study design	<a href="#">#4</a>	Present key elements of study design early in the paper	5
Setting	<a href="#">#5</a>	Describe the setting, locations, and relevant dates, including periods of	5

recruitment, exposure, follow-up, and data collection

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3	Eligibility criteria	<a href="#">#6a</a>	Give the eligibility criteria, and the sources and methods of selection of participants. 5
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6		<a href="#">#7</a>	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable 6
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10	Data sources /	<a href="#">#8</a>	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable. 5
11	measurement		
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17	Bias	<a href="#">#9</a>	Describe any efforts to address potential sources of bias 7
18			
19	Study size	<a href="#">#10</a>	Explain how the study size was arrived at 6
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21	Quantitative	<a href="#">#11</a>	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why 6
22	variables		
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25	Statistical	<a href="#">#12a</a>	Describe all statistical methods, including those used to control for confounding 7
26	methods		
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29	Statistical	<a href="#">#12b</a>	Describe any methods used to examine subgroups and interactions 7
30	methods		
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33	Statistical	<a href="#">#12c</a>	Explain how missing data were addressed 5
34	methods		
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37	Statistical	<a href="#">#12d</a>	If applicable, describe analytical methods taking account of sampling strategy 6
38	methods		
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41	Statistical	<a href="#">#12e</a>	Describe any sensitivity analyses 8
42	methods		
43			
44	<b>Results</b>		
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47	Participants	<a href="#">#13a</a>	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable. 6
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55	Participants	<a href="#">#13b</a>	Give reasons for non-participation at each stage 6
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57	Participants	<a href="#">#13c</a>	Consider use of a flow diagram 6
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1	Descriptive data	<a href="#">#14a</a>	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	9
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6	Descriptive data	<a href="#">#14b</a>	Indicate number of participants with missing data for each variable of interest	5
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10	Outcome data	<a href="#">#15</a>	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	9
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14	Main results	<a href="#">#16a</a>	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11
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19	Main results	<a href="#">#16b</a>	Report category boundaries when continuous variables were categorized	6
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21	Main results	<a href="#">#16c</a>	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11
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25	Other analyses	<a href="#">#17</a>	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	11
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29	<b>Discussion</b>			
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31	Key results	<a href="#">#18</a>	Summarise key results with reference to study objectives	13
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34	Limitations	<a href="#">#19</a>	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	15
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39	Interpretation	<a href="#">#20</a>	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	14
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41				
42				
43				
44	Generalisability	<a href="#">#21</a>	Discuss the generalisability (external validity) of the study results	16
45				
46				
47	<b>Other</b>			
48	<b>Information</b>			
49				
50				
51	Funding	<a href="#">#22</a>	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16
52				
53				
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## Factors associated with viral load non-suppression in people living with HIV on ART in Nigeria: cross-sectional analysis from 2017 to 2021

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# Factors associated with viral load non-suppression in people living with HIV on ART in Nigeria: cross-sectional analysis from 2017 to 2021

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## 1 **Abstract**

2 **Objectives** Identify factors (demographic and clinical) associated with a non-suppressed viral load  
3 of patients on antiretroviral therapy in Nigeria.

4  
5 **Design** Cross-sectional study.

6  
7 **Setting** Sixteen United States Agency for International Development (USAID) supported states in  
8 Nigeria.

9  
10 **Participants** 585,632 people living with HIV (PLHIV) on antiretroviral therapy (ART).

11  
12 **Primary outcome measures** Viral load (VL) non-suppression (defined as having a VL of at least  
13 1,000 HIV ribonucleic acid copies per mL of plasma). Chi-square testing and multivariable logistic  
14 regression were conducted on routinely collected ART program data.

15  
16 **Results** Sixty-six percent of the study population were females. The largest age groups were 25-  
17 34 and 35–44, accounting for 32.1% and 31.1%, respectively. Males had 9% greater risk  
18 (ARR=1.09) of being non-suppressed. The age groups below the 60+ age group (ARR=0.65) had  
19 higher risk of having a non-suppressed VL, with the highest odds in the 0–14 age group  
20 (ARR=2.56). Clients enrolled at tertiary and secondary level facilities had the greatest risk of  
21 having a non-suppressed VL. Clients who started ART between 2010 and 2015 had the greatest  
22 risk of viral non-suppression (ARR=6.53). A shorter time on ART until the last VL (1 years  
23 [ARR=3.9]) was associated with a higher risk of a non-suppressed VL. Clients receiving care at  
24 private facilities had lower risk of viral non-suppression. Clients in the Edo (ARR=2.82) and Borno  
25 (ARR=2.62) states had the greatest risk of viral non-suppression.

26  
27 **Conclusions** Targeting male clients within the younger age groups, receiving care for less than 3  
28 years at tertiary and secondary health facilities, small and medium facilities, and in the Edo, Borno  
29 and Niger states for interventions could lead to improvements in VL suppression in Nigeria. The  
30 independent factors associated with a non-suppressed VL can guide improvements in ART  
31 program development and VL suppression of PLHIV in Nigeria.



## 32 **Strengths and limitations of the study**

- 33 • The study uses data from over 500,000 PLHIV enrolled on ART across 16 Nigeria states  
34 over four years between 2017 and 2021.
- 35 • The data used is routinely collected by clinics.
- 36 • The study included distal factors such as state, facility level, size and, ownership.
- 37 • Variables such as education level and marital status/cohabiting, adherence to treatment,  
38 opportunistic infections and side effects were not available.

## 40 **Introduction**

41 In 2020, 37.7 million people were living with HIV (PLHIV) globally; currently, 27.5 million  
42 (73%) have access to antiretroviral therapy (ART) [1]. In 2020, 66% of PLHIV were virally  
43 suppressed [1]. Nigeria, a country with one of the highest global HIV infection rates, was reported  
44 to have 78% of PLHIV on ART virally suppressed, against a target of 95% [1,2]. The Nigeria  
45 National Guidelines for HIV Prevention, Treatment, and Care define virologic suppression as  
46 having a viral load (VL) below 1,000 HIV ribonucleic acid copies per mL of plasma [3] (viral load  
47 non-suppression is defined as having a VL of at least 1,000 HIV ribonucleic acid copies per mL  
48 of plasma). Given that an undetectable VL significantly reduces the transmission risk of HIV,  
49 suppressing the VL of 95% of PLHIV on ART is key to achieving epidemic control [4,5].

50 Globally, including in some Nigerian states, factors that were found to be predictors of viral  
51 suppression were age, sex, duration on ART [6–9], current ART regimen [10], and adherence to  
52 medications [11]. This study explored whether similar associations alongside other factors such as  
53 geo-political zones and facility level existed in Nigeria using data over a period of four years from  
54 16 States that were not necessarily under investigation before, contributing to the body of  
55 knowledge and allowing better targeted interventions to improve HIV programs, the VL of clients,  
56 and epidemic control in the country.

57 The objective of this study was to determine which factors were associated with a non-suppressed  
58 VL in Nigeria using a large cross-sectional database of clients who received ART. We explored  
59 several variables—sex, age group, duration on ART, facility level, facility ownership, State and  
60 geopolitical zone—to identify which factors were associated with viral non-suppression. The  
61 objective of this analysis is to guide HIV programs to target population groups at the highest risk.

## 62 **Methods**

### 63 **Study design, setting, and population**

64 The study was a cross-sectional analysis of clients who were enrolled on ART at 580 facilities  
65 across 16 States in Nigeria that were supported by the United States Agency for International  
66 Development (USAID). The data set covered a period of 4 years, with the last drug pickup dates  
67 ranging from January 1, 2017, December 31, 2021. The study was carried out to investigate the  
68 clinical and demographic factors associated with a non-suppressed VL among more than 500,000  
69 HIV clients who had a VL test on record.

### 71 **Data Source and Management**

72 The data were routinely collected by the USAID-supported implementing partners (IPs) through  
73 their quarterly data submission using the retention and audit determination tool (RADET). Each  
74 IP submission was then combined into a single data set that was used for this study. The RADET  
75 dataset provides cross-sectional information for every client ever enrolled on ART at their last  
76 point of visit to the clinics supported of USAID and associated IPs. That is, longitudinal records  
77 for variables are not available nor ethically approved for studying, for example only the last  
78 recorded viral load test for each client is available. Depending on the purpose of the clinical visit  
79 of the clients, the data is collected to reflect the most recent clinical details of a particular client.

80  
81 The data set received contained 775,013 non-longitudinal, cross-sectional client records with a last  
82 drug pickup date between January 1<sup>st</sup>, 2017, and December 31<sup>st</sup>, 2021, were retained for  
83 downstream analysis to isolate a cohort that was active during the latest VL suppression policy  
84 rolled out in Nigeria, whereby every client on treatment for 6 months is due for a VL test, and VL  
85 tests should be repeated every 12 months[12]. Due to missing unique client identifiers for 153,433  
86 clients, a unique identifier was created for data deduplication using the date of birth, sex, database-  
87 provided unique identifier, and client hospital number. For clarification, unique identifiers are not  
88 provided for all clients, in such cases a client hospital number is captured instead. Data cleaning  
89 involved removing duplicate unique identifiers (n=5,973). Data which may have contained a typo,  
90 like records with a date of birth occurring after the ART start date (n=48) or after the date of last  
91 drug pickup (n=240) were removed. Clients with an ART start date earlier than 2002 (n=74) when  
92 the ART program started in Nigeria [13] were also excluded from the analysis. Additional 166,037

93 clients without a date of viral load sample collection were removed alongside a further 17,009 who  
 94 did not receive their VL test results. After data cleaning, 585,632 client records were retained for  
 95 analyses (Figure 1).

96

97 **Figure 1. Data cleaning process, excluded data, and study population subset analysed.**

98

### 99 **Variables engineered as predictors of a non-suppressed viral load**

100 The age variable was calculated as the time difference (in years) between the date of VL sample  
 101 collection and the date of birth of the client. Then, age group was reclassified into six groups: 0–  
 102 14, 15–24, 25–34, 35–44, 45–59, and 60+ years.

103 Similarly, the “duration on ART to last VL test” variable was created by calculating the time  
 104 difference (in months) between the date of received current VL and the ART start date. The  
 105 duration on ART was reclassified as <1 year, 1–3 years, and 3+ years, and labelled as “Time on  
 106 ART.”

107 The “Facility Size” variable was calculated by determining the number of clients receiving care at  
 108 the facility, then group as small ([0,25) percentiles), medium ([25,75) percentiles), or large  
 109 ([75,100] percentiles). The number and distribution of clients into the small, medium, and large  
 110 facilities is presented in Table 1.

111 **Table 1. Summary of the distribution of facility size by the number of clients in care.**

Facility Size	Number Of Facilities	Number Of Clients				
		Total	Min.	Max.	Mean	Median
Small	143	5,360	4	62	37	39
Medium	295	92,348	63	1,078	313	199
Large	146	487,924	1,088	13,585	3,342	2,879

112

113

114 The “Facility Level” variable was obtained from the Nigeria Health Facility Registry (HFR) [14].

115 The classification resulted in three levels of facilities: primary (operate at Local Government  
 116 level), secondary (operate at State level), and tertiary (operate at Federal Government level) [15].

117 Similarly, the “Facility Ownership” variable was created by grouping the facilities in their  
 118 respective ownership type (public or private) according to their classification in the Nigeria HFR  
 119 system [14].

