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Evaluation of immunological and virological markers among people living with HIV in Abakaliki, Ebonyi State, Nigeria

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Abstract

Human immunodeficiency virus (HIV) infection remains a major public health concern, particularly in sub-Saharan Africa, where monitoring immunological and virological outcomes is essential for evaluating the effectiveness of antiretroviral therapy (ART). This study assessed the socio-demographic characteristics, immunological status, and virological outcomes of people living with HIV attending the antiretroviral clinic at Alex Ekwueme Federal Teaching Hospital (FETHA), Abakaliki, Ebonyi State, Nigeria. A total of 200 plasma samples were collected from HIV-infected individuals receiving care at the ART clinic. Sociodemographic data were obtained, while immunological and virological parameters, including $CD4^+$ T-cell count and HIV viral load, were analysed. Statistical associations between viral load suppression and sociodemographic variables were assessed using the Chi-square test, with $p < 0.05$ considered statistically significant. Among the study participants, females constituted the majority (73.0%), while males accounted for 27.0%. The 31–40 age group accounted for the largest share of participants (35.0%), whereas individuals aged ≥51 years accounted for the smallest share (6.0%). Most participants were married (57.0%) and had a tertiary education (68.0%). Civil servants (30.0%) and students (26.0%) were the predominant occupational groups. Immunological assessment revealed that the majority of participants (83.0%) had CD4 counts ≥350 cells/μL, while 10.0% had CD4 counts between 201–349 cells/μL and 7.0% had CD4 counts <200 cells/μL. Virological analysis showed that 69.0% of participants had viral loads ≤40 copies/mL, 21.0% had viral loads between 41–999 copies/mL, and 10.0% had viral loads ≥1000 copies/mL. Overall, 90.0% of the participants achieved viral suppression (<1000 copies/mL), while 10.0% remained virologically unsuppressed.

A statistically significant association was observed between age and viral load suppression ($\chi^2 = 10.12$, $p = 0.018$), indicating improved viral suppression with increasing age. However, no significant associations were found between viral load suppression and sex, marital status, educational level, occupation, or religion ($p > 0.05$). Additionally, no significant relationship was observed between CD4 cell count and viral suppression ($\chi^2 = 0.31$, $p = 0.857$). These findings demonstrate high levels of viral suppression among HIV-infected individuals receiving ART in Abakaliki and underscore the effectiveness of ongoing treatment programs.

Keywords: Evaluation; Immunological Markers; Virological Markers; HIV; Nigeria.

1. Introduction

Human Immunodeficiency Virus (HIV) infection remains a major global public health concern, particularly in low- and middle-income countries, with sub-Saharan Africa accounting for the highest burden of the disease. HIV primarily

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targets the immune system, leading to progressive depletion of CD4+ T-lymphocytes, immune dysfunction, opportunistic infections, and ultimately Acquired Immune Deficiency Syndrome (AIDS) if untreated (World Health Organization [WHO], 2023). The course of HIV infection and the effectiveness of treatment are best assessed using immunological and virological markers, notably CD4 cell counts and plasma HIV viral load.

Globally, significant progress has been made in HIV prevention, diagnosis, and treatment following the scale-up of antiretroviral therapy (ART). The use of combination ART has transformed HIV infection from a fatal disease into a manageable chronic condition, improving survival and quality of life for people living with HIV (PLWH) (UNAIDS, 2023). Monitoring immunological recovery through CD4 cell counts and virological suppression through viral load testing is central to HIV clinical management, treatment monitoring, and public health surveillance (WHO, 2021).

Nigeria bears one of the largest HIV burdens globally, ranking among the countries with the highest number of PLWH. Although national HIV prevalence has declined over the years due to improved prevention strategies and expanded access to ART, the country still faces significant challenges, including late diagnosis, treatment failure, poor adherence, and regional disparities in disease burden (National Agency for the Control of AIDS [NACA], 2022). The Nigerian HIV epidemic is heterogeneous, with marked differences in prevalence, treatment outcomes, and access to care across states and local government areas.

