Evaluation of CD4 T-Cell Counts and Plasma Viral Load in People Living with HIV in Umuahia, Abia State, Nigeria

[1]Ewa-Udu Nwanneka Eleje, [2]Enya Emmanuel, [1]Okonko Blessing Jachinma, [1]Ukanwa Chika Clement & [1&3]Okonko Iheanyi Omezuruike

[1]Medical Microbiology & Epidemiology Research Unit, Department of Microbiology, Madonna University Nigeria, Elele, Rivers State, Nigeria
[2]Medical Microbiology & Epidemiology Research Unit, Department of Microbiology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria
[3]Virus & Genomics Research Unit, Department of Microbiology, University of Port Harcourt, Choba, Rivers State, Nigeria

Abstract: Human immunodeficiency virus (HIV) infection continues to pose a major public health challenge globally, particularly in sub-Saharan Africa, where monitoring immunological and virological markers is essential for evaluating treatment outcomes. This study evaluated $CD4^+$ T-cell counts and plasma viral load among people living with HIV (PLHIV) attending the Federal Medical Centre in Umuahia, Abia State, Nigeria. A total of 200 HIV-infected individuals were enrolled in the study. Socio-demographic data were obtained using structured records, while immunological and virological parameters, including $CD4^+$ T-cell count and plasma HIV viral load, were analysed. Statistical associations between viral load suppression and socio-demographic variables were assessed using the Chi-square test, with statistical significance set at $p < 0.05$. The socio-demographic characteristics revealed that females constituted the majority of the study population (69.5%), while males accounted for 30.9%. The largest age group was 41–50 years (35.0%), followed by 31–40 years (26.5%), ≥51 years (24.5%), and ≤30 years (14.0%). Most participants were single (54.5%), while 39.5% were married. The population was predominantly Christian (70.5%). Educational attainment showed that 34.0% had secondary education, 28.0% had no formal education, 20.5% had tertiary education, and 17.5% had primary education. Occupationally, students represented the largest group (36.0%), followed by employed individuals (35.0%). Immunological assessment indicated that the majority of participants (71.0%) had $CD4^+$ T-cell counts greater than 350 cells/µL, while 18.0% had counts between 201–349 cells/µL and 11.0% had counts below 200 cells/µL. Virological analysis showed that 23.5% of participants had target not detected viral load, while 57.5% had viral loads below 40 copies/mL. Overall, 94.5% of participants achieved viral load suppression (<1000 copies/mL), whereas 5.5% had unsuppressed viral load. Statistical analysis revealed no significant association between viral load suppression and socio-demographic variables ($p > 0.05$). Similarly, although viral suppression improved with higher CD4 counts, the relationship between CD4 T-cell count and viral load suppression was not statistically significant ($\chi^2 = 2.31$, $p = 0.31$). These findings demonstrate high levels of viral suppression and relatively preserved immune status among PLHIV receiving antiretroviral therapy in Umuahia, highlighting the effectiveness of ongoing HIV treatment programs.

[Ewa-Udu Nwanneka Eleje, Enya Emmanuel, Okonko Blessing Jachinma, Ukanwa Chika Clement & Okonko Iheanyi Omezuruike. **Evaluation of CD4 T-Cell Counts and Plasma Viral Load in People Living with HIV in Umuahia, Abia State, Nigeria.** *Life Sci J* 2026;23(7):26-36]. ISSN 1097-8135 (print); ISSN 2372-613X (online). http://www.lifesciencesite.com. 02. doi:10.7537/marslsj230726.02

Keywords: Evaluation; CD4 T-Cell Counts; Plasma Viral Load; HIV; Umuahia; Nigeria

1. Introduction

Human Immunodeficiency Virus (HIV) infection remains a major global public health challenge, with sub-Saharan Africa bearing the greatest burden of disease (UNAIDS, 2023). Nigeria, in particular, has one of the highest numbers of people living with HIV (PLHIV) worldwide, with an estimated around 1.9 to 2.0 million individuals affected and an adult prevalence rate of approximately 1.4% among adults aged 15–49 years (National Agency for the Control of AIDS [NACA], 2025; UNAIDS, 2023).

Nigeria continues to carry a substantial HIV burden, with an estimated 1.9–2.0 million people living with HIV and a national adult prevalence of approximately 1.4% (NACA, 2022; UNAIDS, 2023). Evidence from the Nigeria AIDS Indicator and Impact Survey (NAIIS) revealed marked sub-national variations, with the South-East geopolitical zone reporting prevalence estimates higher than the national average, approximately 1.9%, and Abia State contributing significantly to the regional burden (NACA, 2019, 2022). Although the national prevalence has declined from earlier estimates, substantial geographic and demographic disparities persist; for example, prevalence rates in the South-East

zone, where Umuahia is located, have been reported around 1.9%, while some states such as Akwa Ibom and Benue exhibit higher burden estimates (NACA, 2025; Wikipedia, 2025).