120

1  
2  
3 121 The “geopolitical zone” variable was created by grouping the 16 USAID-supported States into  
4  
5 122 their nationally recognized geopolitical zones. This resulted in five geopolitical zone groupings:  
6  
7 123 North-Central (Kwara and Niger States), North-East (Adamawa, Bauchi, Borno, and Yobe States),  
8  
9 124 North-West (Jigawa, Kano, Kebbi, Sokoto, and Zamfara States), South-South (Akwa Ibom,  
10  
11 125 Bayelsa, Cross River, and Edo States), and South-West (Lagos).  
12  
13

### 14 127 **Patient and public involvement**

15 128 Patients or the public were not involved in the design, or conduct, or reporting, or dissemination  
16  
17 129 plans of our research.  
18  
19 130

### 20 131 **Statistical analysis**

21  
22 132 For the population with a last VL test on record, the Pearson's chi-square test was used to examine  
23  
24 133 the association of each variable with a non-suppressed VL at a client's last VL test date.  
25  
26 134 Unadjusted and adjusted logistic regression models were run to explore the association of variables  
27  
28 135 with a non-suppressed VL (a VL above 1,000 ribonucleic acid copies per mL of plasma). Current  
29  
30 136 ART status was excluded as a factor from the regression modelling because at the time of the VL  
31  
32 137 test, all clients were active, even though they may now have a different status (interruption in  
33  
34 138 treatment (IIT) defined as missing a drug-pickup appointment for longer than 28 days, deceased,  
35  
36 139 transferred out, or stopped treatment). Similarly, the regimen line was excluded from the  
37  
38 140 regression analysis because other regimen lines, aside from the first-line regimen, are prescribed  
39  
40 141 in the case of a non-suppressed VL or reaction or a reported side effect from the current ARVs.  
41  
42 142 The regimen line was therefore dependent on the VL outcome investigated and it could not be used  
43  
44 143 as an independent variable associated with VL non-suppression. The variables included in the  
45  
46 144 models were sex, age group, ART start year, time on ART to last VL test, facility level, facility  
47  
48 145 size, facility ownership and, State. The group accounting for the most clients in each of the  
49  
50 146 independent variables analysed was set as the reference group for the respective variable. A two-  
51  
52 147 tailed P value of  $P < 0.05$  was used to define statistical significance. Model selection was done using  
53  
54 148 forward addition and backward elimination of variables where the Akaike's information criterion  
55  
56 149 (AIC) was used to evaluate variable inclusion in the final model. The retained model with the  
57  
58 150 lowest AIC resulted in the exclusion of the geopolitical zone variable. Multicollinearity was tested  
59  
60 151 using the generalized variance inflation factor (GVIF) for the set of variables used in the logistic

1  
2  
3 152 regression model, and none of the variables exhibited multicollinearity (having a GVIF below 1.4).  
4  
5 153 The odds ratio (OR) and confidence intervals for the logistic regression models were converted to  
6  
7 154 risk ratios (RR) using Equation 1 [16] where  $P_0$  is the prevalence of non-suppressed VL in the  
8  
9 155 unexposed (reference) group of each explanatory variable. This was done to avoid over-estimation  
10  
11 156 of the OR caused by the high prevalence of non-suppressed VL across some explanatory variables  
12  
13 157 in the dataset which was above the 10% recommended threshold [16]. All data were analysed using  
14  
15 158 R software for Statistical Computing v4.0. [17].

$$16 \quad 159 \quad RR = \frac{OR}{(1 - P_0) + (P_0 \times OR)} \quad \text{Equation 1.}$$

17  
18 160  
19  
20 161

## 21 162 **Results**

22  
23 163 Of the 585,632 clients included in the analysis, 35,539 (6.07%) were virologically non-suppressed  
24  
25 164 while the remaining 93.9% were virologically suppressed (Table 2). Sixty-five percent of the  
26  
27 165 clients were female, with 6.1% of both sexes virologically non-suppressed. Clients ages 25–34 and  
28  
29 166 35–44 were the largest age groups, accounting for 32.1% and 31.1% of the total number of clients  
30  
31 167 in the analysis, respectively. Clients in the 0–14 age group was the smallest group (3.4%) and had  
32  
33 168 the largest proportion of virally non-suppressed individuals (17.8%).

34 169  
35 170 The Current ART status was recorded as active for 88.9% of the clients, with the remaining 11.1%  
36  
37 171 being dead (1.7%), had stopped treatment (0.5%) had transferred out to another facility (3.1%), or  
38  
39 172 had interrupted treatment (5.8%) (Table 2). Most clients (95.8%) were on the adult first-line ART  
40  
41 173 regimen, with 94.5% of them being virally suppressed. Clients on the adult second-line and  
42  
43 174 paediatric first-line regimens each accounted for 2% of the clients in the study, with 81.7% and  
44  
45 175 82% of clients on the two regimen lines being virally suppressed, respectively.

46 176  
47 177 Most clients were receiving ART at a secondary health facility (52.2%), followed by primary  
48  
49 178 health facilities (35.7%) (Table 2). Clients receiving treatment at a tertiary (9.7%) or secondary  
50  
51 179 health facility (7.0%) were non-suppressed in higher proportions compared with clients receiving  
52  
53 180 ART at a primary health facility.

54 181

182 Ninety-four percent of the clients received ARVs from a publicly owned facility, with 94% of  
 183 them being virally suppressed (Table 2). Only 6% of the clients were receiving treatment from a  
 184 privately owned facility, with 7.4% of these clients virally non-suppressed.

185  
 186 Akwa Ibom state has the highest proportion of clients in the record (36.8%) with viral suppression  
 187 rate of 96.9%. While Zamfara has the smallest proportion of clients (0.9%) with a viral suppression  
 188 rate of 89.6%, Kebbi state has the highest proportion of virally suppressed client with 98.4%  
 189 although, a smaller proportion of the clients (1.6%) in the study. The South-south zone served the  
 190 highest proportion of clients in the cohort and highest suppression rate (54.2% and 95.6%,  
 191 respectively). Similarly, North-Central Zone had the smallest proportion and lowest suppression  
 192 rate (7.4% and 90.6%, respectively).

193 **Table 2. Characteristics of the 517,012 clients with a viral load test on record at Nigerian**  
 194 **facilities between 2017 and 2021.**

Factors	Viral load		Total	p-value (<0.05)
	Suppressed	Non-Suppressed		
<b>Sex</b>				
Female	357 783 (93.9)	23 058 (6.1)	380 841 (65.0)	0.5
Male	192 300 (93.9)	12 491 (6.1)	204 791 (35.0)	0.5
<b>Age Group</b>				
0-14	16 450 (82.2)	3 561 (17.8)	20 011 (3.4)	
15-24	57 434 (92.9)	4 416 (7.1)	61 850 (10.6)	
25-34	177 648 (94.4)	10 580 (5.6)	188 228 (32.1)	
35-44	172 070 (94.5)	10 097 (5.5)	182 167 (31.1)	
45-59	106 743 (94.8)	5 813 (5.2)	112 556 (19.2)	
60+	19 738 (94.8)	1 082 (5.2)	20 820 (3.6)	
<b>Art Start Year</b>				
<2005	542 (94.4)	32 (5.6)	574 (0.1)	
[2005-2010)	40 276 (92.8)	3 113 (7.2)	43 389 (7.4)	
[2010-2015)	82 198 (91.1)	8 012 (8.9)	90 210 (15.4)	
[2015-2020)	220 451 (92.5)	17 808 (7.5)	238 259 (40.7)	
>2020	206 616 (96.9)	6 584 (3.1)	213 200 (36.4)	
<b>Time On Art</b>				
<1 year	156 702 (94.5)	9 085 (5.5)	165 787 (28.3)	
1-3 years	161 118 (94.6)	9 183 (5.4)	170 301 (29.1)	
3+ years	232 263 (93.1)	17 281 (6.9)	249 544 (42.6)	
<b>Regimen Switch</b>				
After VL test	269 102 (94.2)	16 696 (5.8)	285 798 (48.8)	
Before VL test	22 189 (78.5)	6 084 (21.5)	28 273 (4.8)	
Not Switched	258 792 (95.3)	12 769 (4.7)	271 561 (46.4)	



**Current ART Regimen**

3TC-TDF-DTG	517 510 (95.6)	24 011 (4.4)	541 521 (92.5)
3TC-TDF-EFV	8 893 (65.1)	4 759 (34.9)	13 652 (2.3)
ABC-3TC-DTG	9 356 (87.0)	1 403 (13.0)	10 759 (1.8)
Other	14 324 (72.7)	5 376 (27.3)	19 700 (3.4)

**ART dispensed (months)**

1-2	26 476 (67.9)	12 515 (32.1)	38 991 (6.7)
3	99 879 (89.3)	11 911 (10.7)	111 790 (19.1)
3+	423 728 (97.4)	11 123 (2.6)	434 851 (74.3)

**Current ART Status**

Active	501 083 (96.2)	19 544 (3.8)	520 627 (88.9)
Dead	6 568 (67.1)	3 217 (32.9)	9 785 (1.7)
IIT	25 849 (75.7)	8 313 (24.3)	34 162 (5.8)
Stopped	1 911 (71.9)	747 (28.1)	2 658 (0.5)
Transferred out	14 672 (79.7)	3 728 (20.3)	18 400 (3.1)

**Current Regimen Line**

Adult 1st Line	529 898 (94.5)	31 006 (5.5)	560 904 (95.8)
Adult 2nd Line	9 203 (81.7)	2 066 (18.3)	11 269 (1.9)
Adult 3rd Line	21 (58.3)	15 (41.7)	36 (0.006)
Peds 1st Line	10 850 (82.0)	2 382 (18.0)	13 232 (2.3)
Peds 2nd Line	97 (57.7)	71 (42.3)	168 (0.03)
Salvage	14 (60.9)	9 (39.1)	23 (0.004)

**Facility Size**

Small	4 920 (91.8)	440 (8.2)	5 360 (0.9)
Medium	84 429 (91.4)	7 919 (8.6)	92 348 (15.8)
Large	460 734 (94.4)	27 190 (5.6)	487 924 (83.3)

**Facility Level**

Primary	201 847 (96.5)	7 428 (3.5)	209 275 (35.7)
Secondary	284 415 (93.0)	21 275 (7.0)	305 690 (52.2)
Tertiary	63 821 (90.3)	6 846 (9.7)	70 667 (12.1)

**Facility Ownership**

Private	31 279 (92.6)	2 486 (7.4)	33 765 (5.8)
Public	518 804 (94.0)	33 063 (6.0)	551 867 (94.2)

**State**

Adamawa	38 183 (92.7)	3 020 (7.3)	41 203 (7.0)
Akwa Ibom	208 852 (96.9)	6 604 (3.1)	215 456 (36.8)
Bauchi	24 565 (93.8)	1 631 (6.2)	26 196 (4.5)
Bayelsa	11 046 (91.5)	1 025 (8.5)	12 071 (2.1)
Borno	14 595 (87.3)	2 122 (12.7)	16 717 (2.9)
Cross River	59 487 (95.4)	2 893 (4.6)	62 380 (10.7)
Edo	23 832 (87.3)	3 465 (12.7)	27 297 (4.7)
Jigawa	8 580 (88.8)	1 083 (11.2)	9 663 (1.7)
Kano	37 577 (92.8)	2 897 (7.2)	40 474 (6.9)
Kebbi	9 191 (98.4)	147 (1.6)	9 338 (1.6)

Kwara	8 308 (92.2)	705 (7.8)	9 013 (1.5)
Lagos	54 689 (92.2)	4 620 (7.8)	59 309 (10.1)
Niger	30 717 (90.2)	3 333 (9.8)	34 050 (5.8)
Sokoto	8 765 (92.3)	731 (7.7)	9 496 (1.6)
Yobe	7 032 (90.6)	730 (9.4)	7 762 (1.3)
Zamfara	4 664 (89.6)	543 (10.4)	5 207 (0.9)
<b>Zone</b>			
North-Central	39 025 (90.6)	4 038 (9.4)	43 063 (7.4)
North-East	84 375 (91.8)	7 503 (8.2)	91 878 (15.7)
North-West	68 777 (92.7)	5 401 (7.3)	74 178 (12.7)
South-South	303 217 (95.6)	13 987 (4.4)	317 204 (54.2)
South-West	54 689 (92.2)	4 620 (7.8)	59 309 (10.1)

195

196

197 A greater proportion of ART clients received treatment from a large volume facility (83.3%), with  
 198 94.4% of these clients being virally suppressed (Table 2). ART clients at the medium volume  
 199 facilities comprised 15.8% of the total clients, with 91.4% of them being virally suppressed.

200

201 Approximately forty-three percent of the clients had been on ART for more than three years and  
 202 28.3% had been on treatment for less than one year (Table 2). Clients who were on ART for less  
 203 than three years had a higher proportion of viral suppression (94.5%) than those who had been on  
 204 ART for more than three years (both 93.1%). The South-South zone had the largest proportion of  
 205 clients (54.2%) in the sample and had the highest proportion of virally suppressed clients (95.6%)  
 206 (Table 2).