In Ebonyi State, located in Southeast Nigeria, HIV remains a notable public health issue. Abakaliki, the state capital, serves as a major urban and referral center, attracting diverse populations that may influence HIV transmission dynamics. Despite the availability of ART services in public and private health facilities, comprehensive data on immunological and virological responses among PLWH in Abakaliki are limited. Such localized data are essential for evaluating treatment effectiveness, identifying patients at risk of treatment failure, and strengthening HIV care and support services.

Immunological markers, particularly CD4 cell counts, provide insight into the degree of immune suppression and recovery following ART initiation. However, CD4 recovery may be influenced by several factors, including baseline immune status, duration of infection, age, co-infections, and treatment adherence (Boulle et al., 2018). Virological markers, especially plasma HIV viral load, are considered the gold standard for monitoring ART response, as sustained viral suppression is associated with reduced disease progression and prevention of HIV transmission (Eisinger et al., 2019).

In resource-limited settings such as Nigeria, routine viral load monitoring has historically been constrained by cost and infrastructure, leading to reliance on immunological markers alone in some settings. This approach may delay the detection of treatment failure and the emergence of drug resistance (WHO, 2021). Therefore, evaluating both immunological and virological markers among PLWH in Abakaliki is crucial for understanding treatment outcomes, optimizing patient management, and informing state-level HIV control strategies.

This study seeks to evaluate immunological and virological markers among people living with HIV in Abakaliki, Ebonyi State, Nigeria, thereby contributing to the existing body of knowledge and providing evidence to improve HIV care, treatment monitoring, and policy formulation within the region.

2. Materials and Methods

2.1. Study Area

This study was conducted at the Alex Ekwueme Federal University Teaching Hospital, Abakaliki (AE-FETHA), Ebonyi State, Southeast Nigeria. AE-FETHA is a major tertiary health institution and referral center providing comprehensive HIV counseling, testing, treatment, and care services through its Antiretroviral Therapy (ART) clinic. The hospital serves patients from Abakaliki metropolis and neighboring local government areas, making it a suitable setting for evaluating immunological and virological markers among people living with HIV.

2.2. Study Design

This was a hospital-based cross-sectional study designed to evaluate immunological and virological markers among people living with HIV attending the ART clinic of AE-FETHA during the study period.

2.3. Study Population

The study population comprised confirmed HIV-positive individuals receiving care and treatment at the ART clinic of AE-FETHA.

2.3.1. Inclusion Criteria

Participants eligible for inclusion in the study were confirmed HIV-positive individuals, adults aged 18 years and above, patients enrolled in HIV care and currently receiving ART at AE-FETHA and individuals who provided written informed consent.

2.3.2. Exclusion Criteria

The following were excluded from the study: patients who declined to give consent, pregnant women (to avoid pregnancy-related immunological variations), patients with incomplete medical records and individuals with acute severe illness at the time of sample collection.

2.4. Sample Size Determination

The sample size was calculated using the Cochran formula for cross-sectional studies:

$$n = \frac{Z^2 p(1-p)}{d^2}$$

Where: n = minimum sample size, Z = standard normal deviate at 95% confidence level (1.96), p = estimated prevalence of viral suppression from previous studies and d = margin of error (0.05). Published evidence from Nigerian ART settings shows that HIV viral load suppression among adult patients on ART ranges approximately between 83.7% and 91.5% (Kareem et al., 2025). For conservative estimation, a prevalence (p) of 90% (0.90) was used in the calculation.

$$n = \frac{(1.96)^2 \times 0.9(1-0.9)}{(0.05)^2} = \frac{3.8416 \times 0.09}{0.0025} \approx 138.2976$$

Thus, the minimum calculated sample size was 139 participants. To account for possible non-response or incomplete data (estimated at 15%), the sample size was increased:

$$n_{\text{adjusted}} = 139 \times \frac{1}{(1-0.15)} \approx 164$$

Accordingly, a total of 200 participants were recruited for the study.