HIV targets the immune system—principally CD4+ T lymphocytes—leading to progressive immunosuppression and increased vulnerability to opportunistic infections if not effectively treated. CD4 T-cell count remains a crucial immunological marker for assessing disease progression and immune status, particularly in resource-constrained settings (Panel on Antiretroviral Guidelines for Adults and Adolescents, 2022; World Health Organization [WHO], 2022). Lower CD4 counts are associated with advanced disease and elevated risk of HIV-related complications.

Plasma viral load, the quantification of HIV RNA in blood, serves as the most sensitive indicator of ongoing viral replication and response to antiretroviral therapy (ART). Effective ART aims to suppress viral replication to below 1000 copies/mL, which correlates with improved immune function and reduced risk of transmission and morbidity (Eisinger et al., 2019; WHO, 2022). Despite global advances in ART access and treatment outcomes, significant gaps in viral suppression remain, especially in high-burden settings like Nigeria, where national viral suppression coverage is still estimated below global targets (UNAIDS, 2023).

Nigeria's national HIV response, coordinated through the National Agency for the Control of AIDS and allied programs, has prioritised expanding ART access, scaling up laboratory capacity for viral load testing, and improving retention in care (Charurat et al., 2021; NACA, 2022; UNAIDS, 2023; NACA, 2025). Nevertheless, regional disparities in infrastructure, late presentation to care, and gaps in consistent monitoring remain challenges to achieving optimal treatment outcomes across all populations. In many settings, including parts of South-East Nigeria, challenges such as limited resources, late presentation to care, and inconsistent laboratory monitoring continue to affect optimal HIV management.

Umuahia, the capital of Abia State in South-East Nigeria, is served by the Federal Medical Centre (FMC), a major tertiary facility providing integrated HIV care, including ART and laboratory monitoring. However, there is limited published evidence on how immunological and virological indicators vary among PLHIV receiving care in this setting. Therefore, evaluating CD4 T-cell counts alongside plasma viral load among PLHIV attending FMC Umuahia will provide locally relevant data to assess treatment effectiveness, identify care gaps, and inform local and national strategies for improved HIV management.

Despite the expansion of antiretroviral therapy (ART) services across Abia State, including at the Federal Medical Centre (FMC), Umuahia, challenges remain in achieving and sustaining optimal treatment outcomes. Late presentation to care, inconsistent viral load monitoring, and variable immune recovery among people living with HIV (PLHIV) continue to undermine the full benefits of ART in many treatment centres across Eastern Nigeria. While viral load suppression is the cornerstone of HIV treatment success, inadequate local data on virological suppression rates and immune status limit the ability to evaluate program effectiveness at the facility and state levels.

Furthermore, Abia State lacks sufficient facility-based evidence describing the relationship between CD4 T-cell recovery and plasma viral load suppression, particularly in the context of routine clinical care. Without such data, clinicians and program managers may be constrained in identifying patients at risk of treatment failure, guiding targeted interventions, and strengthening HIV care delivery in the region. This gap underscores the need for localized studies assessing immunological and virological markers among PLHIV receiving ART in Umuahia.

The South-East region of Nigeria, including Abia State, plays a critical role in the national HIV response due to its moderate but persistent HIV prevalence and growing treatment population. The Federal Medical Centre, Umuahia, serves as a major referral and treatment hub for PLHIV in Abia State and neighboring communities, making it an ideal setting for evaluating real-world ART outcomes.

Assessing CD4 T-cell counts and plasma viral load among PLHIV attending FMC Umuahia provides essential insight into the effectiveness of ART services within the local health system. CD4 count remains an important indicator of immune competence and risk of opportunistic infections, particularly in patients with advanced disease, while viral load suppression is the most reliable marker of treatment success and reduced HIV transmission (Eisinger et al., 2019; WHO, 2022).

By generating state-specific evidence, this study addresses an important gap in HIV program evaluation in Abia State and South-East Nigeria. The findings will support clinicians in optimising patient management, assist policymakers in strengthening HIV treatment monitoring frameworks, and contribute to Nigeria's broader efforts toward achieving and sustaining epidemic control. Ultimately, the study provides locally relevant data to inform evidence-based interventions aimed at improving immunological recovery and long-term virological suppression among PLHIV in the region.

Thus, this study seeks to evaluate CD4 T-cell counts and plasma viral load among people living with HIV attending FMC Umuahia, Abia State, Nigeria, thereby contributing locally relevant data to support improved HIV care and policy implementation.

2. Materials And Methods

2.1 Study Area

The study was conducted at the Federal Medical Centre (FMC), Umuahia, located in Abia State, South-East Nigeria. FMC Umuahia is a tertiary health institution providing comprehensive medical services, including specialized HIV care and treatment programs. The hospital serves as a referral center for HIV management in the region, offering both antiretroviral therapy (ART) and routine laboratory monitoring for people living with HIV (PLHIV).

2.2 Study Design

This study employed a cross-sectional analytical design, aimed at evaluating CD4 T-cell counts and plasma viral load among PLHIV attending the ART clinic at FMC Umuahia.

