

# **International Journal of Research Publication and Reviews**

Journal homepage: www.ijrpr.com ISSN 2582-7421

# **Evaluating the Healthcare Implications of a Mathematical Model for HIV/AIDS in Kebbi State and IT Control Strategy.**

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#### ABSTRACT

The healthcare implications of a mathematical model for HIV/AIDS in Kebbi State, Nigeria, are assessed in this study with an emphasis on data analysis, treatment results, and control measures. A statistical analysis of ART enrollment, patient retention, viral load suppression, and lost-to-follow-up (LTFU) cases was performed using HIV/AIDS patient data from five healthcare systems. With adult patients making up the majority and pediatric and adolescent involvement remaining low, the results show notable differences in ART uptake. With high viral load suppression (mean = 92.4%) and retention rates ranging from 78% to 88%, treatment adherence appears to be effective. Nonetheless, discrepancies in LTFU and PMTCT acceptance rates draw attention to structural problems such stigma, inaccessibility, and insufficient follow-up procedures. Overall ART enrollment has increased, according to trend analysis, but sporadic drops point to obstacles affecting continuity of care. In order to reduce LTFU rates and improve HIV/AIDS management in Kebbi State, the study emphasizes the necessity of improved maternal HIV interventions, improved patient retention strategies, and focused socioeconomic support.

Keywords: healthcare implications; HIV/AIDS; Control strategy.

#### 1. Introduction

HIV/AIDS remains a significant public health concern in Nigeria, with varying prevalence rates across different states (UNAIDS, 2023). Mathematical models have been instrumental in understanding the transmission dynamics of HIV/AIDS and evaluating the effectiveness of control strategies (Bhunu et al., 2020). These models help policymakers design interventions that optimize resource allocation and improve patient outcomes. Kebbi State, Nigeria, presents unique challenges in HIV/AIDS management due to socioeconomic factors, healthcare accessibility, and variations in patient retention rates. Nigeria now has a 1.4% HIV prevalence rate (USAID, 2019; NAIIS, 2018). Kaduna State has the highest prevalence rate at 1.1%, while the North West Zone has a rate of 0.6%. The prevalence rates are 0.6% in Kano and Kebbi States, 0.5% in Zamfara State, and 0.4% in Sokoto State. At 0.3%, the lowest prevalence rate in the zone is found in Jigawa and Katsina States (NAIIS, 2018). Mycobacterium tuberculosis is the causative agent of tuberculosis (TB), an airborne bacterial infection. It is transmitted from an infected person to an uninfected person via infectious droplets. If left untreated, a person with tuberculosis can have the infection for a long time and may have the infection latently for the rest of their lives. Notably, Nigeria is currently among the top ten nations most impacted by TB, and TB is one of the major causes of death among individuals living with HIV/AIDS worldwide (USAID, 2019). Blood borne viral infections, including HIV and hepatitis C virus (HCV), are often spread in tandem, especially among injecting drug users (PWID) (Alter, 2006; Vickerman et al., 2013). Understanding how these infections are related to one another is crucial.

#### 1.1 Cointegration and Mathematical Modeling of HIV/AIDS and Co-Infections

Cointegration is the term for the interdependence between two or more variables, which has been the subject of much research in recent years. When examining long-term connections between illnesses, including HIV/AIDS and its coinfections, this method is very pertinent (Engle and Granger, 1987). Without control measures, McCluskey (2003) studied HIV/AIDS models with a tiered development. A staged progression HIV model with an incomplete vaccination as the only control measure was also examined by Gummel et al. (2006) and Elbasha and Gummel (2006). The effect of one or more control measures on the spread of HIV/AIDS has generally been mathematically examined in a large number of research. deterministic model that incorporates the stepwise course of HIV/AIDS, as examined by Garba and Gummel (2010), and the impact of teaching uncounseled AIDS persons, as examined by Hussaini et al. (2010), in order to build upon and expand on earlier findings. As previously believed, infections like hepatitis C and tuberculosis are no longer seen as separate entities. About 53,000 deaths were attributed to HIV in 2018, and the prevalence rate among people aged 15 to 59 was 1.5% (Avert, 2019). The working population, which makes up a sizable number of persons living with HIV, may substantially shrink if the 90:90:90 strategy developed by USAID which aims to end the AIDS pandemic by 2030 is not implemented. This would have a detrimental effect on the economy. HIV reduces the likelihood of a successful course of therapy by weakening the immune system, which impacts the clearance rates of HCV and other