2.5. Sampling Technique

A systematic random sampling technique was used to recruit eligible participants from the ART clinic attendance register at AE-FETHA until the required sample size was achieved.

2.6. Sample Collection

Approximately 5 mL of venous blood was collected aseptically from each participant using standard phlebotomy procedures. Blood samples were dispensed into EDTA tubes, appropriately labeled, and transported to the laboratory under recommended conditions for analysis.

2.7. Laboratory Analysis

2.7.1. Determination of CD4+ T-Lymphocyte Count

CD4+ T-cell counts were determined using a flow cytometry-based method (Partec, Germany) according to the manufacturer's instructions. Results were expressed as cells per microliter (cells/μL) and used to assess the immunological status of participants.

2.7.2. Determination of HIV Viral Load

Plasma HIV-1 viral load was quantified using real-time polymerase chain reaction (RT-PCR) techniques. Viral load results were reported in copies per millilitre (copies/mL). Virological suppression was defined as a viral load of <1,000 copies/mL, in line with World Health Organization guidelines.

2.8. Data Collection

Sociodemographic and clinical information, such as age, sex, duration on ART, ART regimen, and adherence history, were obtained using structured questionnaires and patients' medical records.

2.9. Data Analysis

Data were analysed using Statistical Package for Social Sciences (SPSS) version 25.0. Descriptive statistics were used to summarise data. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Inferential statistics were applied to assess relationships between immunological and virological markers, with p-values < 0.05 considered statistically significant.

2.10. Ethical Considerations

Ethical approval for the study was obtained from the Madonna University Nigeria Research Ethics Committee [MUN-REC] MUN/VC/REC/14/PhD/MCB/023/001). Written informed consent was obtained from all participants before enrollment. Confidentiality was ensured by assigning unique identification codes to participants and restricting access to data. The study was conducted in accordance with the principles of the Declaration of Helsinki.

3. Results and Analysis

3.1. Socio-Demographical Features of the Study Participants

A cumulation of 200 plasma samples was obtained from people living with HIV attending an antiretroviral clinic at Alex Ekweme Federal Teaching Hospital, Abakaliki (FETHA), Abakaliki in Ebonyi State, Nigeria. Among the study population, females were the most predominant (73.0%, n=146) than their male counterparts (27.0%, n=54) as shown in Table 1. The age group 31-40 years constitute the largest population (35.0%, n=70), followed by those less than 30 (21.5%, n=43), while the age group 51 and above were the least in the population (6.0%, n=12). As seen in Table 1. The majority of the folks in the study population were married (57.0%, n=114), in contrast to the singles (43.0%, n=86), as indicated in Table 1. Based on education and occupation, participants with a tertiary level of education were the majority (68.0%, n=136), followed by secondary (22.0%, n=44), and the least were participants with primary education (10.0%, n=20). Based on occupation, folks working as civil servants were predominant (30%, n=60), followed by students (26.0%, n=52), teachers (18.0%, n=36), and traders (17.0%, n=34). The least popular were farmers and artisans (n= 10 and 8, 5.0% and 4%), respectively (Table 1).

Table 1 Distribution of HIV-infected persons according to their demographic characteristics

Variables	Number tested	Percentage (%)
Age		
≤30	43	21.5
31-40	70	35.0
41-50	32	16.0
≥51	12	6.0
Sex		
Males	54	27.0
Females	146	73.0
Marital Status		
Married	114	57.0

Single	86	43.0
Educational Status		
Primary	20	10.0
Secondary	44	22.0
Tertiary	136	68.0
Occupations		
Student	54	27.0
Unemployed	36	18.0
Self Employed	46	23.0
Employed	64	32.0
Religion		
Christianity	152	76.0
Islam	29	14.5
Others	19	9.5
Total	200	100.0

3.2. Distribution of Participants According to Immunological and Virological Markers

The results obtained from clinical and immunological parameters from the study population were characterised and are shown in Table 2. Their CD4 count ranges from 200- >350 cells/µl. A high degree of the population had CD4 ≥350 (83.0%, n=166), followed by participants with CD4 of 201-349 (10.0%, n =20). Only a few persons had CD4 of less than 200 (7.0%, n=14) as indicated in Table 2. Concerning virological markers, a majority of participants had a viral load of ≤40 copies/ml (69.0%, n=138), followed by 41-999 copies/ml (21.0%, n=42) and least ≥1000 copies/ml (10%, n=20) as displayed in Table 2.