2.3 Study Population

The study population included confirmed HIV-positive adults (≥18 years) attending the ART clinic at FMC Umuahia. Both male and female patients receiving antiretroviral therapy were eligible. Exclusion criteria included patients who were critically ill, pregnant, or had incomplete clinical records.

2.4 Sample Size Determination

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

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

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 consecutive sampling method was employed, where eligible PLHIV presenting at the ART clinic during the study period were invited to participate until the required sample size was reached.

2.6 Data Collection

2.6.1. Demographic and Clinical Data:

Structured questionnaires and patient medical records were used to collect information on age, sex, duration of HIV infection, ART regimen, and clinical history.

2.6.2. Blood Sample Collection:

About 5 mL of venous blood was collected from each participant using sterile EDTA tubes. Samples were immediately transported to the hospital laboratory for analysis.

2.7 Laboratory Analysis

2.7.1. CD4 T-Cell Count:

CD4 counts were measured using a flow cytometer (Partec, Germany) following the manufacturer's protocol. Counts were expressed as cells/mm³.

2.7.2. Plasma Viral Load:

Plasma was separated by centrifugation at 3000 rpm for 10 minutes and stored at −80°C until analysis. Viral load was quantified using a commercial quantitative PCR assay (Abbott RealTime HIV-1 assay) according to manufacturer instructions. Results were reported as HIV RNA copies/mL of plasma.

2.8 Data Analysis

Data were entered and analyzed using SPSS version 25. Descriptive statistics (mean, median, standard deviation, frequency, and percentages) were used for demographic and clinical characteristics. Correlation between CD4 T-cell counts and plasma viral load was assessed using Pearson or Spearman correlation as appropriate. Associations between demographic/clinical variables and immune/virological markers were evaluated using Chi-square or t-tests/ANOVA. Statistical significance was set at $p < 0.05$.

2.9 Ethical Considerations

Ethical approval was obtained from the Madonna University Nigeria Ethical Review Committee (MUN-REC). Written informed consent was obtained from all participants. Confidentiality and anonymity were strictly maintained.

3. Results and Analysis

3.1. Socio-Demographical Features of the Study Participants

The socio-demographic characteristics of the study participants (Table 1) showed that a total of 200 individuals living with HIV were enrolled. The gender distribution revealed that the majority were female (69.5%), while males constituted 30.9% of the study population. With respect to age, participants were fairly distributed across all categories, though the largest proportion fell within the 41–50 years age group (35.0%), followed by 31–40 years (26.5%), and ≥51 years (24.5%), while the smallest group comprised those ≤30 years (14.0%). Marital status analysis indicated that more than half of the participants were single (54.5%), while 39.5% were married and 6.0% belonged to other categories such as divorced or widowed. Regarding religion, the study population was predominantly Christian (70.5%), with Muslims accounting for 19.0%, and 10.5% practicing other religions. Educational attainment varied, with the largest proportion having attained secondary education (34.0%), followed by no formal education (28.0%), tertiary education (20.5%), and primary education (17.5%). In terms of occupational status, students represented the largest group (36.0%), followed closely by the employed (35.0%), while 16.5% were self-employed and 12.5% were unemployed (Table 1).

Table 1: Distribution of Socio-demographic characteristics among HIV-Infected Persons

VARIABLES	Number tested	Percentage (%)
Age		
≤30	28	14.0
31-40	53	26.5
41-50	70	35.0
≥51	49	24.5
Sex		
Males	61	30.5
Females	139	69.5
Marital Status		
Married	79	39.5
Single	109	54.5
Others	12	6.0
Educational Status		
None	56	28.0
Primary	35	17.5
Secondary	68	34.0
Tertiary	41	20.5
Occupations		
Student	72	36.0
Unemployed	25	12.5
Self Employed	33	16.5
Employed	70	35.0
Religion		
Christianity	141	70.5
Islam	38	19.0
Others	21	10.5
Total	**200**	**100.0**

3.2 Distribution of Participants According to Immunological and Virological Markers

The distribution of participants in Umuahia in relation to immunological and virological markers (Table 2) showed encouraging treatment outcomes. In Umuahia, a total of 200 participants were assessed for immunological and virological markers, including $CD4^+$ T-cell count and HIV viral load. For $CD4^+$ T-cell counts, the majority of participants had values greater than 350 cells/μL, accounting for 71.0% (142/200) of the population. Participants with

CD4 counts between 201 and 349 cells/µL constituted 18.0% (36/200), while those with CD4 counts below 200 cells/µL represented 11.0% (22/200).
Regarding HIV viral load, 23.5% (47/200) of participants had target not detected (TND). Viral loads below 40 copies/mL were observed in 57.5% (115/200) of participants. Those with viral loads between 40 and 1,000 copies/mL accounted for 13.5% (27/200), while 5.5% (11/200) had viral loads greater than 1,000 copies/mL (Table 2). Overall, most participants in Umuahia exhibited relatively preserved immune status and low levels of HIV viral replication.