opportunistic infections (Kim and Chung, 2009). Co-infected patients are considerably more likely to be older, Black, and injectable drug users (IDUs), with a 31.6% frequency of HCV co-infection. According to a multivariate analysis, patients who were co-infected with HIV and HCV had a significantly shorter survival span from the time of AIDS diagnosis (hazard ratio: 1.84). This suggests that people with HIV frequently co-infect with HCV (Katie et al., 2004). With the development of new drugs and a growing emphasis on drug-resistant TB, treatment approaches for HIV and co-infections are changing globally. The dynamics of HIV, TB, and HCV co-infections have changed dramatically as a result of managing people with numerous co-infections. More than 50% of individuals without active TB are expected to get the disease, and more than one-third of the 39.5 million persons living with HIV are co-infected with TB at this time (USAID, 2019). The prevalence rate of tuberculosis in Nigeria is 4% (WHO, 2019), while there are still data limitations because of difficulties with new assessment methods. In order to better understand the magnitude of co-infection dynamics in Nigeria's HIV epidemic, especially in the North West area, this project intends to investigate different modeling approaches for HIV/AIDS and specific opportunistic illnesses (such as TB and HCV). Descriptive statistics and time series analysis are thoroughly examined in the sections that follow. Determining if the time series data is stationary is essential for applying the cointegration approach. The differencing approach can be used to achieve stationarity if the data sets being considered are non-stationary. About 80% of new HIV infections in Nigeria are caused by unprotected heterosexual sexual contact, with the remaining cases mostly occurring among key populations such as transgender people, sex workers, men who have sex with men, and injecting drug users (Sheehy et al., 2022; NACA, 2022; Djomand et al., 2022).

### 1.2 HIV Prevalence, Transmission, and Mathematical Modeling Approaches

According to UNAIDS (2013), the adult prevalence of HIV in the general population is estimated to be 2% or less, which is still a relatively low prevalence in West Africa. In Nigeria, the 2018 Nigeria AIDS Indicator and Impact Survey (NAIIS) estimated adult HIV prevalence at 1.4% among individuals aged 15–49 years. A population-based survey called NAIIS was carried out to assess progress toward the UNAIDS 95-95-95 targets, track important national HIV-related indicators, and provide information for financing and policy decisions (UNAIDS, 2022). The President's Emergency Plan for AIDS Relief (PEPFAR) provided the majority of the funding and support for the implementation of NAIIS in Nigeria, with additional funding coming from the Global Fund. Predicting resource requirements, planning and assessing preventive and treatment initiatives, and keeping an eye on the epidemic all depend on accurate HIV prevalence estimates (Bärnighausen et al., 2011). 23% of adult men and 16% of adult women in Sub-Saharan Africa do not take part in HIV testing, according to an analysis of the Demographic and Health Surveys (DHS), the most popular nationally representative surveys for HIV prevalence in the region. The rates of non-participation vary greatly, from as low as 3% for women in Rwanda (2005) to as high as 37% for men in Zimbabwe (2005–2006).

#### How Does HIV Spread Between Individuals?

Only certain acts can spread HIV, and the most frequent ones are:

- Having anal or vaginal sex with someone who has the virus without a condom or while taking medicine for prevention or therapy. Compared to vaginal intercourse, anal sex is more dangerous.
- Sharing injectable supplies, including needles, with someone who has HIV. Mother-to-child transmission during pregnancy, childbirth, or breastfeeding is one of the less frequent forms of transfer.
- iii. Unintentional contact with sharp objects or needles tainted with HIV.

A fractional model for HIV transmission in a homogeneous-mixing population that takes anti-HIV preventative vaccinations into account was presented by Huo et al. (2015).