Table 2 Distribution of HIV-infected persons according to their Immunological Markers and Virological Markers

Markers	**No. Tested**	**%**
CD4 Count (cells/ul)		
≤200	14	7.0
201-349	20	10.0
≥ 350	166	83.0
Viral load (Copies/ml)		
TND	0	0.0
<40	138	69.0
40-1000	42	21.0
>1000	20	10.0
TOTAL	200	100

TND: Target not detected

3.3. Statistical Relationship between Distribution of Virological Markers and Sociodemographic Characteristics

A total of 200 HIV-infected individuals were included in the study. Overall, 180 participants (90.0%) achieved viral suppression with HIV viral load <1,000 copies/mL, while 20 participants (10.0%) were virologically unsuppressed.

3.3.1. Age

Viral load suppression varied significantly across age groups. Participants aged ≤30 years had the lowest proportion of viral suppression (72.1%), with 27.9% remaining unsuppressed. In contrast, higher levels of viral suppression were observed among older age groups, particularly those aged 41–50 years (96.9%) and ≥51 years (91.7%). Statistical analysis showed a significant association between age and viral load suppression ($\chi^2 = 10.12$, $p = 0.018$), indicating that viral suppression improved with increasing age (Table 3).

3.3.2. Sex

Among males, 90.7% achieved viral suppression compared to 89.7% of females. The proportion of unsuppressed viral load was similar between males (9.3%) and females (10.3%). There was no statistically significant association between sex and viral load suppression ($p = 1.000$) as shown in Table 3.

3.3.3. Marital Status

Viral suppression was slightly higher among married participants (91.2%) compared to single participants (88.4%). However, the difference was not statistically significant ($\chi^2 = 0.18$, $p = 0.668$), indicating that marital status did not significantly influence viral load suppression (Table 3).

3.3.4. Educational Status

Participants with primary education had the highest viral suppression rate (95.0%), followed by those with tertiary education (90.4%) and secondary education (86.4%). Despite these variations, no significant association was observed between educational status and viral load suppression ($\chi^2 = 1.23$, $p = 0.540$) as shown in Table 3.

3.3.5. Occupation

Viral suppression was highest among unemployed participants (97.2%) and students (90.7%), while employed participants had the lowest suppression rate (82.8%). Nonetheless, occupation was not significantly associated with viral load suppression ($\chi^2 = 3.53$, $p = 0.316$) as shown in Table 3.

3.3.6. Religion

High levels of viral suppression were observed across all religious groups: 90.8% among Christians, 89.7% among Muslims, and 84.2% among participants of other religions. The differences were not statistically significant ($\chi^2 = 0.82$, $p = 0.665$) as shown in Table 3.

Table 3 Statistical Relationship of Virological Markers in HIV-infected persons and their socio-demographic characteristics

Variables	**No Tested**	**%**	**Suppressed (<1000)**	**%**	**Unsuppressed (>1000)**	**%**	**χ^2 test**	**p-value**
Age (years)							10.12	0.018*
≤30	43	21.5	31	72.1	11	27.9		
31–40	70	35.0	63	90.0	7	10.0		
41–50	32	16.0	31	96.9	1	3.1		
≥51	12	6.0	11	91.7	1	8.3		
Sex							0.00	1.000
Male	54	27.0	49	90.7	5	9.3		
Female	146	73.0	131	89.7	15	10.3		
Marital Status							0.18	0.668
Married	114	57.0	104	91.2	10	8.8		
Single	86	43.0	76	88.4	10	11.6		