207

208 A multivariable logistic regression model was run using the sex, age group, ART start year, time  
 209 on ART, facility level, facility size, facility ownership, State and Zone. The AIC for this model  
 210 did not change when Zone was included or excluded from the model by forward addition and  
 211 backward elimination (AIC= 245,641.3), therefore the Zone variable was removed from the model.  
 212 The odds ratios (OR) and risk ratios (RR) generated using the logistic regression model assessing  
 213 the relationship between predictor variables and a non-suppressed VL among ART clients are  
 214 presented in Table 3. All factors used in the adjusted logistic regression model were statistically  
 215 significant, with a p-value of below 0.05.

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3 217 Males (adjusted risks ratio [ARR]=1.09, 95% CI: 1.07–1.12, P<0.05) were found to have 9%  
4  
5 218 higher odds of being virally non-suppressed than females, however, unadjusted logistic regression  
6  
7 219 did not identify a significant difference between the odds of viral non-suppression of females and  
8  
9 220 males (Table 3). Univariable and multivariable logistic regression indicated with statistical  
10  
11 221 significance that young people ages 0–24 were associated with higher odds of viral non-  
12  
13 222 suppression compared with the 35–44 age group. Younger clients ages 0–14 years had the highest  
14  
15 223 unadjusted and adjusted risk of viral non-suppression (ARR = 1.87, 95% CI: 1.79–1.95, P<0.05).

16 224  
17 225 Clients who start ART between 2010 and 2015 (ARR = 6.53, CI: 6.26-6.82) had greater risk of  
18  
19 226 viral non-suppression compared to clients that started before 2010 or after 2015. Compared with  
20  
21 227 clients who had been on ART for more than three years, those who had been on treatment between  
22  
23 228 1 and 3 years had greater risk to be virally non-suppressed (ARR=1.67, 95% CI: 1.62–1.72),  
24  
25 229 whereas clients on ART for less than one year were found to have an even greater risk of viral  
26  
27 230 non-suppression (ARR=3.9, 95% CI: 3.77–4.03).

28 231  
29 232 Clients receiving ARVs at tertiary health facilities were 74% more likely to be virally non-  
30  
31 233 suppressed (ARR=1.74, 95% CI: 1.67 –1.82) than primary health facilities (Table 3). Moreover,  
32  
33 234 clients receiving care at small (ARR=1.66, 95% CI: 1.51–1.83) and medium (ARR=1.49, 95% CI:  
34  
35 235 1.45–1.54) facilities were found to have the higher risk of viral non-suppression compared to large  
36  
37 236 facilities. Clients receiving treatment at privately owned facilities (ARR=0.86, CI: 0.82-0.9) had a  
38  
39 237 lower risk of viral non-suppression than clients at publicly owned facilities.

40 238 Compared with the Akwa Ibom state, clients in the Edo (ARR = 2.82, 95% CI: 2.69–2.95) and  
41  
42 239 Borno (ARR =2.62, 95% CI: 2.48–2.76) states had greater odds of VL non-suppression (P<0.05)  
43  
44 240 (Table 3). Clients in the Kebbi state had the lowest risk for VL non-suppression (ARR = 0.33, 95%  
45  
46 241 CI: 0.28–0.38).

242 **Table 3. Factors associated with a non-suppressed viral load presented as unadjusted and adjusted odds ratios and risk ratios**  
 243 **derived using logistic regression.**

Factors	Univariable			Multivariable		
	uOR	uRR	p-value (<0.05)	aOR	aRR	p-value (<0.05)
<b>Sex</b>						
Female	1 [ref]	1 [ref]		1 [ref]	1 [ref]	
Male	1.01 [0.99 - 1.03]	1.01 [0.99 - 1.03]	0.49	1.1 [1.07 - 1.13]	1.09 [1.07 - 1.12]	
<b>Age Group</b>						
0-14	3.63 [3.49 - 3.79]	3.16 [3.06 - 3.28]		2.82 [2.7 - 2.94]	2.56 [2.47 - 2.65]	
15-24	1.29 [1.24 - 1.34]	1.27 [1.22 - 1.31]		1.33 [1.28 - 1.38]	1.31 [1.26 - 1.35]	
25-34	1 [ref]	1 [ref]		1 [ref]	1 [ref]	
35-44	0.99 [0.96 - 1.01]	0.99 [0.96 - 1.01]	0.3	0.85 [0.83 - 0.88]	0.86 [0.84 - 0.89]	
45-59	0.91 [0.88 - 0.94]	0.91 [0.89 - 0.94]		0.7 [0.67 - 0.72]	0.71 [0.68 - 0.73]	
60+	0.92 [0.86 - 0.98]	0.92 [0.87 - 0.98]		0.64 [0.6 - 0.69]	0.65 [0.61 - 0.7]	
<b>ART Start Year</b>						
<2005	1.85 [1.3 - 2.65]	1.8 [1.29 - 2.52]		5.69 [3.96 - 8.18]	4.97 [3.63 - 6.69]	
[2005-2010)	2.43 [2.32 - 2.53]	2.33 [2.23 - 2.42]		6.7 [6.29 - 7.13]	5.69 [5.4 - 5.99]	
[2010-2015)	3.06 [2.96 - 3.16]	2.88 [2.79 - 2.96]		7.94 [7.53 - 8.38]	6.53 [6.26 - 6.82]	
[2015-2020)	2.53 [2.46 - 2.61]	2.42 [2.35 - 2.49]		4.96 [4.76 - 5.16]	4.42 [4.26 - 4.57]	
>2020	1 [ref]	1 [ref]		1 [ref]	1 [ref]	
<b>Time On ART</b>						
<1 year	0.78 [0.76 - 0.8]	0.79 [0.77 - 0.81]		4.97 [4.75 - 5.19]	3.9 [3.77 - 4.03]	
1-3 years	0.77 [0.75 - 0.79]	0.78 [0.76 - 0.8]		1.76 [1.7 - 1.82]	1.67 [1.62 - 1.72]	
3+ years	1 [ref]	1 [ref]		1 [ref]	1 [ref]	
<b>Facility Size</b>						
Small	1.52 [1.37 - 1.67]	1.48 [1.34 - 1.61]		1.73 [1.56 - 1.92]	1.66 [1.51 - 1.83]	
Medium	1.59 [1.55 - 1.63]	1.54 [1.5 - 1.57]		1.54 [1.49 - 1.59]	1.49 [1.45 - 1.54]	
Large	1 [ref]	1 [ref]		1 [ref]	1 [ref]	
<b>Facility Level</b>						
Primary	1 [ref]	1 [ref]		1 [ref]	1 [ref]	
Secondary	2.03 [1.98 - 2.09]	1.96 [1.91 - 2.01]		1.51 [1.46 - 1.55]	1.48 [1.44 - 1.52]	

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<b>Tertiary</b>	2.91 [2.82 - 3.02]	2.73 [2.65 - 2.82]	1.79 [1.71 - 1.88]	1.74 [1.67 - 1.82]
<b>Facility Ownership</b>				
Private	1.25 [1.2 - 1.3]	1.23 [1.19 - 1.28]	0.85 [0.81 - 0.89]	0.86 [0.82 - 0.9]
Public	1 [ref]	1 [ref]	1 [ref]	1 [ref]
<b>State</b>				
Adamawa	2.5 [2.39 - 2.61]	2.39 [2.29 - 2.49]	1.95 [1.86 - 2.04]	1.89 [1.81 - 1.98]
Akwa Ibom	1 [ref]	1 [ref]	1 [ref]	1 [ref]
Bauchi	2.1 [1.99 - 2.22]	2.03 [1.93 - 2.14]	1.6 [1.51 - 1.7]	1.57 [1.49 - 1.66]
Bayelsa	2.93 [2.74 - 3.14]	2.76 [2.6 - 2.94]	2.15 [2 - 2.31]	2.08 [1.94 - 2.22]
Borno	4.6 [4.37 - 4.84]	4.14 [3.96 - 4.33]	2.76 [2.6 - 2.92]	2.62 [2.48 - 2.76]
Cross River	1.54 [1.47 - 1.61]	1.51 [1.45 - 1.58]	1.31 [1.26 - 1.38]	1.3 [1.25 - 1.36]
Edo	4.6 [4.4 - 4.8]	4.14 [3.98 - 4.29]	2.99 [2.84 - 3.15]	2.82 [2.69 - 2.95]
Jigawa	3.99 [3.73 - 4.27]	3.65 [3.44 - 3.88]	2.36 [2.19 - 2.53]	2.26 [2.11 - 2.42]
Kano	2.44 [2.33 - 2.55]	2.34 [2.24 - 2.43]	1.59 [1.51 - 1.67]	1.56 [1.49 - 1.64]
Kebbi	0.51 [0.43 - 0.6]	0.52 [0.44 - 0.61]	0.32 [0.27 - 0.37]	0.33 [0.28 - 0.38]
Kwara	2.68 [2.48 - 2.91]	2.55 [2.37 - 2.75]	1.68 [1.54 - 1.83]	1.65 [1.51 - 1.78]
Lagos	2.67 [2.57 - 2.78]	2.54 [2.45 - 2.63]	2.09 [2.01 - 2.18]	2.02 [1.95 - 2.1]
Niger	3.43 [3.29 - 3.58]	3.19 [3.07 - 3.31]	2.76 [2.64 - 2.89]	2.62 [2.51 - 2.73]
Sokoto	2.64 [2.44 - 2.86]	2.51 [2.34 - 2.7]	1.74 [1.61 - 1.89]	1.7 [1.58 - 1.84]
Yobe	3.28 [3.03 - 3.56]	3.06 [2.85 - 3.3]	2.21 [2.03 - 2.4]	2.13 [1.97 - 2.3]
Zamfara	3.68 [3.36 - 4.04]	3.4 [3.13 - 3.69]	2.02 [1.83 - 2.22]	1.96 [1.78 - 2.14]

## 245 Discussion

246 Our study found that male clients in younger age groups (0-24) who started treatment before 2020  
247 and have been on treatment for less than one year, receiving care at small and medium facilities  
248 that are specialised to a secondary and tertiary level facilities that are publicly owned and located  
249 in the Edo, Borno and, Niger states had the highest association with VL non-suppression. Other  
250 studies have found similar results for the risk of viral non-suppression in younger age groups in  
251 Cambodia, Uganda, and South Carolina (USA) [6,8,18], and among males [19–21]. Our findings  
252 suggest that in some Nigerian states, the health seeking behavior of certain demographics can be  
253 improved or given more attention to by HIV care programs, specifically for younger-aged males.  
254 In that same regard, the quality of HIV healthcare programs can be improved across several states  
255 in Nigeria with consideration the facility types, size, and public ownership.

256  
257 The increased risk of viral non-suppression among ART clients who received treatment at tertiary  
258 health facilities have not been observed in Ethiopia where higher risk of viral non-suppression was  
259 associated with primary health facilities in Ethiopia [22]. Small and medium facilities were  
260 identified to be associated with viral-non-suppression of HIV clients on treatment and this was  
261 consistent with findings that clients were more likely to miss consecutive visits at lower volume  
262 facilities. This could be due to smaller clinics being located within smaller communities, as a result,  
263 patients may avoid stigmatisation within their community and may not pick-up treatment as  
264 routinely as patients that attend clinics that are outside of their communities [23]. Such clients that  
265 would miss their drug pickup appointments more frequently, are reasonably expected to have non-  
266 suppressed viral loads. A possible circumvention of the stigmatisation within communities would  
267 be to offer clients that live within communities a referral to HIV care facilities that are located  
268 outside of their communities. However, consideration should be given to the distance needed for  
269 travel as well because although a distance less than one kilometre to the clinic was associated with  
270 higher IIT [23], mean distances above 4.7 km to clinics were associate with higher IIT [24].