According to the study, in the absence of immunizations, the fundamental reproduction number acts as a stringent threshold for disease eradication when it reaches unity. Nonetheless, the model showed that a backward bifurcation takes place at low vaccination efficacy or dosage, indicating that even when the reproduction number is less than unity, a stable disease-free equilibrium (DFE) and a stable endemic equilibrium (EE) coexist. This suggests that eliminating disease requires more than just bringing the reproduction number down below unity. As a threshold for total disease eradication, a new critical value should be set at the tipping point. Additionally, the authors provided adequate criteria for the global asymptotic stability of the disease-free equilibrium point by generalizing the integer LaSalle invariant set theorem into a fractional system. According to their findings, boosting vaccination effectiveness and dosage are crucial steps in halting the HIV virus's spread. HIV is still an incurable illness that gradually erodes and degrades the human immune system, leaving the body open to infection. It can seriously harm the heart, kidneys, and brain, possibly resulting in death if treatment is not received. Despite the lack of a recognized treatment, the risk of death is considerably decreased with appropriate counseling and antiretroviral therapy (ART) administration (Ibrahim et al., 2021).

Between the late 19th and early 20th centuries, HIV is thought to have spread from non-human primates in Sub-Saharan Africa to humans. Approximately three-quarters of all HIV infections occur through sexual transmission, making it a prevalent sexually transmitted disease (STD) (WHO, 1993). Although male-to-male sexual transmission is a common occurrence worldwide, heterosexual transmission accounts for the majority of HIV infections. Research shows that the likelihood of acquiring HIV increases with the number of sexual partners and through unprotected anal intercourse (Gaodert et al., 1944; Pickering, 1986). In addition to sexual contact, HIV can spread through blood transfusions and from mother to child during pregnancy, delivery, or breastfeeding (WHO, 2008). A number of studies have examined the dynamics of HIV/AIDS transmission, with Srinivasa (2003) developing a theoretical framework for the disease's spread. Disease outbreak mathematical models are useful tools for predicting the course of epidemics, taking into

This study evaluates the healthcare implications of a mathematical model for HIV/AIDS in Kebbi State by analyzing patient retention, lost-to-follow-up (LTFU) rates, and viral load suppression across selected healthcare facilities. The research further explores the impact of control strategies such as Antiretroviral Therapy (ART), Prevention of Mother-to-Child Transmission (PMTCT), and pre-exposure prophylaxis (PrEP) programs in mitigating disease progression and transmission.

# 1.3 Objectives

The aim of this study is to evaluate the healthcare implications of a mathematical model for HIV/AIDS in Kebbi State and assess the effectiveness of control strategies in managing the disease. With the following objectives

- To analyze the trends and variations in HIV/AIDS patient data, including ART uptake, retention rates, and viral load suppression across selected healthcare facilities in Kebbi State.
- 2. To assess the impact of LTFU rates and other socio-demographic factors on HIV/AIDS treatment outcomes.
- To evaluate the effectiveness of different control strategies, including PMTCT, PrEP, and patient retention mechanisms, in reducing HIV/AIDS prevalence and improving health outcomes.

## 1.4 Research Area

This study focuses on Kebbi State, Nigeria, examining HIV/AIDS treatment and control strategies across five major healthcare facilities: Sir Yahaya Memorial Hospital (Birnin Kebbi), Federal Medical Center (Argungu), General Hospital Jega (Jega), Yauri Specialist Hospital (Yauri), and General Hospital Koko (Koko/Besse). These facilities were selected based on their role in HIV/AIDS management and the availability of comprehensive patient records. The study aims to provide data-driven insights that can inform healthcare policies and improve HIV/AIDS treatment strategies in Kebbi State.

# 2. Method of Data Analysis

The study employs both descriptive and inferential statistical techniques to analyze the HIV/AIDS dataset. Descriptive statistics, including mean, standard deviation, and frequency distribution, provide insights into ART enrollment trends, retention rates, and LTFU variations. Inferential methods such as trend analysis, survival analysis, and regression modeling assess the relationships between patient retention, LTFU, and viral load suppression. Furthermore, survival analysis techniques, including Kaplan-Meier estimates, evaluate patient adherence over time and identify critical factors influencing treatment discontinuation. The data analysis process is conducted using statistical software such as SPSS and R.

#### 3. Data Analysis and Interpretation

The study reveals significant variations in HIV/AIDS patient data across five healthcare facilities in Kebbi State. Adult patients on ART are 546.6, with lower enrollments for adolescents and pediatrics. The mean patient retention rate is 82.6%, with higher rates indicating stronger support mechanisms. High LTFU rates are associated with socioeconomic factors and stigma. High viral load suppression rates indicate effective ART regimens and adherence among retained patients, but occasional dips highlight potential adherence challenges.