Educational Status							1.23	0.540
Primary	20	10.0	19	95.0	1	5.0		
Secondary	44	22.0	38	86.4	6	13.6		
Tertiary	136	68.0	123	90.4	13	9.6		
Occupation							3.53	0.316
Student	54	27.0	49	90.7	5	9.3		
Unemployed	36	18.0	35	97.2	1	2.8		
Self-employed	46	23.0	40	87.0	5	13.0		
Employed	64	32.0	53	82.8	9	17.2		
Religion							0.82	0.665
Christianity	152	76.0	138	90.8	14	9.2		
Islam	29	14.5	26	89.7	3	10.3		
Others	19	9.5	16	84.2	3	15.8		
Total	200	100.0	180	90.0	20	10.0		

In summary, there was a statistically significant association between age group and viral load suppression among HIV-infected persons ($\chi^2 = 10.12$, $p = 0.018$), indicating that viral suppression improved with increasing age. However, no statistically significant associations were observed between viral load suppression and sex, marital status, educational level, occupation, or religion ($p > 0.05$).

3.4. Relationship between Immunological Markers and Virological Markers

The relationship between immunological status, as measured by CD4 cell count, and virological outcome was assessed among the study participants. Overall, 180 (90.0%) participants achieved viral suppression, while 20 (10.0%) were virologically unsuppressed.

Among participants with CD4 counts <200 cells/μL, 85.7% achieved viral suppression, while 14.3% had unsuppressed viral load. Participants with CD4 counts between 201–349 cells/μL showed a viral suppression rate of 90.0%, with 10.0% remaining unsuppressed. Similarly, those with CD4 counts >350 cells/μL had a viral suppression rate of 90.4%, while 9.6% were unsuppressed.

Statistical analysis using the Chi-square test showed no statistically significant association between CD4 cell count and viral load suppression ($\chi^2 = 0.31$, $p = 0.857$). This indicates that, within the study population, virological suppression was achieved across all CD4 categories and was not significantly influenced by immunological status at the time of assessment.

Table 4 Statistical Relationship between Immunological Markers and Virological Markers

CD4 Count (cells/μL)	**No. Tested**	**%**	**Suppressed (<1000)**	**%**	**Unsuppressed (>1000)**	**%**	**χ^2 test**	**p-value**
<200	14	7.0	12	85.7	2	14.3	0.31	0.857
201–349	20	10.0	18	90.0	2	10.0		
>350	166	83.0	150	90.4	16	9.6		
Total	200	100.0	180	90.0	20	10.0		

4. Discussion of Findings

The present study investigated the socio-demographic, immunological, and virological characteristics of people living with HIV (PLHIV) attending the antiretroviral therapy (ART) clinic at Alex Ekwueme Federal Teaching Hospital (FETHA), Abakaliki, Ebonyi State, Nigeria. The findings provide insight into the demographic structure of the study population and the relationship between sociodemographic factors, immune status, and viral suppression among HIV-infected individuals. This study also evaluated the relationship between demographic characteristics, immunological markers (CD4 cell count), and virological markers (HIV viral load) among people living with HIV attending the Antiretroviral Therapy (ART) clinic at Alex Ekwueme Federal University Teaching Hospital, Abakaliki (AE-FETHA), Ebonyi State, Nigeria. The findings provide important insight into treatment outcomes and factors influencing viral suppression in a tertiary healthcare setting. Studies have shown that earlier initiation of ART and consistent follow-up care significantly enhance immune recovery (Smit et al., 2015).

The socio-demographic characteristics of the participants revealed that females constituted the majority of the study population (73.0%), while males accounted for only 27.0%. This pattern may reflect the higher health-seeking behaviour among women, particularly in HIV care settings, as women often access healthcare services through antenatal programmes and routine reproductive health services more frequently than men. Similar female predominance among HIV clinic attendees has been reported in several Nigerian studies (Okonko et al., 2023a; Ugwu et al., 2023b). The age distribution showed that the majority of participants were within the economically productive age group of 31–40 years (35.0%), followed by those younger than 30 years (21.5%). This observation is consistent with previous epidemiological reports indicating that HIV infection is most prevalent among adults in their reproductive and economically active years (Ugwu et al., 2023a). The relatively lower representation of individuals aged 51 years and above may reflect lower testing rates or survival patterns among older populations.