271 Clients that received care at privately owned facilities have lower risk of a non-suppressed VL  
272 seeing that there are fewer clients represented in the private sector. However, clients receiving care  
273 at privately owned facilities were non-suppressed in higher proportion than those receiving care at  
274 public facilities. Nevertheless, given the higher number of virally non-suppressed clients at public  
275 facilities, those clients are at higher risk if of the unfavourable outcome. Another study has found

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3 276 that HIV care was of greater quality at public facilities than private in Anambra state in Nigeria  
4 [25]. This may be reflected in our unadjusted, univariable results for the ownership of the facilities  
5 277 as well, which depicted that patients receiving care at private facilities were more likely to be  
6 278 virally non-suppressed.  
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10 281 ART clients who had their last VL test conducted within less than one year on treatment were less  
11 282 likely to be virally non-suppressed compared with clients who had their VL tested after one year  
12 283 on ART. Our finding was consistent with the Center for Disease Control and Prevention's finding  
13 284 that PLHIV on ART could be virally suppressed within six months of initiation, provided that they  
14 285 adhered to their medication [26]. Moreover, a greater likelihood of viral suppression was found  
15 286 among PLHIV who were initiated on treatment for less than one year compared with those on ART  
16 287 for more than one year [27]. This could suggest that greater attention to patients enrolled on ART  
17 288 for less than one year could be given to perhaps cultivate a habit of adhering to the treatment,  
18 289 which could result to better viral load outcomes. However, contrary to this, a shorter time on ART  
19 290 was identified as a factor associated with a non-suppressed VL in South Africa [28]. The  
20 291 contradictory findings in the literature could speak to the specific adherence patterns of the  
21 292 populations investigated and models that may be specific to the study settings. Also, elucidating  
22 293 that clients more engaged in care can have more opportunities for non-suppressed viral load test  
23 294 results, though, this does not necessarily mean that this population is more likely to be non-  
24 295 suppressed. Nevertheless, this advocates for support of newly enrolled clients into developing  
25 296 treatment-adherence habits because it is possible that in some clinical settings adherence habits are  
26 297 better developed earlier on due to more attentive healthcare programs. Therefore, improving HIV  
27 298 care may ultimately result in better treatment-adherence habits and consequential VL suppression.  
28 299

29 300 A possible explanation for the clients receiving care in the Kwara and Niger states in the North-  
30 301 Central zone having higher risk of viral non-suppression could be linked to health-seeking  
31 302 behaviour such as non-use of the service, poor adherence to treatment, and possibly religious  
32 303 affiliation (for example Islamic religion predominant in northern Nigeria) where in certain  
33 304 circumstances women require permission to leave the premises of a household which can reduce  
34 305 access to healthcare [29,30]. Community refills (door-to-door) could be implemented in such  
35 306 communities, perhaps staffed by female health workers. On the other hand, in Borno and Yobe

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3 307 states in the North-East zone of Nigeria, the incessant insecurity in the region has largely led to  
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5 308 people often been displaced and this has largely impacted on the health-seeking behavior,  
6  
7 309 One of the limitations of our study was the inaccessibility of the longitudinal data set, leaving us  
8  
9 310 unable to conduct a longitudinal study to explore the factors affecting viral non-suppression over  
10  
11 311 time. We were therefore restricted to conducting a cross-sectional study. The study cohort was  
12  
13 312 composed of clients that received care at USAID-supported facilities, therefore, it may not be a  
14  
15 313 true representation of the risk of VL suppression throughout the country. In facilities that support  
16  
17 314 is better, the results here could overestimate the contribution of some of the factors to VL non-  
18  
19 315 suppression. Vice-versa, where support is lacking, the contribution of some of the factors presented  
20  
21 316 here on VL non-suppression could be underestimated.

22  
23 317  
24 318 It is possible that some of the 21.6% of client records (eliminated from analysis) without a VL test  
25  
26 319 on record are a consequence of poor adherence to treatment which could lead to viral load non-  
27  
28 320 suppression that is not tested/recorded. This assumption is based on the concept that patients need  
29  
30 321 to attend clinic visits to either receive treatment or have their VL samples collected and tested.  
31  
32 322 Investigating the factors that are associated with an untested viral load could provide useful insight.  
33  
34 323 At the same time, longitudinal studies into both viral load non-testing and viral load non-  
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36 324 suppression may ultimately be of greatest use. Additional variables relating to the capacity of  
37  
38 325 clinical facilities to conduct testing would reveal whether the lack of viral load testing is also  
39  
40 326 affected by a low capacity.

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42 327  
43 328 Other unavailable variables that could be explored in future studies to identify their association  
44  
45 329 with viral suppression are tuberculosis status, adherence level, ART drug regimen, side-effects,  
46  
47 330 IIT, marital status, and education level, however, these variables would need to be provided and  
48  
49 331 analysed longitudinally. The absence of VL suppression data for recently initiated clients may  
50  
51 332 have also had an impact on the study seeing that they had to be excluded, therefore only the results  
52  
53 333 of tested patients could be analysed, leaving out the results of those without a test.

## 54 334 55 335 **Conclusions**

56 336 Targeting males, below 35 that started treatment before 2020 and have been on treatment for less  
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58 337 than three years, receiving care at tertiary health facility, small and medium facilities, publicly

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3 338 owned, and in the Edo, Borno, Niger states for interventions could lead to improvements in VL  
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5 339 suppression in Nigeria. The independent factors associated here with a non-suppressed VL can  
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7 340 guide the improvement of ART program development and VL suppression of PLHIV in Nigeria.  
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9 341

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11  
12 343

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14 345 EO, ZA; Data analysis: ST, TC, JA; Funding acquisition: DSD, FA, PP; Data Interpretation: All  
15 346 authors; Writing – original draft: ST, TC, JA; Writing – review and editing: All authors. All authors  
16  
17 347 read and approved the final manuscript.  
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19 348

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21  
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23  
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25  
26 352

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28  
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30  
31 355 including bilateral support through USAID Nigeria’s Data for Implementation (Data.FI)  
32  
33 356 mechanism under the terms of Cooperative Agreement 7200AA19CA0004 to Palladium and Right  
34  
35 357 to Care. The contents are the responsibility of the authors and do not necessarily reflect the views  
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39 359 design, data collection and analysis, decision to publish, or preparation of the manuscript. Right to  
40  
41 360 Care, South Africa covers the salaries of ST, TC, JA, FA, CWK, CC and PP. The Palladium Group,  
42  
43 361 Nigeria, covers the salaries of DSD, ZA and EO.  
44  
45 362

46 363 **Data Statement:** The data that support the findings of this study are owned by the Government of  
47  
48 364 Nigeria and were used under license for the current study. Access to these data is subject to  
49  
50 365 restrictions owing to privacy and ethics policies set by the Government of Nigeria so are not  
51  
52 366 publicly available. Requests to access these data should be directed to  
53  
54 367 Dauda.Sulaiman@thepalladiumgroup.com.  
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### 369 **Ethics approval**

370 The study used secondary data. Ethical approvals for this study were obtained in Nigeria and the  
371 United States. Informed consent was waived from all subjects or, if subjects are under 18, from a  
372 parent and/or legal guardian by the expedited institutional review board (IRB) approvals granted  
373 by both the National Health Research Ethics Committee of Nigeria (NHREC), reference number  
374 NHREC/01/01/2007, and the HML IRB in the United States, reference number 772EQH20. Data  
375 were anonymised and handled confidentially during all phases of the research. All methods were  
376 carried out in accordance with relevant guidelines and regulations. All experimental protocols were  
377 granted approval by the institutional review board (IRB) of the National Health Research Ethics  
378 Committee of Nigeria (NHREC), reference number NHREC/01/01/2007, and the HML IRB in the  
379 United States, reference number 772EQH20.

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### 381 **List of abbreviations**

382	AIC:	Akaike information criterion
383	AOR:	Adjusted odds ratio
384	ARR:	Adjusted risk ratio
385	ART:	Antiretroviral therapy
386	ARV:	Antiretroviral
387	CI:	Confidence interval
388	Data.FI:	Data for Implementation
389	EMR:	Electronic medical records
390	FMOH:	Federal Ministry of health
391	HFR:	Health facility registry
392	HIV:	Human immunodeficiency virus
393	IIT:	Interruption in treatment
394	IP:	Implementing partner
395	MMD:	Multi-month dispensing
396	PEPFAR:	United States President's Emergency Plan for AIDS Relief
397	PLHIV:	People living with HIV
398	RADET:	Retention audit determination tool
399	UNAIDS:	Joint United Nations Programme on HIV/AIDS



400 USAID: United States Agency for International Development

401 VL: Viral load

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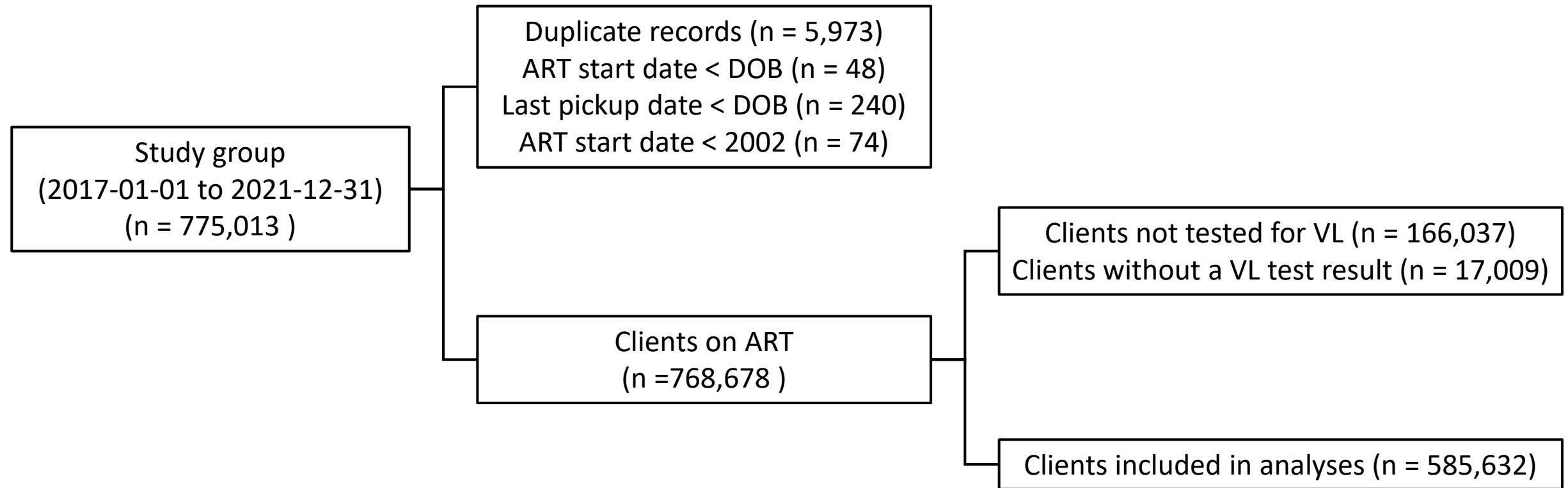
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# Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

## Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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		Reporting Item	Page Number
<b>Title and abstract</b>			
Title	<a href="#">#1a</a>	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	<a href="#">#1b</a>	Provide in the abstract an informative and balanced summary of what was done and what was found	3
<b>Introduction</b>			
Background / rationale	<a href="#">#2</a>	Explain the scientific background and rationale for the investigation being reported	4
Objectives	<a href="#">#3</a>	State specific objectives, including any prespecified hypotheses	4
<b>Methods</b>			
Study design	<a href="#">#4</a>	Present key elements of study design early in the paper	5
Setting	<a href="#">#5</a>	Describe the setting, locations, and relevant dates, including periods of	5

recruitment, exposure, follow-up, and data collection

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3	Eligibility criteria	<a href="#">#6a</a>	Give the eligibility criteria, and the sources and methods of selection of participants. 5
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6		<a href="#">#7</a>	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable 6
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10	Data sources /	<a href="#">#8</a>	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable. 5
11	measurement		
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17	Bias	<a href="#">#9</a>	Describe any efforts to address potential sources of bias 7
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19	Study size	<a href="#">#10</a>	Explain how the study size was arrived at 6
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21	Quantitative	<a href="#">#11</a>	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why 6
22	variables		
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25	Statistical	<a href="#">#12a</a>	Describe all statistical methods, including those used to control for confounding 7
26	methods		
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29	Statistical	<a href="#">#12b</a>	Describe any methods used to examine subgroups and interactions 7
30	methods		
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33	Statistical	<a href="#">#12c</a>	Explain how missing data were addressed 5
34	methods		
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37	Statistical	<a href="#">#12d</a>	If applicable, describe analytical methods taking account of sampling strategy 6
38	methods		
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41	Statistical	<a href="#">#12e</a>	Describe any sensitivity analyses 8
42	methods		
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44	<b>Results</b>		
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47	Participants	<a href="#">#13a</a>	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable. 6
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55	Participants	<a href="#">#13b</a>	Give reasons for non-participation at each stage 6
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57	Participants	<a href="#">#13c</a>	Consider use of a flow diagram 6
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1	Descriptive data	<a href="#">#14a</a>	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	9
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6	Descriptive data	<a href="#">#14b</a>	Indicate number of participants with missing data for each variable of interest	5
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10	Outcome data	<a href="#">#15</a>	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	9
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14	Main results	<a href="#">#16a</a>	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11
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19	Main results	<a href="#">#16b</a>	Report category boundaries when continuous variables were categorized	6
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21	Main results	<a href="#">#16c</a>	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11
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25	Other analyses	<a href="#">#17</a>	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	11
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29	<b>Discussion</b>			
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31	Key results	<a href="#">#18</a>	Summarise key results with reference to study objectives	13
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34	Limitations	<a href="#">#19</a>	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	15
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39	Interpretation	<a href="#">#20</a>	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	14
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44	Generalisability	<a href="#">#21</a>	Discuss the generalisability (external validity) of the study results	16
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47	<b>Other</b>			
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51	Funding	<a href="#">#22</a>	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16
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# BMJ Open

## Factors associated with viral load non-suppression in people living with HIV on ART in Nigeria: cross-sectional analysis from 2017 to 2021

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# Factors associated with viral load non-suppression in people living with HIV on ART in Nigeria: cross-sectional analysis from 2017 to 2021

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## 1 **Abstract**

2 **Objectives** Identify factors (demographic and clinical) associated with a non-suppressed viral load  
3 of PLHIV on antiretroviral therapy in Nigeria.