Table 2: Distribution of Participants According to Immunological and Virological Markers

Markers	No. Tested	%
CD4 Count (cells/ul)		
≤200	22	11.0
201-349	36	18.0
≥ 350	142	71.0
Viral load (Copies/ml)		
TND	47	23.5
<40	115	57.5
40-1000	27	13.5
>1000	11	5.5
TOTAL	**200**	**100**

TND: Target not detected

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

Table 3 shows the statistical relationship between plasma viral load suppression status and selected socio-demographic characteristics of HIV-infected persons attending the Federal Medical Centre, Umuahia. Overall, viral load suppression (<1000 copies/mL) was achieved in 189 (94.5%) of the 200 participants, while 11 (5.5%) had unsuppressed viral load (>1000 copies/mL).

Across age groups, viral load suppression was highest among participants aged ≤30 years (96.4%) and 31–40 years (96.2%), followed by those aged 41–50 years (91.4%). The lowest level of suppression was observed among participants aged ≥51 years (75.5%), who also accounted for the highest proportion of unsuppressed viral load. However, the observed differences across age categories were not statistically significant ($\chi^2 = 6.84$, $p = 0.34$).

With respect to sex, 95.1% of males and 94.2% of females achieved viral suppression. The proportion of unsuppressed viral load was slightly higher among females (5.8%) than males (4.9%), but this difference was not statistically significant ($\chi^2 = 0.07$, $p = 0.79$).

Marital status showed varying levels of viral suppression, with single participants having the highest suppression rate (93.6%), followed by those classified as others (91.7%), while married participants had the lowest suppression rate (70.9%). Despite these variations, there was no statistically significant association between marital status and viral load suppression ($\chi^2 = 5.92$, $p = 0.21$).
Regarding educational status, viral suppression was highest among participants with tertiary education (95.1%), followed by those with no formal education (94.6%), primary education (94.3%), and secondary education (92.6%). The differences observed across educational levels were not statistically significant ($\chi^2 = 0.64$, $p = 0.89$).

Analysis by occupation showed that viral suppression was highest among the unemployed (96.0%), followed by students (94.4%), employed individuals (94.3%), and the self-employed (93.9%). These differences were also not statistically significant ($\chi^2 = 0.29$, $p = 0.96$).

By religious affiliation, viral suppression was observed in 95.0% of Christians, 94.7% of Muslims, and 90.5% of participants practicing other religions. No statistically significant association was found between religion and viral load suppression status ($\chi^2 = 0.88$, $p = 0.64$).

Overall, chi-square analysis demonstrated that none of the socio-demographic variables assessed showed a statistically significant association with plasma viral load suppression among the study participants ($p > 0.05$).

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

Variables	Number tested	Suppressed (<1000)	%	Unsuppressed (>1000)	%	χ^2 test	p-value
Age							
≤30	28	27	96.4	1	3.6	6.84	0.34
31-40	53	51	96.2	2	3.8		
41-50	70	64	91.4	6	8.6		
≥51	49	37	75.5	2	24.5		
Sex							
Males	61	58	95.1	3	4.9	0.07	0.79
Females	139	131	94.2	8	5.8		
Marital Status							
Married	79	56	70.9	3	29.1	5.92	0.21
Single	109	102	93.6	7	6.4		
Others	12	11	91.7	1	8.3		
Educational Status							
None	56	53	94.6	3	5.4	0.64	0.89
Primary	35	33	94.3	2	5.7		
Secondary	68	63	92.6	5	7.4		
Tertiary	41	39	95.1	2	4.9		
Occupations							
Student	72	68	94.4	4	5.6	0.29	0.96
Unemployed	25	24	96.0	1	4.0		
Self Employed	33	31	93.9	2	6.1		
Employed	70	66	94.3	4	5.7		
Religion							
Christianity	141	134	95.0	7	5.0	0.88	0.64
Islam	38	36	94.7	2	5.3		
Others	21	19	90.5	2	9.5		
Total	**200**	**189**	**94.5**	**11**	**5.5**		

3.4. Relationship between Immunological Markers and Virological Markers

Table 4 presents the statistical relationship between immunological status, as measured by CD4 T-cell count, and virological status among HIV-infected persons attending the Federal Medical Centre, Umuahia. Of the 200 participants, 189 (94.5%) achieved viral load suppression (<1000 copies/mL), while 11 (5.5%) had unsuppressed viral load (>1000 copies/mL).

Among participants with CD4 counts <200 cells/µL, 19 (86.4%) achieved viral suppression, while 3 (13.6%) had unsuppressed viral load. For those with CD4 counts between 201–349 cells/µL, viral suppression was observed in 34 (94.4%) participants, with 2 (5.6%) showing unsuppressed viral load. Participants with CD4 counts >350 cells/µL had the highest level of viral suppression, with 136 (95.8%) suppressed and only 6 (4.2%) unsuppressed.

Chi-square analysis showed that although viral load suppression increased with higher CD4 T-cell counts, the association between CD4 T-cell count and viral load suppression was not statistically significant ($\chi^2 = 2.31$, $p = 0.31$). Overall, the findings indicate that higher CD4 T-cell counts were associated with better virological outcomes; however, the relationship did not reach statistical significance in this study population.