Marital status distribution indicated that more than half of the participants were married (57.0%), while 43.0% were single. This finding aligns with earlier studies suggesting that married individuals may still remain at risk of HIV infection due to factors such as partner transmission, limited disclosure of HIV status, and inconsistent condom use within marital relationships (Okonko et al., 2023c). With respect to educational status, most participants had tertiary education (68.0%), followed by those with secondary education (22.0%). Higher educational attainment among participants may reflect increased awareness of HIV testing and treatment services, as well as improved health-seeking behaviour among individuals with higher levels of education. Previous studies have similarly reported higher engagement in HIV care among individuals with higher educational backgrounds (Cookey et al., 2022).

Regarding occupational distribution, civil servants constituted the largest occupational group (30.0%), followed by students (26.0%), teachers (18.0%), and traders (17.0%), while farmers and artisans represented the least proportion of participants. The dominance of formally employed individuals and students may reflect the urban hospital setting and accessibility of ART services to individuals residing within or near the urban centre. Similar occupational distributions have been reported in other hospital-based HIV studies in Nigeria (Okonko et al., 2023a).

Assessment of immunological status showed that a substantial proportion of participants (83.0%) had $CD4^+$ T-cell counts ≥350 cells/μL, indicating relatively good immune status among the majority of individuals in the cohort. Only a small fraction (7.0%) had CD4 counts below 200 cells/μL, which is typically indicative of advanced immunosuppression. This finding suggests effective ART uptake and improved immune recovery among the study participants. Previous studies have similarly reported improved CD4 cell counts among patients receiving sustained antiretroviral therapy in Nigeria (Aaron et al., 2021; Innocent-Adiele et al., 2021).

Virological assessment revealed that nearly two-thirds of participants (63.3%) had HIV viral loads below 40 copies/mL, while an additional 11.8% had target not detected (TND), indicating effective viral suppression in the majority of the cohort. Viral suppression is a key indicator of ART success and is central to achieving the UNAIDS 95–95–95 targets, as it reduces HIV-related morbidity and virtually eliminates the risk of onward transmission (UNAIDS, 2022).

The study recorded a high virological suppression rate of 90.0%, with only 10.0% of participants having unsuppressed viral load (>1,000 copies/mL). This level of viral suppression exceeds the UNAIDS 95–95–95 target second and third indicators and reflects the success of Nigeria's ART scale-up and the effectiveness of current first-line antiretroviral regimens, particularly dolutegravir-based therapies (UNAIDS, 2023; WHO, 2021). High viral suppression is a critical public health achievement, as it reduces HIV-related morbidity, mortality, and transmission, consistent with the Undetectable = Untransmittable (U=U) principle (Eisinger et al., 2019).

The overall viral suppression observed in this study aligns with recent national reports showing gradual improvements in virological outcomes among Nigerians receiving ART (Avert, 2023). Notably, Abakaliki recorded a higher proportion of participants with viral loads below 40 copies/mL. While the outcomes indicate effective viral control, the absence of TND results in Abakaliki may reflect differences in laboratory reporting practices, assay sensitivity, or viral load testing platforms used at the study sites. Previous studies have emphasised that inter-laboratory variability can influence viral load categorisation, particularly at very low detection thresholds (WHO, 2023b, e, f).

The higher proportion of participants with viral loads exceeding 1,000 copies/mL in Abakaliki is clinically significant, as viral loads above this threshold are often associated with poor adherence, treatment failure, or the emergence of drug resistance (Sadoh & Sadoh, 2018b). This finding underscores the need for continuous viral load monitoring, adherence counselling, and timely regimen switching where necessary. Overall, the immunological and virological patterns observed in this study demonstrate encouraging ART outcomes, with most participants achieving immune recovery and viral suppression.