4  
5 **Design** Cross-sectional study.

6  
7 **Setting** Sixteen United States Agency for International Development (USAID) supported states in  
8 Nigeria.

9  
10 **Participants** 585,632 people living with HIV (PLHIV) on antiretroviral therapy (ART).

11  
12 **Primary outcome measures** Viral load (VL) non-suppression (defined as having a VL of at least  
13 1,000 HIV ribonucleic acid copies per mL of plasma). Chi-square testing and multivariable  
14 modified Poisson regression with robust variance estimates were conducted on routinely collected  
15 ART program data.

16  
17 **Results** Sixty-six percent of the study population were females. The largest age groups were 25-  
18 34 and 35–44, accounting for 32.1% and 31.1%, respectively. Males had a 9% greater likelihood  
19 (APR=1.09) of being non-suppressed. The age groups below 60+ (APR=0.67) had a higher  
20 likelihood of a non-suppressed VL, with the highest in the 0–14 age group (APR=2.38). Clients  
21 enrolled at tertiary and secondary level facilities had the greatest likelihood of a non-suppressed  
22 VL. Clients who started ART between 2010 and 2015 had the greatest likelihood of viral non-  
23 suppression (APR=6.19). A shorter time on ART (<1 year [APR=3.92]) was associated with a  
24 higher likelihood of a non-suppressed VL. Clients receiving care at private facilities had a lower  
25 likelihood of viral non-suppression in the adjusted model. Clients in the Edo (APR=2.66) and  
26 Niger (APR=2.54) states had the greatest likelihood of viral non-suppression.

27  
28 **Conclusions** Targeting males, clients of younger age, those on treatment for less than 3 years,  
29 clients at tertiary and secondary health facilities, small and medium facilities, and clients in the  
30 Edo, Niger, and Borno states for interventions could lead to improvements in VL suppression in

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3 31 Nigeria. The independent factors associated with a non-suppressed VL can guide improvements  
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5 32 in ART program development and VL suppression of PLHIV on ART in Nigeria.  
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### 8 34 **Strengths and limitations of the study**

- 10 35 • The study used data from over 500,000 PLHIV enrolled on ART in 16 Nigeria states over  
11  
12 36 four years between 2017 and 2021 which can allow the results to cover a broad portion of  
13  
14 37 HIV healthcare in Nigeria in recent times.
- 15 38 • The data used was routinely collected by clinics, reflecting the actual state of HIV  
16  
17 39 healthcare in Nigeria during the period of the study.
- 18  
19 40 • The study included distal factors such as state, facility level, size, and ownership which can  
20  
21 41 guide intervention at an infrastructural level.
- 22  
23 42 • Variables such as education level and marital status/cohabiting, treatment adherence,  
24  
25 43 opportunistic infections, and side effects were not available, and some of these factors  
26  
27 44 could have been confounders of the predictors used in this study.  
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### 30 46 **Introduction**

31  
32 47 In 2020, there were 37.7 million people living with HIV (PLHIV) globally; in 2021, 27.5 million  
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34 48 (73%) had access to antiretroviral therapy (ART) [1]. In 2020, 66% of PLHIV were virally  
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36 49 suppressed [1]. Nigeria is a country with one of the highest numbers of PLHIV in the world (1.9  
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38 50 million), with a prevalence rate of 1.4% and an incidence rate of 0.34 per 1,000 capita with  
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40 51 approximately 74,000 individuals newly infected as estimated in 2021. It was also estimated that  
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42 52 86% of the PLHIV on ART in Nigeria were virally suppressed in 2021 [2]. The Nigeria National  
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44 53 Guidelines for HIV Prevention, Treatment, and Care define virologic suppression as having a viral  
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46 54 load (VL) below 1,000 HIV ribonucleic acid copies per mL of plasma [3] (viral load non-  
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48 55 suppression is defined as having a VL of at least 1,000 HIV ribonucleic acid copies per mL of  
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50 56 plasma). Given that an undetectable VL significantly reduces the transmission risk of HIV,  
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52 57 suppressing the VL of 95% of PLHIV on ART is key to achieving epidemic control [4,5].  
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54 58 Globally, including in some Nigerian states, factors that were found to be predictors of viral  
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56 59 suppression were age, sex, duration on ART [6–9], current ART regimen [10], and adherence to  
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58 60 medications [11]. This study explored whether similar associations alongside other factors such as  
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60 61 state and facility level existed in Nigeria using data over a period of four years from 16 States that

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3 62 were not necessarily under investigation before, contributing to the body of knowledge and  
4 63 allowing better targeted interventions to improve HIV programs, the VL of clients, and epidemic  
5 64 control in the country.

6 65 The objective of this study was to determine which factors were associated with a non-suppressed  
7 66 VL in Nigeria using a large cross-sectional database of clients who received ART. We explored  
8 67 several variables—sex, age group, ART start year, time on ART, facility size, facility level, facility  
9 68 ownership, and state—to identify which factors were associated with viral non-suppression. The  
10 69 findings from the analysis can be used to guide HIV programs to conduct targeted intervention for  
11 70 the PLHIV on ART with the highest likelihood of having a non-suppressed VL.

12 71

## 13 72 **Methods**

### 14 73 **Study design, setting, and population**

15 74 The study was a cross-sectional analysis of clients who were enrolled on ART at 580 facilities  
16 75 across 16 States (Adamawa, Akwa Ibom, Bauchi, Bayelsa, Borno, Cross River, Edo, Jigawa,  
17 76 Kano, Kebbi, Kwara, Lagos, Niger, Sokoto, Yobe, Zamfara) in Nigeria that were supported by the  
18 77 United States Agency for International Development (USAID). The data set covered a period of 4  
19 78 years, with the last drug pickup dates ranging from January 1, 2017 to December 31, 2021. The  
20 79 study was carried out to investigate the clinical and demographic factors associated with a non-  
21 80 suppressed VL among more than 500,000 HIV clients who had a VL test on record. The age of  
22 81 clients ranged between 0 and 101 with a median of 37 and a mean of 37.2.

23 82

### 24 83 **Data Source and Management**

25 84 The data were routinely collected by the USAID-supported implementing partners (IPs) through  
26 85 their quarterly data submissions using the retention and audit determination tool (RADET). Each  
27 86 IP submission was then combined into a single data set that was used for this study. The RADET  
28 87 dataset provides cross-sectional information for every client ever enrolled on ART at their last  
29 88 point of visit to the clinics supported by USAID and associated IPs. That is, longitudinal records  
30 89 for variables were not available nor ethically approved for studying, for example only the last  
31 90 recorded viral load test for each client was available. Depending on the purpose of the clinical visit  
32 91 of the clients, the data was collected to reflect the most recent clinical details of a particular client.

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2  
3 93 The data set received contained 775,013 non-longitudinal, cross-sectional client records with a last  
4 94 drug pickup date between January 1<sup>st</sup>, 2017, and December 31<sup>st</sup>, 2021. Due to missing unique client  
5 95 identifiers for 153,433 clients, a unique identifier was created for data deduplication using the date  
6 96 of birth, sex, database-provided unique identifier, and client hospital number. For clarification,  
7 97 unique identifiers were not provided for all clients, in such cases a client hospital number was  
8 98 captured instead. Data cleaning involved removing duplicate unique identifiers (n=5,973). Data  
9 99 which may have contained a typo, like records with a date of birth occurring after the ART start  
10 100 date (n=48) or after the date of last drug pickup (n=240) were removed. Clients with an ART start  
11 101 date earlier than 2002 (n=74) when the ART program started in Nigeria [12] were also excluded  
12 102 from the analysis. An additional 166,037 client records without a date of viral load sample  
13 103 collection were removed alongside a further 17,009 who did not receive their VL test results at the  
14 104 time of the data collection. After data cleaning, 585,632 client records were retained for  
15 105 downstream analyses (Figure 1) to isolate a cohort that was active during the latest VL suppression  
16 106 policy rolled out in Nigeria, which indicates that every client on treatment for 6 months is due for  
17 107 a VL test, and VL tests should be repeated every 12 months [13].  
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31 109 **Figure 1. Data cleaning process, excluded data, and study population subset analyzed.**  
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34 111 **Variables engineered as predictors of a non-suppressed viral load**

35 112 The age variable was calculated as the time difference (in years) between the date of VL sample  
36 113 collection and the date of birth of the client. Then, age group was reclassified into six groups: 0–  
37 114 14, 15–24, 25–34, 35–44, 45–59, and 60+ years. Similarly, the “duration on ART to last VL test”  
38 115 variable was created by calculating the time difference (in months) between the date of received  
39 116 current VL and the ART start date. The duration on ART was reclassified as <1 year, 1–3 years,  
40 117 and 3+ years, and labelled as “Time on ART”. The “Facility Size” variable was calculated by  
41 118 determining the number of clients receiving care at the facility, then grouped as small ([0,25)  
42 119 percentiles), medium ([25,75) percentiles), or large ([75,100] percentiles). The number and  
43 120 distribution of clients into the small, medium, and large facilities is presented in Table 1.  
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54 123 **Table 1. Summary of the distribution of facility size by the number of clients in care.**

Facility Size	Number Of	Number Of Clients
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	Facilities	Total	Min.	Max.	Mean	Median
Small	143	5,360	4	62	37	39
Medium	295	92,348	63	1,078	313	199
Large	146	487,924	1,088	13,585	3,342	2,879

124  
125 The “Facility Level” variable was obtained from the Nigeria Health Facility Registry (HFR) [14].  
126 The classification resulted in three levels of facilities: primary (operate at Local Government  
127 level), secondary (operate at State level), and tertiary (operate at Federal Government level) [15].  
128 Similarly, the “Facility Ownership” variable was created by grouping the facilities in their  
129 respective ownership type (public or private) according to their classification in the Nigeria HFR  
130 system [14].

131  
132 The “geopolitical zone” variable was created by grouping the 16 USAID-supported States into  
133 their nationally recognized geopolitical zones. This resulted in five geopolitical zone groupings:  
134 North-Central (Kwara and Niger States), North-East (Adamawa, Bauchi, Borno, and Yobe States),  
135 North-West (Jigawa, Kano, Kebbi, Sokoto, and Zamfara States), South-South (Akwa Ibom,  
136 Bayelsa, Cross River, and Edo States), and South-West (Lagos).

137  
138 **Patient and public involvement**  
139 Patients or the public were not involved in the design, or conduct, or reporting, or dissemination  
140 plans of our research.