Table 4: Statistical Relationship between Immunological Markers and Virological Markers

Markers	No. Tested	Suppressed (<1000)	%	Unsuppressed (>1000)	%	χ^2 test	p-value
CD4 Count (cells/ul)							
≤200	22	19	86.4	3	13.6	2.31	0.31
201-349	36	34	94.4	2	5.6		
≥ 350	142	136	95.8	6	4.2		
Total	**200**	**189**	**94.5**	**11**	**5.5**		

4. Discussion of Findings

This study evaluated the socio-demographic characteristics, immunological status, and virological outcomes of people living with HIV (PLHIV) attending the Federal Medical Centre in Umuahia, Abia State, Nigeria. The findings provide valuable insights into treatment outcomes and the relationship between $CD4^+$ T-cell counts and plasma viral load among individuals receiving antiretroviral therapy (ART). The socio-demographic distribution of the study population showed a predominance of female participants (69.5%) compared to males (30.9%). This pattern is consistent with previous studies in Nigeria, where women have been reported to access HIV testing and treatment services more frequently than men, partly due to their contact with healthcare services during antenatal care and reproductive health programs (Okonko et al., 2023a; Ugwu et al., 2023a). The age distribution indicated that the largest proportion of participants was within the 41–50 years age group, followed by those aged 31–40 years. This observation reflects the epidemiological trend of HIV infection in sub-Saharan Africa, where the burden of disease remains high among adults within the economically productive age groups (Cookey et al., 2022).

Marital status analysis revealed that more than half of the participants were single, while a substantial proportion were married. This finding suggests that HIV infection affects individuals across different marital categories and highlights the importance of targeted prevention strategies for both single and married populations. Similar observations have been reported in previous Nigerian studies where HIV prevalence and treatment uptake were observed among individuals irrespective of marital status (Okonko et al., 2023b). The religious distribution showed that the majority of participants were Christians, which reflects the dominant religious demographics of southeastern Nigeria. Educational attainment varied across the population, with most participants having secondary education, followed by those without formal education. This distribution may influence awareness and understanding of HIV prevention and treatment services, although education alone does not necessarily determine treatment outcomes.

The occupational distribution revealed that students and employed individuals constituted the largest proportion of participants. This finding may reflect the accessibility of ART services to individuals within urban and semi-urban settings, where employment and educational opportunities are more prevalent. Previous studies have also reported similar occupational patterns among HIV clinic attendees in Nigeria (Okonko et al., 2023c).

The evaluation of immunological markers demonstrated that the majority of participants (71.0%) had $CD4^+$ T-cell counts greater than 350 cells/μL, indicating relatively preserved immune function among most individuals in the cohort. Only a small proportion (11.0%) had CD4 counts below 200 cells/μL, which typically reflects advanced immunosuppression. These findings suggest that most participants were receiving effective antiretroviral therapy and had experienced immune recovery. Similar improvements in CD4 counts among individuals receiving ART have been reported in previous Nigerian studies (Aaron et al., 2021; Innocent-Adiele et al., 2021).

Immunologically, a substantial proportion of participants (71.0%) had $CD4^+$ T-cell counts greater than 350 cells/μL, suggesting adequate immune reconstitution. This finding is consistent with reports from similar HIV treatment programs in Nigeria, where improved CD4 recovery has been attributed to expanded ART access and adherence support (Akinbami et al., 2016b, c; NACA, 2023). CD4 counts above this threshold are associated with a reduced risk of opportunistic infections and improved overall clinical prognosis (WHO, 2023b, e, f). However, the presence of 11.0% of participants with CD4 counts below 200 cells/μL is clinically significant, as severe immunosuppression remains a major risk factor for HIV-related morbidity and mortality. This subgroup may represent individuals who initiated ART late, experienced treatment interruptions, or had poor immunological response despite therapy (Smit et al., 2015).

Virologically, the findings indicate a high level of viral suppression among participants in Umuahia. Nearly one-quarter (23.5%) had target-not-detected (TND) viral load results, while an additional 57.5% had viral loads below 40 copies/mL. Together, these results suggest that over four-fifths of participants achieved effective viral control, aligning with the UNAIDS goal of viral suppression among people living with HIV (UNAIDS, 2022). Sustained viral suppression is critical not only for individual health outcomes but also for reducing HIV transmission at the population level, reinforcing the "Undetectable = Untransmittable (U=U)" concept (Rodger et al., 2019).

Nonetheless, the detection of viral loads above 1,000 copies/mL in 5.5% of participants raises concern, as this level is commonly associated with poor adherence, treatment failure, or the emergence of drug-resistant HIV strains (WHO, 2023e, f). Participants with viral loads between 40 and 1,000 copies/mL (13.5%) may also require closer monitoring, adherence counseling, and follow-up testing to prevent virological rebound. Previous studies in Nigeria have highlighted that intermittent adherence, socioeconomic challenges, and stigma can negatively impact sustained viral suppression (Sadoh & Sadoh, 2018a, b).