Similarly, virological assessment revealed a high level of viral suppression among the participants. Approximately 90.0% of the study population achieved viral suppression (<1,000 copies/mL), while only 10.0% remained virologically unsuppressed. Furthermore, the majority of participants (69.0%) had viral loads ≤40 copies/mL, indicating optimal virological control. This high level of viral suppression may reflect adherence to antiretroviral therapy and effective HIV treatment monitoring within the ART clinic. Comparable levels of viral suppression have been reported in HIV treatment cohorts in Nigeria following the scale-up of antiretroviral therapy programmes (Aaron et al., 2021; Cookey et al., 2021).

The analysis of the relationship between viral suppression and sociodemographic characteristics revealed a statistically significant association between age and viral load suppression ($\chi^2 = 10.12$, $p = 0.018$). Viral suppression improved with increasing age, with older participants showing higher suppression rates compared with younger individuals. Participants aged ≤30 years demonstrated the lowest suppression rate, with a considerable proportion remaining virologically unsuppressed. This observation may be attributed to challenges commonly faced by younger patients, including poorer treatment adherence, stigma, psychosocial instability, and inconsistent clinic attendance. Similar findings have been reported in previous studies where younger age groups were associated with poorer treatment outcomes and lower viral suppression rates (Ugwu et al., 2023b).

Age was the only demographic variable significantly associated with viral load suppression in this study ($\chi^2 = 10.12$, $p = 0.018$). Younger participants (≤30 years) had the lowest viral suppression rate (72.1%), while older age groups, particularly those aged 41–50 years, demonstrated markedly higher suppression rates (96.9%). This finding aligns with previous studies in Nigeria and sub-Saharan Africa, which have consistently reported poorer virological outcomes among younger people living with HIV (PLWH), often attributed to suboptimal adherence, psychosocial challenges, stigma, and mobility (Bulsara et al., 2018; NACA, 2022).

The improved virological outcomes observed among older participants may reflect better health-seeking behaviour, greater treatment adherence, and longer duration on ART. This finding highlights the need for age-specific adherence support and youth-friendly HIV services, particularly targeting adolescents and young adults.

In contrast, no statistically significant associations were observed between viral suppression and other sociodemographic variables such as sex, marital status, educational level, occupation, or religion ($p > 0.05$). Although slight variations in suppression rates were observed across these variables, the differences were not statistically meaningful. For example, viral suppression rates were comparable between males (90.7%) and females (89.7%), suggesting that both sexes benefited similarly from antiretroviral therapy. This finding is consistent with previous studies that reported no significant sex-based differences in virological outcomes among individuals receiving ART (Okonko et al., 2023a; Ugwu et al., 2023b).

No statistically significant association was observed between sex and viral load suppression ($p = 1.000$). Both males (90.7%) and females (89.7%) achieved comparable levels of viral suppression. This finding is consistent with several Nigerian studies reporting minimal sex-based differences in virological outcomes once patients are retained in care and receiving ART (Adejumo et al., 2020). It suggests equitable access to treatment and comparable treatment response between sexes at AE-FETHA.

Similarly, marital status did not significantly influence viral suppression, despite slightly higher suppression rates among married participants compared to singles. This suggests that access to treatment, adherence to therapy, and clinical monitoring may play a more important role in virological outcomes than marital status alone. Although married participants showed a slightly higher viral suppression rate (91.2%) compared to single participants (88.4%), the

difference was not statistically significant (p = 0.668). While marital support has been associated with improved adherence in some settings, the lack of statistical significance in this study suggests that structured ART programs and counseling services may mitigate social differences related to marital status (Okonko et al., 2021).

Participants across all educational levels achieved high rates of viral suppression, with no significant association between educational status and virological outcome (p = 0.540). This finding contrasts with earlier assumptions that higher educational attainment directly predicts better treatment outcomes. The result underscores the effectiveness of standardized ART counseling and monitoring protocols that support patients irrespective of educational background (WHO, 2021). Educational level also did not significantly affect viral suppression, even though participants with primary education demonstrated slightly higher suppression rates. The absence of a significant association may indicate that ART programmes have been successful in delivering effective treatment outcomes across different educational groups.