141  
142 **Statistical analysis**  
143 For the 585,632 clients with a last VL test on record, the Pearson's chi-square test was used to  
144 examine the association of each variable with a non-suppressed VL at a client's last VL test date.  
145 Unadjusted and adjusted modified Poisson regression with robust variance estimates models were  
146 conducted to explore the association of variables with a non-suppressed VL (a VL above 1,000  
147 ribonucleic acid copies per mL of plasma). Current ART status was excluded as a factor from the  
148 regression modelling because at the time of the VL test, all clients were active, even though they  
149 may now have a different status (interruption in treatment (IIT) defined as missing a drug-pickup  
150 appointment for longer than 28 days, deceased, transferred out, or stopped treatment). Similarly,  
151 the regimen line was excluded from the regression analysis because other regimen lines, aside



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3 152 from the first-line regimen, are prescribed in the case of a non-suppressed VL or reaction or a  
4  
5 153 reported side effect from the current ARVs. The regimen line was therefore dependent on the VL  
6  
7 154 outcome investigated and it could not be used as an independent variable associated with VL non-  
8  
9 155 suppression. The multi-month dispensing variable (MMD) was excluded from the regression  
10  
11 156 models because the variable is not independent of the VL outcome. That is, eligibility criteria for  
12  
13 157 MMD requires that clients are virally suppressed. Model selection was done using forward  
14  
15 158 addition and backward elimination of variables where the Akaike's information criterion (AIC)  
16  
17 159 was used to evaluate variable inclusion in the final model. The retained model with the lowest AIC  
18  
19 160 (249,787.3) resulted in the exclusion of the geopolitical zone variable. The variables included in  
20  
21 161 the models were sex, age group, ART start year, time on ART to last VL test, facility level, facility  
22  
23 162 size, facility ownership and, state. The group accounting for the most clients in each of the  
24  
25 163 independent variables analysed was set as the reference group for the respective variable. A two-  
26  
27 164 tailed P value of  $P < 0.05$  was used to define statistical significance. Multicollinearity was tested  
28  
29 165 using the generalized variance inflation factor (GVIF) for the set of variables used in the modified  
30  
31 166 Poisson regression model, and none of the variables exhibited multicollinearity (having a GVIF  
32  
33 167 below 1.4). All data processing and analysis were conducted using the R software for Statistical  
34  
35 168 Computing v4.0. [16].

169

## 170 **Results**

36 171 Of the 585,632 clients included in the analysis, 35,549 (6.1%) were virologically non-suppressed  
37  
38 172 while the remaining 93.9% were virologically suppressed (Table 2). Sixty-five percent of the  
39  
40 173 clients were female, with 6.1% of both sexes virologically non-suppressed. Clients ages 25–34 and  
41  
42 174 35–44 were the largest age groups, accounting for 32.1% and 31.1% of the total number of clients  
43  
44 175 in the analysis, respectively. Clients in the 0–14 age group was the smallest group (3.4%) and had  
45  
46 176 the largest proportion of virally non-suppressed individuals (17.8%).

177

48 178 The Current ART status was recorded as active for 88.9% of the clients, with the remaining 11.1%  
49  
50 179 being dead (1.7%), had stopped treatment (0.5%) had transferred out to another facility (3.1%), or  
51  
52 180 had interrupted treatment (5.8%) (Table 2). Most clients (95.8%) were on the adult first-line ART  
53  
54 181 regimen, with 94.5% of them being virally suppressed. Clients on the adult second-line and

1  
2  
3 182 paediatric first-line regimens each accounted for 2% of the clients in the study, with 81.7% and  
4  
5 183 82% of clients on the two regimen lines being virally suppressed, respectively.

6 184  
7  
8 185 Approximately forty-three percent of the clients were on ART for more than three years and 28.3%  
9  
10 186 were on treatment for less than one year (Table 2). Clients who were on ART for less than three  
11  
12 187 years had a higher proportion of viral suppression (94.5%) than those who were on ART for more  
13  
14 188 than three years (both 93.1%).

15 189  
16  
17 190 A greater proportion of ART clients received treatment from a large volume facility (83.3%), with  
18  
19 191 94.4% of these clients being virally suppressed (Table 2). ART clients at the medium volume  
20  
21 192 facilities comprised 15.8% of the total clients, with 91.4% of them being virally suppressed. Most  
22  
23 193 clients were receiving ART at a secondary health facility (52.2%), followed by primary health  
24  
25 194 facilities (35.7%) (Table 2). Clients receiving treatment at a tertiary (9.7%) or secondary health  
26  
27 195 facility (7.0%) were non-suppressed in higher proportions compared with clients receiving ART  
28  
29 196 at a primary health facility. Ninety-four percent of the clients received ARVs from a publicly  
30  
31 197 owned facility, with 94% of them being virally suppressed (Table 2). Only 6% of the clients were  
32  
33 198 receiving treatment from a privately owned facility, with 7.4% of these clients virally non-  
34  
35 199 suppressed.

36 200  
37  
38 201 Akwa Ibom state had the highest proportion of client records (36.8%) with viral suppression rate  
39  
40 202 of 96.9%. While Zamfara had the smallest proportion of clients (0.9%) with a viral suppression  
41  
42 203 rate of 89.6%, Kebbi state had the highest proportion of virally suppressed client with 98.4%  
43  
44 204 although, a smaller proportion of the clients (1.6%) in the study. The South-South zone served the  
45  
46 205 highest proportion of clients in the cohort and highest suppression rate (54.2% and 95.6%,  
47  
48 206 respectively). Similarly, North-Central Zone had the smallest proportion and lowest suppression  
49  
50 207 rate (7.4% and 90.6%, respectively) (Table 2).

51 208  
52 209  
53 210  
54 211

212 **Table 2. Characteristics of the 517,012 clients with a viral load test on record at Nigerian**  
 213 **facilities between 2017 and 2021.**

Factors	Viral load		Total	p-value (<0.05)
	Suppressed	Non-Suppressed		
<b>Sex</b>				
Female	357 783 (93.9)	23 058 (6.1)	380 841 (65.0)	0.5
Male	192 300 (93.9)	12 491 (6.1)	204 791 (35.0)	0.5
<b>Age Group</b>				
0-14	16 450 (82.2)	3 561 (17.8)	20 011 (3.4)	
15-24	57 434 (92.9)	4 416 (7.1)	61 850 (10.6)	
25-34	177 648 (94.4)	10 580 (5.6)	188 228 (32.1)	
35-44	172 070 (94.5)	10 097 (5.5)	182 167 (31.1)	
45-59	106 743 (94.8)	5 813 (5.2)	112 556 (19.2)	
60+	19 738 (94.8)	1 082 (5.2)	20 820 (3.6)	
<b>Art Start Year</b>				
<2005	542 (94.4)	32 (5.6)	574 (0.1)	
[2005-2010)	40 276 (92.8)	3 113 (7.2)	43 389 (7.4)	
[2010-2015)	82 198 (91.1)	8 012 (8.9)	90 210 (15.4)	
[2015-2020)	220 451 (92.5)	17 808 (7.5)	238 259 (40.7)	
>2020	206 616 (96.9)	6 584 (3.1)	213 200 (36.4)	
<b>Time On Art</b>				
<1 year	156 702 (94.5)	9 085 (5.5)	165 787 (28.3)	
1-3 years	161 118 (94.6)	9 183 (5.4)	170 301 (29.1)	
3+ years	232 263 (93.1)	17 281 (6.9)	249 544 (42.6)	
<b>Regimen Switch</b>				
After VL test	269 102 (94.2)	16 696 (5.8)	285 798 (48.8)	
Before VL test	22 189 (78.5)	6 084 (21.5)	28 273 (4.8)	
Not Switched	258 792 (95.3)	12 769 (4.7)	271 561 (46.4)	
<b>Current ART Regimen</b>				
3TC-TDF-DTG	517 510 (95.6)	24 011 (4.4)	541 521 (92.5)	
3TC-TDF-EFV	8 893 (65.1)	4 759 (34.9)	13 652 (2.3)	
ABC-3TC-DTG	9 356 (87.0)	1 403 (13.0)	10 759 (1.8)	
Other	14 324 (72.7)	5 376 (27.3)	19 700 (3.4)	
<b>ART dispensed (months)</b>				
1-2	26 476 (67.9)	12 515 (32.1)	38 991 (6.7)	
3	99 879 (89.3)	11 911 (10.7)	111 790 (19.1)	
3+	423 728 (97.4)	11 123 (2.6)	434 851 (74.3)	
<b>Current ART Status</b>				
Active	501 083 (96.2)	19 544 (3.8)	520 627 (88.9)	
Dead	6 568 (67.1)	3 217 (32.9)	9 785 (1.7)	
IIT	25 849 (75.7)	8 313 (24.3)	34 162 (5.8)	
Stopped	1 911 (71.9)	747 (28.1)	2 658 (0.5)	
Transferred out	14 672 (79.7)	3 728 (20.3)	18 400 (3.1)	
<b>Current Regimen Line</b>				

1				
2				
3	Adult 1st Line	529 898 (94.5)	31 006 (5.5)	560 904 (95.8)
4	Adult 2nd Line	9 203 (81.7)	2 066 (18.3)	11 269 (1.9)
5	Adult 3rd Line	21 (58.3)	15 (41.7)	36 (0.006)
6	Peds 1st Line	10 850 (82.0)	2 382 (18.0)	13 232 (2.3)
7	Peds 2nd Line	97 (57.7)	71 (42.3)	168 (0.03)
8	Salvage	14 (60.9)	9 (39.1)	23 (0.004)
9				
10	<b>Facility Size</b>			
11	Small	4 920 (91.8)	440 (8.2)	5 360 (0.9)
12	Medium	84 429 (91.4)	7 919 (8.6)	92 348 (15.8)
13	Large	460 734 (94.4)	27 190 (5.6)	487 924 (83.3)
14				
15	<b>Facility Level</b>			
16	Primary	201 847 (96.5)	7 428 (3.5)	209 275 (35.7)
17	Secondary	284 415 (93.0)	21 275 (7.0)	305 690 (52.2)
18	Tertiary	63 821 (90.3)	6 846 (9.7)	70 667 (12.1)
19				
20	<b>Facility Ownership</b>			
21	Private	31 279 (92.6)	2 486 (7.4)	33 765 (5.8)
22	Public	518 804 (94.0)	33 063 (6.0)	551 867 (94.2)
23				
24	<b>State</b>			
25	Adamawa	38 183 (92.7)	3 020 (7.3)	41 203 (7.0)
26	Akwa Ibom	208 852 (96.9)	6 604 (3.1)	215 456 (36.8)
27	Bauchi	24 565 (93.8)	1 631 (6.2)	26 196 (4.5)
28	Bayelsa	11 046 (91.5)	1 025 (8.5)	12 071 (2.1)
29	Borno	14 595 (87.3)	2 122 (12.7)	16 717 (2.9)
30	Cross River	59 487 (95.4)	2 893 (4.6)	62 380 (10.7)
31	Edo	23 832 (87.3)	3 465 (12.7)	27 297 (4.7)
32	Jigawa	8 580 (88.8)	1 083 (11.2)	9 663 (1.7)
33	Kano	37 577 (92.8)	2 897 (7.2)	40 474 (6.9)
34	Kebbi	9 191 (98.4)	147 (1.6)	9 338 (1.6)
35	Kwara	8 308 (92.2)	705 (7.8)	9 013 (1.5)
36	Lagos	54 689 (92.2)	4 620 (7.8)	59 309 (10.1)
37	Niger	30 717 (90.2)	3 333 (9.8)	34 050 (5.8)
38	Sokoto	8 765 (92.3)	731 (7.7)	9 496 (1.6)
39	Yobe	7 032 (90.6)	730 (9.4)	7 762 (1.3)
40	Zamfara	4 664 (89.6)	543 (10.4)	5 207 (0.9)
41				
42	<b>Zone</b>			
43	North-Central	39 025 (90.6)	4 038 (9.4)	43 063 (7.4)
44	North-East	84 375 (91.8)	7 503 (8.2)	91 878 (15.7)
45	North-West	68 777 (92.7)	5 401 (7.3)	74 178 (12.7)
46	South-South	303 217 (95.6)	13 987 (4.4)	317 204 (54.2)
47	South-West	54 689 (92.2)	4 620 (7.8)	59 309 (10.1)
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3 216 All factors used in the adjusted multivariable modified Poisson regression model were statistically  
4 significant, with a p-value below 0.05. Males (adjusted prevalence ratio [APR]=1.09, 95% CI:  
5 217 1.06–1.11) were found to have 9% higher odds of being virally non-suppressed than females,  
6 218 however, the unadjusted modified Poisson regression did not identify a significant difference  
7 219 between the odds of viral non-suppression of females and males (Table 3). The adjusted model  
8 220 indicated that young people ages 0–24 were associated with higher likelihood of viral non-  
9 221 suppression compared with the 25–34 age group. Younger clients ages 0–14 years had the highest  
10 222 APR of viral non-suppression (APR = 2.38, 95% CI: 2.29–2.47).  
11 223  
12 224

13 225 Clients who started ART between 2010 and 2015 (APR = 6.19, CI: 5.9-6.51) had greater likelihood  
14 226 of viral non-suppression compared to clients that started before 2010 or after 2015. Compared with  
15 227 clients who were on ART for more than three years, those who were on treatment between 1 and  
16 228 3 years had greater likelihood to be virally non-suppressed (APR=1.67, 95% CI: 1.62–1.72),  
17 229 whereas clients on ART for less than one year were found to have the greatest likelihood of viral  
18 230 non-suppression (APR=3.92, 95% CI: 3.77–4.08).  
19 231

20 232 Clients receiving ARVs at tertiary health facilities were 68 % more likely to be virally non-  
21 233 suppressed (APR=1.68, 95% CI: 1.61 –1.76) than primary health facilities (Table 3). Moreover,  
22 234 clients receiving care at small (APR=1.63, 95% CI: 1.48–1.8) and medium (APR=1.47, 95% CI:  
23 235 1.43–1.51) facilities were found to have the higher likelihood of viral non-suppression compared  
24 236 to large facilities. Clients receiving treatment at privately owned facilities (APR=0.87, CI: 0.84-  
25 237 0.91) had a lower likelihood of viral non-suppression than clients at publicly owned facilities.