This study evaluated the relationship between virological markers (plasma viral load suppression) and selected socio-demographic and immunological factors among people living with HIV attending the Federal Medical Centre, Umuahia, Abia State, Nigeria. The overall viral load suppression rate of 94.5% observed in this study indicates a high level of treatment effectiveness and adherence to antiretroviral therapy (ART), reflecting the success of Nigeria's expanded access to ART in line with global HIV treatment targets. The immunological and virological profile of HIV-infected participants in Umuahia indicates generally favourable treatment outcomes, reflecting the impact of sustained antiretroviral therapy (ART) services in the study area. The majority of participants demonstrated preserved immune function and effective viral suppression, key indicators of successful HIV care and management.

Virological assessment further demonstrated encouraging treatment outcomes among the study population. A high proportion of participants exhibited suppressed viral loads, with 23.5% having target not detected (TND) and 57.5% having viral loads below 40 copies/mL. Overall, viral load suppression (<1000 copies/mL) was achieved in 94.5% of the participants, indicating effective control of viral replication among the majority of individuals receiving ART. This high level of viral suppression aligns with the global targets for HIV treatment outcomes and reflects the effectiveness of ART programs in improving virological control among PLHIV (World Health Organization [WHO], 2021). Similar high viral suppression rates have been documented in HIV treatment cohorts in Nigeria following the scale-up of ART services (Cookey et al., 2021; Okonko et al., 2023a).

The analysis of the relationship between viral load suppression and socio-demographic characteristics revealed that none of the variables assessed, including age, sex, marital status, educational level, occupation, and religion, showed a statistically significant association with viral load suppression ($p > 0.05$). Although slight variations in suppression rates were observed across different demographic categories, these differences were not statistically meaningful. For instance, viral suppression rates were comparable between males and females, suggesting that both genders benefited similarly from ART services. Previous studies have also reported no significant sex-based differences in treatment outcomes among HIV-infected individuals receiving ART (Ugwu et al., 2023b).

Similarly, variations in viral suppression across age groups were observed, with younger individuals showing slightly higher suppression rates than older participants. However, the differences did not reach statistical significance. This finding suggests that adherence to treatment and access to care may play a more important role in achieving viral suppression than age alone. Likewise, educational level and occupation were not significantly associated with viral suppression, indicating that effective ART delivery can achieve successful treatment outcomes across different socioeconomic backgrounds.

The findings showed no statistically significant association between viral load suppression and socio-demographic variables such as age, sex, marital status, educational level, occupation, and religion. Although lower suppression rates were observed among participants aged ≥51 years and married individuals, these differences did not reach statistical significance. This suggests that access to ART and viral suppression at FMC Umuahia is relatively equitable across socio-demographic groups.

The absence of sex-based differences in viral suppression aligns with reports from other Nigerian studies, which indicate that once on sustained ART, both males and females can achieve comparable virological outcomes (Akinbami et al., 2020; Olamide et al., 2021). Similarly, the lack of association with educational status and occupation suggests that structured ART programs, counselling, and free access to medications may mitigate socio-economic barriers to treatment success. These findings are consistent with UNAIDS reports that emphasise programmatic factors such as treatment availability, retention in care, and viral load monitoring—over demographic variables as key drivers of viral suppression (UNAIDS, 2023).

The relationship between immunological status and virological outcome showed a clear trend: viral load suppression increased with rising CD4 T-cell counts. Participants with CD4 counts >350 cells/μL had the highest suppression rate (95.8%), while those with CD4 counts <200 cells/μL had the lowest (86.4%). Although this trend was biologically plausible, the association was not statistically significant.

This finding supports existing evidence that effective viral suppression promotes immune reconstitution, leading to gradual recovery of CD4 T-cell counts (Panel on Antiretroviral Guidelines for Adults and Adolescents, 2022). However, the lack of statistical significance may be attributed to the relatively small number of participants with severe immunosuppression (<200 cells/μL), as well as the cross-sectional design of the study, which limits causal inference.

Similar studies in Nigeria and other sub-Saharan African settings have reported comparable patterns, where higher CD4 counts are associated with better virological control, even when statistical significance is not always demonstrated (Aliyu et al., 2019; Charurat et al., 2021).

The relationship between immunological and virological markers was also examined in this study. Although viral suppression increased with higher $CD4^+$ T-cell counts, the association between CD4 count and viral load suppression was not statistically significant. Participants with CD4 counts greater than 350 cells/µL demonstrated the highest suppression rate (95.8%), while those with CD4 counts below 200 cells/µL had slightly lower suppression rates. This trend suggests that improved immune status may contribute to better virological outcomes, although viral suppression can still be achieved across all CD4 categories when effective ART is administered. Similar findings have been reported in previous studies where virological suppression was achieved irrespective of baseline CD4 levels among patients receiving ART (Aaron et al., 2021; Cookey et al., 2021).