Although unemployed participants demonstrated the highest viral suppression rate (97.2%) and employed participants the lowest (82.8%), the association between occupation and viral suppression was not statistically significant (p = 0.316). Similar findings have been reported in Nigerian ART cohorts, where occupational status did not independently predict virological outcomes after ART initiation (Adebayo et al., 2019). Work-related stress and time constraints may partially explain lower suppression among employed individuals, but structured clinic follow-up appears to mitigate these effects.

No significant association was found between religion and viral load suppression (p = 0.665). High suppression rates across religious groups suggest that ART adherence and treatment outcomes at AE-FETHA are not influenced by religious affiliation. This is encouraging in a culturally diverse setting and indicates effective patient education that counters faith-based misconceptions regarding HIV treatment.

The relationship between CD4 cell count and viral load suppression was not statistically significant (χ^2 = 0.31, p = 0.857). Viral suppression rates were consistently high across all CD4 categories, including participants with CD4 counts <200 cells/μL. This finding supports existing evidence that virological suppression can be achieved even in patients with advanced immunosuppression, provided ART adherence is optimal (Boulle et al., 2018). The lack of a significant association further reinforces the WHO recommendation that viral load monitoring remains the gold standard for assessing ART response, as CD4 count alone may not reliably reflect virological control in the era of potent ART regimens (WHO, 2021).

The relationship between immunological status and virological outcome was also examined in this study. Although participants with higher CD4 cell counts tended to have slightly higher viral suppression rates, the association between CD4 count and viral load suppression was not statistically significant (χ^2 = 0.31, p = 0.857). Viral suppression occurred across all CD4 categories, suggesting that effective ART can achieve virological control regardless of baseline immunological status. This finding highlights the effectiveness of modern antiretroviral therapy regimens in suppressing viral replication even among individuals with varying levels of immune competence. Similar observations have been reported in other Nigerian studies where viral suppression was achieved across multiple CD4 categories among patients receiving ART (Aaron et al., 2021; Cookey et al., 2021).

Overall, the findings of this study demonstrate encouraging treatment outcomes among people living with HIV attending the ART clinic in Abakaliki, with high levels of viral suppression and relatively good immune status observed among the majority of participants. The significant association between age and viral suppression underscores the need for targeted adherence support and treatment monitoring among younger individuals living with HIV. Strengthening adherence counselling, youth-focused HIV care services, and continuous monitoring of treatment outcomes may further improve viral suppression rates and overall clinical outcomes among this population.

The findings demonstrate excellent ART program performance at AE-FETHA, with high virological suppression and minimal demographic disparities. However, the poorer outcomes observed among younger participants highlight a critical gap that requires targeted interventions, including youth-friendly services, enhanced adherence counselling, and psychosocial support.

5. Conclusion

The study showed that the viral load suppression among people living with HIV attending AE-FETHA was generally high. Age was the only demographic factor significantly associated with viral load suppression, with younger participants showing poorer virological outcomes. Other sociodemographic variables, including sex, marital status, education, occupation, and religion, showed no significant association with virological suppression. Also, there was no

significant relationship between immunological markers (CD4 count) and virological markers (viral load suppression) among people living with HIV attending AE-FETHA ($p > 0.05$), suggesting effective virological control irrespective of CD4 cell count category.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this study. The research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Statement of ethical approval

Ethical approval for this study was obtained from the Research Ethics Committee of Madonna University Nigeria, Elele, Rivers State, Nigeria (Approval Number: MUN/VC/REC/14/PhD/MCB/023/001). The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (World Medical Association, 2013) for research involving human subjects. All protocols were reviewed and approved before the commencement of the study.

Statement of informed consent.

Written informed consent was obtained from all participants prior to enrollment in the study. Participants were adequately informed about the purpose, procedures, potential risks, and benefits of the research. Confidentiality and anonymity of participants were strictly maintained throughout the study. Participation was entirely voluntary, and participants were informed of their right to withdraw at any stage without any consequences to their care or treatment.

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