26 238 Compared with the Akwa Ibom state, clients in the Edo (APR = 2.66, 95% CI: 2.54–2.79) and  
27 239 Niger (APR =2.54, 95% CI: 2.44–2.66) states had greater likelihood of VL non-suppression (Table  
28 240 3). Clients in the Kebbi state had the lowest likelihood for VL non-suppression (APR = 0.34, 95%  
29 241 CI: 0.29–0.4).  
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247 **Table 3. Factors associated with a non-suppressed viral load presented as unadjusted and**  
 248 **adjusted prevalence ratios derived using modified Poisson regression. P-values were**  
 249 **indicated when above 0.05.**

Factors	Univariable		Multivariable	
	UPR	p-value (<0.05)	APR	p-value (<0.05)
<b>Sex</b>				
Female	1 [ref]		1 [ref]	
Male	1.01 [0.99 - 1.03]	0.51	1.09 [1.06 - 1.11]	
<b>AgeGroup</b>				
0-14	3.17 [3.05 - 3.29]		2.38 [2.29 - 2.47]	
15-24	1.27 [1.23 - 1.32]		1.29 [1.24 - 1.34]	
25-34	1 [ref]		1 [ref]	
35-44	0.99 [0.96 - 1.01]	0.31	0.86 [0.84 - 0.89]	
45-59	0.92 [0.89 - 0.95]		0.72 [0.7 - 0.75]	
60+	0.92 [0.87 - 0.98]		0.67 [0.63 - 0.72]	
<b>ArtStartYear</b>				
<2005	1.81 [1.28 - 2.55]		4.64 [3.27 - 6.59]	
[2005-2010)	2.32 [2.23 - 2.42]		5.34 [5.04 - 5.66]	
[2010-2015)	2.88 [2.78 - 2.97]		6.19 [5.9 - 6.51]	
[2015-2020)	2.42 [2.35 - 2.49]		4.08 [3.93 - 4.23]	
>2020	1 [ref]		1 [ref]	
<b>Time On ART</b>				
<1 year	0.79 [0.77 - 0.81]		3.92 [3.77 - 4.08]	
1-3 years	0.78 [0.76 - 0.8]		1.63 [1.58 - 1.69]	
3+ years	1 [ref]		1 [ref]	
<b>Facility Size</b>				
Small	1.47 [1.34 - 1.62]		1.63 [1.48 - 1.8]	
Medium	1.54 [1.5 - 1.58]		1.47 [1.43 - 1.51]	
Large	1 [ref]		1 [ref]	
<b>Facility Level</b>				
Primary	1 [ref]		1 [ref]	
Secondary	1.96 [1.91 - 2.01]		1.45 [1.4 - 1.49]	
Tertiary	2.73 [2.64 - 2.82]		1.68 [1.61 - 1.76]	
<b>Facility Ownership</b>				
Public	1 [ref]		1 [ref]	
Private	1.23 [1.18 - 1.28]		0.87 [0.84 - 0.91]	
<b>State</b>				
Adamawa	2.39 [2.29 - 2.5]		1.86 [1.78 - 1.94]	
Akwa Ibom	1 [ref]		1 [ref]	
Bauchi	2.03 [1.92 - 2.14]		1.56 [1.48 - 1.65]	
Bayelsa	2.77 [2.59 - 2.96]		2.02 [1.89 - 2.16]	
Borno	4.14 [3.94 - 4.35]		2.46 [2.33 - 2.6]	
Cross River	1.51 [1.45 - 1.58]		1.3 [1.24 - 1.36]	

Edo	4.14 [3.97 - 4.32]	2.66 [2.54 - 2.79]
Jigawa	3.66 [3.43 - 3.9]	2.19 [2.05 - 2.35]
Kano	2.34 [2.24 - 2.44]	1.55 [1.48 - 1.62]
Kebbi	0.51 [0.44 - 0.6]	0.34 [0.29 - 0.4]
Kwara	2.55 [2.36 - 2.76]	1.64 [1.51 - 1.77]
Lagos	2.54 [2.45 - 2.64]	1.98 [1.91 - 2.06]
Niger	3.19 [3.06 - 3.33]	2.54 [2.44 - 2.66]
Sokoto	2.51 [2.33 - 2.71]	1.69 [1.56 - 1.83]
Yobe	3.07 [2.84 - 3.31]	2.08 [1.92 - 2.25]
Zamfara	3.4 [3.12 - 3.71]	1.92 [1.76 - 2.11]

250  
251 Some of the states such as Edo (766, 25.2%) and Borno (697, 26.3%), had the highest prevalence  
252 of VL non-suppression for clients on treatment less than one year (Table 4). However, those same  
253 states also had high prevalence of VL non-suppression of clients on ART for longer than three  
254 years. By contrast, Bayelsa had high prevalence of VL non-suppression for clients on ART for  
255 longer than one year.

256

257 **Table 4. Cross table of the State variable by the number of years on ART.**

State	Years On ART [Non-suppressed/Total (%)]		
	<1 year	1-3 years	3+ years
Akwa Ibom	2 566 / 86 893 (3)	2 180 / 87 555 (2.5)	1 858 / 41 008 (4.5)
Adamawa	762 / 8 207 (9.3)	713 / 8 490 (8.4)	1 545 / 24 506 (6.3)
Bauchi	451 / 6 935 (6.5)	321 / 4 001 (8)	859 / 15 260 (5.6)
Bayelsa	189 / 4 467 (4.2)	313 / 3 100 (10.1)	523 / 4 504 (11.6)
Borno	697 / 2 648 (26.3)	461 / 3 255 (14.2)	964 / 10 814 (8.9)
Cross River	627 / 14 601 (4.3)	866 / 22 022 (3.9)	1 400 / 25 757 (5.4)
Edo	766 / 3 045 (25.2)	727 / 5 145 (14.1)	1 972 / 19 107 (10.3)
Jigawa	173 / 1 075 (16.1)	241 / 1 965 (12.3)	669 / 6 623 (10.1)
Kano	372 / 5 171 (7.2)	662 / 6 956 (9.5)	1 863 / 28 347 (6.6)
Kebbi	29 / 1 842 (1.6)	34 / 2 279 (1.5)	84 / 5 217 (1.6)
Kwara	125 / 1 247 (10)	191 / 2 039 (9.4)	389 / 5 727 (6.8)
Lagos	1 038 / 15 290 (6.8)	1 193 / 11 901 (10)	2 389 / 32 118 (7.4)
Niger	955 / 10 923 (8.7)	792 / 6 695 (11.8)	1 586 / 16 432 (9.7)
Sokoto	130 / 1 674 (7.8)	193 / 2 198 (8.8)	408 / 5 624 (7.3)
Yobe	96 / 800 (12)	145 / 1 432 (10.1)	489 / 5 530 (8.8)
Zamfara	109 / 969 (11.2)	151 / 1 268 (11.9)	283 / 2 970 (9.5)



## 259 Discussion

260 Our study found that males, clients in younger age groups (0-24), those who started treatment  
261 before 2020, clients on treatment for less than one year, those receiving care at small and medium  
262 facilities, receiving care at secondary and tertiary level facilities, publicly owned facilities, and  
263 clients receiving care in the Edo, Niger and, Borno states had the highest association with VL non-  
264 suppression. Other studies have found similar results for the likelihood of viral non-suppression in  
265 younger age groups in Cambodia, Uganda, and South Carolina (USA) [6,8,17], and among males  
266 [18–20]. Our findings suggest that the health seeking behavior of certain demographics can be  
267 improved or given more attention to by HIV care programs. In that same regard, considerations  
268 should be given to the facility types, size, and public ownership.

269  
270 The increased likelihood of viral non-suppression among ART clients who received treatment at  
271 tertiary health facilities have not been observed in Ethiopia where higher likelihood of viral non-  
272 suppression was associated with primary health facilities in Ethiopia [21]. Here, we found that  
273 small and medium facilities were associated with viral non-suppression of HIV clients on treatment  
274 and this was consistent with findings that clients were more likely to miss consecutive visits at  
275 lower volume facilities [22]. This could be due to smaller clinics being located within smaller  
276 communities, as a result, patients may avoid stigmatization within their community by not pick-  
277 up treatment as routinely as patients that attend clinics that are outside of their communities [22].  
278 Such clients that would miss their drug pickup appointments more frequently to avoid stigma, are  
279 reasonably expected to have non-suppressed viral loads. A possible circumvention of the  
280 stigmatization within communities would be to offer clients a referral to HIV care facilities that  
281 are located outside of their communities. However, consideration should be given to the distance  
282 needed for travel as well because although a distance less than one kilometer to the clinic was  
283 associated with higher IIT in Rwanda [22], while mean distances above 4.7 km to clinics were  
284 associated with higher IIT in Malawi [23].

285  
286 Clients that received care at privately owned facilities had lower likelihood of a non-suppressed  
287 VL when adjusting for the other variables included in the model. Nevertheless, another study had  
288 found that HIV care was of greater quality at public facilities than private in Anambra state in  
289 Nigeria [24]. This was also reflected in our unadjusted, univariable results.



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5 291 ART clients who had their last VL test conducted within less than one year on treatment were less  
6  
7 292 likely to be virally non-suppressed compared with clients who had their VL tested after one year  
8  
9 293 on ART in the unadjusted model. Our finding was consistent with the Center for Disease Control  
10  
11 294 and Prevention's finding that PLHIV on ART could be virally suppressed within six months of  
12  
13 295 initiation, provided that they adhered to their medication [25]. Moreover, a greater likelihood of  
14  
15 296 viral suppression was found among PLHIV who were on treatment for less than one year compared  
16  
17 297 with those on ART for more than one year according to a study in Ethiopia [26]. This elucidates  
18  
19 298 that clients more engaged in care can have more opportunities for non-suppressed viral load test  
20  
21 299 results, though, this does not necessarily mean that this population is more likely to be non-  
22  
23 300 suppressed. However, our adjusted model reflected the reverse, more specifically, a higher  
24  
25 301 likelihood for clients on ART for less than 1 year to be virally non-suppressed. We attribute this  
26  
27 302 to the high prevalence of virally non-suppressed clients in some of the states, such as Edo and  
28  
29 303 Borno (Table 4). Similarly, a shorter time on ART was identified as a factor associated with a non-  
30  
31 304 suppressed VL in South Africa [27]. This could suggest that although in general, clients on ART  
32  
33 305 for longer than one year may need more attention, greater attention should be given to patients  
34  
35 306 enrolled on ART for less than one year in states such as Edo and Borno, where non-suppression is  
36  
37 307 more common in early initiates. Examples of interventions that could be implemented include  
38  
39 308 enhanced/intensive adherence counselling, improved follow-up programs or more frequent follow-  
40  
41 309 ups to perhaps cultivate a habit of adherence and retention in treatment, which could result in better  
42  
43 310 viral load outcomes. The contradictory findings in the literature as well as those identified between  
44  
45 311 the unadjusted and adjusted models could speak to the specific adherence patterns of the  
46  
47 312 population investigated and models that may be specific to the study setting. Nevertheless, these  
48  
49 313 findings motivate for support of newly enrolled clients, at least in some states, to develop  
50  
51 314 treatment-adherence habits.