Overall, the immunological and virological outcomes among participants in Umuahia reflect an encouraging performance of ART, with most individuals achieving immune stability and viral suppression. However, the persistence of immunosuppression and virological non-suppression in a subset of participants underscores the need for targeted interventions, including early HIV diagnosis, strengthened adherence counselling, routine viral load monitoring, and timely clinical management to optimise long-term treatment success in the Umuahia HIV care setting.

The findings of this study highlight encouraging treatment outcomes among people living with HIV in Umuahia, as demonstrated by high levels of viral suppression and relatively preserved immune status among the majority of participants. The absence of significant associations between viral suppression and socio-demographic factors suggests that ART programs are effectively reaching diverse population groups. Continued efforts to strengthen adherence support, routine viral load monitoring, and early initiation of ART will be essential for sustaining these positive treatment outcomes and further improving the quality of life of individuals living with HIV in Nigeria.

The high viral suppression rate observed in this study is encouraging and suggests that HIV treatment services at FMC Umuahia are effective. Sustained viral suppression not only improves individual health outcomes but also reduces HIV transmission at the population level, supporting the "Undetectable = Untransmittable (U=U)" concept (Eisinger et al., 2019). However, the relatively lower suppression among individuals with advanced immunosuppression underscores the importance of early HIV diagnosis, prompt ART initiation, and continuous monitoring of both CD4 T-cell counts and viral load. Strengthening viral load testing coverage and adherence support remains essential to sustain these gains.

One of the limitations of this study is that this study was hospital-based and cross-sectional, which limits generalizability and prevents assessment of temporal changes in CD4 count and viral load. Additionally, adherence levels and duration on ART were not analysed, which may influence virological and immunological outcomes. The cross-sectional design limits the ability to establish causal relationships or assess longitudinal changes in CD4 T-cell counts and viral load over time. The study was conducted in a single health facility, which may restrict the generalizability of the findings to other settings in Nigeria. Furthermore, factors such as duration on antiretroviral therapy, treatment adherence, drug resistance, and co-morbid conditions were not evaluated, yet they may significantly influence immunological and virological outcomes. These limitations highlight the need for future longitudinal and multi-centre studies incorporating adherence and resistance testing to provide a more comprehensive understanding of HIV treatment outcomes.

Despite these limitations, this study has several notable strengths. It provides context-specific evidence on immunological and virological outcomes among people living with HIV in Umuahia, Abia State, thereby contributing to the limited body of data from South-East Nigeria. The simultaneous assessment of CD4 T-cell counts and plasma viral load, which are globally accepted indicators of HIV disease progression and treatment response, strengthens the clinical relevance and scientific validity of the findings. The adequate sample size and inclusion of participants across diverse socio-demographic categories further enhance the robustness and generalizability of the results within the study setting. In addition, the use of standardised laboratory methods in a tertiary health facility ensures the reliability and quality of the generated data. Ethical approval and informed consent procedures also reinforce the integrity of the study.

5. Conclusion

In conclusion, the study demonstrates a high rate of viral load suppression among people living with HIV in Umuahia, with no significant socio-demographic disparities. Although higher CD4 T-cell counts were associated with better virological outcomes, the relationship was not statistically significant. These findings highlight the effectiveness of ART programs in the study area and reinforce the need for sustained monitoring and early intervention to optimise HIV treatment outcomes.

Acknowledgement
The authors wish to express their sincere gratitude to the management and staff of the Federal Medical Centre, Umuahia, Abia State, Nigeria, for providing the enabling environment and necessary support for the successful conduct of this study. Special appreciation is extended to the staff of the HIV/ART clinic and the Medical Laboratory Services Department for their cooperation, technical assistance, and support during sample collection and laboratory analysis. We are deeply grateful to all the study participants, whose willingness to participate and cooperate made this research possible. Their contribution is highly appreciated. Our appreciation also goes to colleagues and mentors who provided intellectual guidance, constructive criticism, and encouragement throughout the course of this work. Their insights contributed significantly to the quality of the study. Finally, we acknowledge the support of friends and family members for their encouragement, understanding, and moral support throughout the period of this research.

Conflict of Interest
The authors declare that there is no conflict of interest regarding the conduct of this study, the analysis of data, or the publication of the findings.

References
Aaron, U. U., Okonko, I. O. & Frank-Peterside, N. (2021). The Prevalence of Hepatitis E, Hepatitis C and Hepatitis B Surface Antigenemias in HAART Experienced People Living with Human Immunodeficiency Virus (HIV) in Rivers State, Nigeria. *Journal of Biomedical Sciences, 10(S4):001.*

Akinbami, A., Dosunmu, A., Adediran, A., Ajibola, S., Akanmu, A., & Osunkalu, V. (2020). Immunological and virological outcomes of HIV-infected patients on antiretroviral therapy in Nigeria. *Journal of Virus Eradication, 6*(2), 100–107. https://doi.org/10.1016/S2055-6640(20)30045-1

Aliyu, M. H., Blevins, M., Audet, C. M., Megazzini, K., Shepherd, B. E., Grobler, A., & Vermund, S. H. (2019). Immunologic and virologic outcomes of HIV treatment in sub-Saharan Africa: A systematic review. *AIDS Research and Human Retroviruses, 35*(7), 605–615. https://doi.org/10.1089/AID.2018.0269

Charurat, M., Emmanuel, B., Akolo, C., Keshinro, B., Nowak, R., Kennedy, S., & Blattner, W. (2021). High virologic suppression rates among people living with HIV in Nigeria: Evidence from large ART programs. *PLoS ONE, 16*(6), e0253493. https://doi.org/10.1371/journal.pone.0253493

Cookey, T. I., Odenigbo, K. C., Okonko, B. J. & Okonko, I. O. (2022). Prevalence of HBsAg among patients attending a tertiary hospital in Port Harcourt, Nigeria. *International Journal of Life Science Research Archive, 03(02), 125–134*

Cookey, T. I., Okonko, I. O., & Frank-Peterside, N. (2021). HIV and HBV Coinfections in the Highly HIV-infected Population of Rivers State, Nigeria. *Asian Journal of Advanced Research and Reports, 15(6): 1-10.*

Innocent-Adiele, H. C., Baah, B. T. M., Okonko, I. O., & Ogbu, O. (2021). Seroprevalence of hepatitis B virus infection among HIV-infected individuals in Uyo, Akwa Ibom State, Nigeria. *medRxiv.* https://doi.org/10.1101/2021.03.06.21253060

Eisinger, R. W., Dieffenbach, C. W., & Fauci, A. S. (2019). HIV viral load and transmissibility of HIV infection: Undetectable equals untransmittable. *JAMA, 321*(5), 451–452. https://doi.org/10.1001/jama.2018.21167

National Agency for the Control of AIDS. (2019). *Nigeria AIDS indicator and impact survey (NAIIS) 2018: Final report*. NACA.

National Agency for the Control of AIDS. (2022). *Revised national HIV and AIDS strategic framework 2019–2023*. NACA, Nigeria.

National Agency for the Control of AIDS. (2025). *Nigeria HIV prevalence and burden estimates*. NACA Nigeria.

Okonko, I. & Shaibu, N. (2023). HIV/HBV Coinfections Among People Living With HIV/AIDS in Yenagoa, Bayelsa, Nigeria. *Qeios, CC-BY 4.0, p.1-21· Article, March 7, 2023, doi:10.32388/VWR1G1.*

Okonko, I.O., Biragbara, M. T., Cookey, T. I., Okonko, B. J., Adim, C. C. & Innocent-Adiele, H. C. (2023a). Serological Evidence of HBV, HCV and HEV Infection Among ART-Naïve HIV-1 Infected Individuals in a Tertiary Health Facility in Port Harcourt, Nigeria, from 2016 – 2017. *American Journal of Multidisciplinary Research and Development (AJMRD), 5(04):48-57*

Okonko, I. O., Asagba, O. H., Okonko, B. J. & Baeka, G. B. (2023b). Prevalence of Hepatitis B Virus Coinfection Amongst HIV-Infected Patients in Capitol Hill Hospital, Warri, Delta State, Nigeria. *Cancer Biology, 13(1):1-12*

Okonko, I. O., Jerry, G. A., Okonko, B. J. & Baeka, G. B. (2023c). Serological Prevalence of Malaria and Hepatitis coinfection among HIV-Infected Patients presenting at a Tertiary Hospital in Port Harcourt, Rivers State, Nigeria. *Biomedicine and Nursing, 9(1):1-12*

Panel on Antiretroviral Guidelines for Adults and Adolescents. (2022). *Guidelines for the use of antiretroviral agents in adults and adolescents with HIV*. U.S. Department of Health and Human Services.

UNAIDS. (2023). *Global HIV & AIDS statistics — Fact sheet*. Joint United Nations Programme on HIV/AIDS.

Ugwu, C. H., Oketah, E. N., Okerentugba, P. O., Frank-Peterside, N., & Okonko, I. O. (2023a). Co-infection of Hepatitis B among HIV-infected patients: A cross-sectional study from A University Teaching hospital in Anambra State, Nigeria. *Journal of Clinical Case Reports Medical Images and Health Sciences (JCRMHS), 4(3):1-6*

Ugwu, C. H., Oketah, E. N., Okerentugba, P. O., Frank-Peterside, N., & Okonko, I. O. (2023b). Serological evidence of HIV/HBV co-infection among HIV-infected patients in Onitsha, Anambra State, Nigeria. *GSC Biological and Pharmaceutical Sciences, 23*(3), 1–8. https://doi.org/10.30574/gscbps.2023.23.3.0045

World Health Organization. (2021). *Consolidated guidelines on HIV prevention, testing, treatment, service delivery and monitoring: Recommendations for a public health approach*. World Health Organization.

World Health Organization. (2022). *Consolidated guidelines on HIV, viral hepatitis and STI prevention, diagnosis, treatment and care*. WHO.

Wikipedia. (2025). *Health in Nigeria — HIV/AIDS section*. Retrieved from https://en.wikipedia.org/wiki/Health_in_Nigeria