52  
53 315  
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55 316 A possible explanation for the clients receiving care in the Kwara and Niger states in the North-  
56  
57 317 Central zone having higher likelihood of viral non-suppression could be linked to health-seeking  
58  
59 318 behavior such as non-use of the service, poor adherence to treatment, and possibly religious  
60  
319 affiliation (for example Islamic religion predominant in northern Nigeria) where in certain  
320  
circumstances women require permission to leave the premises of a household which can reduce

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2  
3 321 access to healthcare [28,29]. Community refills, regular visits from case managers, and enhanced  
4  
5 322 adherence counselling could be implemented in such communities in a door-to-door manner,  
6  
7 323 perhaps staffed by female health workers, to improve VL outcomes. On the other hand, in Borno  
8  
9 324 and Yobe states in the North-East zone of Nigeria, the incessant insecurity in the region has largely  
10  
11 325 led to people often been displaced and this has largely impacted on the health-seeking behavior,  
12  
13 326

14 327 One of the limitations of our study was the inaccessibility of the longitudinal data set. We were  
15  
16 328 therefore restricted to conducting a cross-sectional study. The study cohort was composed of  
17  
18 329 clients that received care at USAID-supported facilities, therefore, it may not be a true  
19  
20 330 representation of the likelihood of VL non-suppression throughout the country. In facilities that  
21  
22 331 support is better, the results here could overestimate the contribution of some of the factors to VL  
23  
24 332 non-suppression. Vice-versa, where support is lacking, the contribution of some of the factors  
25  
26 333 presented here on VL non-suppression could be underestimated.

27  
28 334  
29 335 It is possible that some of the 21.6% of client records (eliminated from analysis) without a VL test  
30  
31 336 on record are a consequence of poor adherence to treatment which could lead to viral load non-  
32  
33 337 suppression that is not tested/recorded. This assumption is based on the concept that patients need  
34  
35 338 to attend clinic visits to either receive treatment or have their VL samples collected and tested.  
36  
37 339 Investigating the factors that are associated with an untested viral load could provide useful insight.  
38  
39 340 At the same time, longitudinal studies into both viral load non-testing and viral load non-  
40  
41 341 suppression may ultimately be of greatest use. Additional variables relating to the capacity of  
42  
43 342 clinical facilities to conduct testing would reveal whether the lack of viral load testing is also  
44  
45 343 affected by a low capacity.

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47 344  
48 345 Other unavailable variables that could be explored in future studies to identify their association  
49  
50 346 with viral suppression are tuberculosis status, adherence level, ART drug regimen, side-effects,  
51  
52 347 IIT, marital status, and education level, however, these variables would need to be provided and  
53  
54 348 analysed longitudinally. Ultimately, the factors reflected in this study may not be exhaustive. The  
55  
56 349 absence of VL suppression data for recently initiated clients may have also had an impact on the  
57  
58 350 study seeing that they had to be excluded, therefore only the results of tested patients could be  
59  
60 351 analysed, leaving out the VL outcomes of those without a test.

352

**Conclusions**

354 Targeting males, those below 35 years of age, those who started treatment before 2020 and those  
355 on treatment for less than three years, receiving care at tertiary health facility, small and medium  
356 facilities, publicly owned, and in the Edo, Borno, and Niger states for interventions could lead to  
357 improvements in VL suppression in Nigeria. The independent factors associated here with a non-  
358 suppressed VL can guide the improvement of ART program development and VL suppression of  
359 PLHIV in Nigeria.

361 **Competing interests:** None declared.

362  
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364 EO, ZA; Data analysis: ST, TC, JA; Funding acquisition: DSD, FA, PP; Data Interpretation: All  
365 authors; Writing – original draft: ST, TC, JA; Writing – review and editing: All authors. All authors  
366 read and approved the final manuscript.

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380 Nigeria, covers the salaries of DSD, ZA and EO.

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3 382 **Data Statement:** The data that support the findings of this study are owned by the Government of  
4  
5 383 Nigeria and were used under license for the current study. Access to these data is subject to  
6  
7 384 restrictions owing to privacy and ethics policies set by the Government of Nigeria so are not  
8  
9 385 publicly available. Requests to access these data should be directed to  
10  
11 386 Dauda.Sulaiman@thepalladiumgroup.com.  
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387

### 388 **Ethics approval**

15 389 The study used secondary data. Ethical approvals for this study were obtained in Nigeria and the  
16  
17 390 United States. Informed consent was waived from all subjects or, if subjects are under 18, from a  
18  
19 391 parent and/or legal guardian by the expedited institutional review board (IRB) approvals granted  
20  
21 392 by both the National Health Research Ethics Committee of Nigeria (NHREC), reference number  
22  
23 393 NHREC/01/01/2007, and the HML IRB in the United States, reference number 772EQH20. Data  
24  
25 394 were anonymized and handled confidentially during all phases of the research. All methods were  
26  
27 395 carried out in accordance with relevant guidelines and regulations. All experimental protocols were  
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29 396 granted approval by the institutional review board (IRB) of the National Health Research Ethics  
30  
31 397 Committee of Nigeria (NHREC), reference number NHREC/01/01/2007, and the HML IRB in the  
32  
33 398 United States, reference number 772EQH20.  
34

399

### 400 **List of abbreviations**

36 401 AIC: Akaike information criterion  
37  
38 402 APR: Adjusted prevalence ratio  
39  
40 403 ART: Antiretroviral therapy  
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42 404 ARV: Antiretroviral  
43  
44 405 CI: Confidence interval  
45  
46 406 Data.FI: Data for Implementation  
47  
48 407 EMR: Electronic medical records  
49  
50 408 FMOH: Federal Ministry of health  
51  
52 409 HFR: Health facility registry  
53  
54 410 HIV: Human immunodeficiency virus  
55  
56 411 IIT: Interruption in treatment  
57  
58 412 IP: Implementing partner  
59

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3	413	MMD:	Multi-month dispensing
4			
5	414	PEPFAR:	United States President's Emergency Plan for AIDS Relief
6			
7	415	PLHIV:	People living with HIV
8			
9	416	RADET:	Retention audit determination tool
10			
11	417	UNAIDS:	Joint United Nations Programme on HIV/AIDS
12			
13	418	UPR:	Unadjusted prevalence ratio
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15	419	USAID:	United States Agency for International Development
16			
17	420	VL:	Viral load
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19	421		

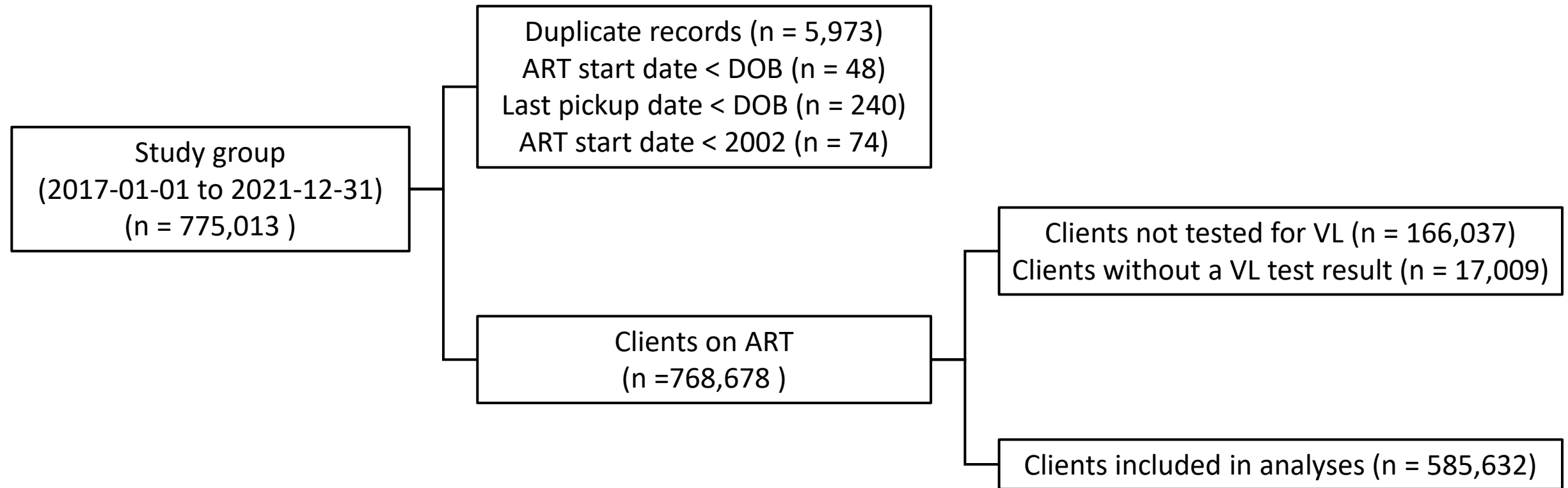
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# Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

## Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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			Page
		Reporting Item	Number
<b>Title and abstract</b>			
Title	<a href="#">#1a</a>	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	<a href="#">#1b</a>	Provide in the abstract an informative and balanced summary	3

of what was done and what was found

## Introduction

Background / rationale	<a href="#">#2</a>	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	<a href="#">#3</a>	State specific objectives, including any prespecified hypotheses	5
<b>Methods</b>			
Study design	<a href="#">#4</a>	Present key elements of study design early in the paper	5
Setting	<a href="#">#5</a>	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Eligibility criteria	<a href="#">#6a</a>	Give the eligibility criteria, and the sources and methods of selection of participants.	5-8
	<a href="#">#7</a>	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources / measurement	<a href="#">#8</a>	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	5-6
Bias	<a href="#">#9</a>	Describe any efforts to address potential sources of bias	7-8
Study size	<a href="#">#10</a>	Explain how the study size was arrived at	6

1	Quantitative	<a href="#">#11</a>	Explain how quantitative variables were handled in the	6-7
2				
3	variables		analyses. If applicable, describe which groupings were chosen,	
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5			and why	
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9	Statistical	<a href="#">#12a</a>	Describe all statistical methods, including those used to control	7-8
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11	methods		for confounding	
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14	Statistical	<a href="#">#12b</a>	Describe any methods used to examine subgroups and	7-8
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16	methods		interactions	
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19	Statistical	<a href="#">#12c</a>	Explain how missing data were addressed	6
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21	methods			
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25	Statistical	<a href="#">#12d</a>	If applicable, describe analytical methods taking account of	6
26				
27	methods		sampling strategy	
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30	Statistical	<a href="#">#12e</a>	Describe any sensitivity analyses	8
31				
32	methods			
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36	<b>Results</b>			
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39	Participants	<a href="#">#13a</a>	Report numbers of individuals at each stage of study—eg	6,10
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41			numbers potentially eligible, examined for eligibility, confirmed	
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43			eligible, included in the study, completing follow-up, and	
44				
45			analysed. Give information separately for for exposed and	
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47			unexposed groups if applicable.	
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51	Participants	<a href="#">#13b</a>	Give reasons for non-participation at each stage	6
52				
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54	Participants	<a href="#">#13c</a>	Consider use of a flow diagram	6
55				
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57	Descriptive data	<a href="#">#14a</a>	Give characteristics of study participants (eg demographic,	10
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clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.

8	Descriptive data	<a href="#">#14b</a>	Indicate number of participants with missing data for each variable of interest	5
13	Outcome data	<a href="#">#15</a>	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	10
21	Main results	<a href="#">#16a</a>	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-14
31	Main results	<a href="#">#16b</a>	Report category boundaries when continuous variables were categorized	6-7
36	Main results	<a href="#">#16c</a>	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
42	Other analyses	<a href="#">#17</a>	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	14
47	<b>Discussion</b>			
50	Key results	<a href="#">#18</a>	Summarise key results with reference to study objectives	15
53	Limitations	<a href="#">#19</a>	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	17

1	Interpretation	<a href="#">#20</a>	Give a cautious overall interpretation considering objectives,	15-17
2			limitations, multiplicity of analyses, results from similar studies,	
3			and other relevant evidence.	
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9	Generalisability	<a href="#">#21</a>	Discuss the generalisability (external validity) of the study	17
10			results	
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14	<b>Other Information</b>			
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16				
17	Funding	<a href="#">#22</a>	Give the source of funding and the role of the funders for the	18
18			present study and, if applicable, for the original study on which	
19			the present article is based	
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27 made by the [EQUATOR Network](#) in collaboration with [Penelope.ai](#)  
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