The trend analysis shows an increase in ART enrollment, PMTCT uptake, and maternal HIV interventions, but inconsistencies suggest stockouts, migration, and treatment adherence challenges. Higher retention correlates with lower LTFU cases, with well-established facilities showing better outcomes

# Table 1: HIV/AID Data set

S/N	Facility Name	Facility Code	LGA	State	Reporti ng Poriod Start	Repor ting Period End	Adult Patient 5 on ART	Adalesce at Patients on ART	Pedia tric Patie nti os ART	PMT CT Moth ers	Expo sed Infan ts	PrE P Patie NIS	PEP Pati ents	Lost to Falle w-Up (LTF U)	Tra asfe rred Out	Dec eas ed Pas iest s	No W Pa tie atts	Came lative Patien II	Patie nts Rete stion Rate (%)	Viral Load Suppre stion (%)
1	Sir Yahaya Memorial Hespital	KE001	Bernin Kebbi	Kebbi	01-01-20 24	29-02/ 2024	798	172	30	150	51	10	21	28	5	3	.115	385	85%	95%
2	Federal Medical Center	KE002	Argung 11	Kebbi	01:01:20 24	29/02/ 2024	625	138	22	120	40	8	15	20	4	2	72	305	88%	94%
3	General Hospital Sega	KE003	Jega	Kebbi	01/01/20 24	29/02/ 2024	540	112	18	90	35	6	13	15	3	2	65	280	82%	32%
4	Yanri Specialist Hospital	KE004	Yaari	Kebbi	91-01-20 24	29/02/ 2024	410	95	15	75	28	5	10	12	2	1	50	229	80%	92%
5	General Hospital Koko	KE005	Koko' Besse	Kebhi	01/01/20 24	29/02/ 2024	360	88	14	60	25	4	9	10	1	1	+0	200	78%	90%

Variable	Count	Mean	Std Dev	Min	25%	50%	75%	Max
Adult Patients on ART	5	546.6	175.26	360	410	540	625	798
Adolescent Patients on ART	5	121.0	34.41	88	95	112	138	172
Pediatric Patients on ART	5	19.8	6.5	14	15	18	22	30
PMTCT Mothers	5	99.0	36.12	60	75	90	120	150
Exposed Infants	5	35.8	10.33	25	28	35	40	51
PrEP Patients	5	6.6	2.41	4	5	6	8	10
PEP Patients	5	13.6	4.77	9	10	13	15	21
Lost to Follow-Up (LTFU)	5	17.0	7.21	10	12	15	20	28
Transferred Out	5	3.0	1.58	1	2	3	4	5
Deceased Patients	5	1.8	0.84	1	1	2	2	3
New Patients	5	62.4	17.78	40	50	65	72	85
Cumulative Patients	5	277.0	73.11	200	220	280	300	385
Patients Retention Rate (%)	5	82.6	3.97	78	80	82	85	88
Viral Load Suppression (%)	5	92.4	2.07	90	91	92	94	95

#### **Table 2: Descriptive Statistics**

The descriptive analysis of HIV/AIDS consolidated data across five healthcare facilities in Kebbi State provides significant insights into the distribution and variation of patient statistics. The mean number of adult patients on ART is 546.6, with a standard deviation of 175.26, indicating a wide variation in ART uptake among facilities. The range extends from a minimum of 360 to a maximum of 798, reflecting differences in patient enrollment rates and facility capacity. Similarly, the mean adolescent and pediatric ART enrollments stand at 121.0 and 19.8, respectively, showing that pediatric patients constitute the smallest proportion of ART users. The variation in PMTCT mothers (mean = 99.0, SD = 36.12) and exposed infants (mean = 35.8, SD = 10.33) further suggests differences in antenatal HIV interventions across facilities. The retention rate, a crucial indicator of treatment adherence, has a mean of 82.6% (SD = 3.97), ranging from 78% to 88%. The highest retention rate of 88% suggests that certain facilities may have more effective patient follow-up mechanisms, whereas those with lower retention rates might face challenges such as inadequate counseling or socioeconomic barriers. Similarly, the lost-to-follow-up (LTFU) rates show variability, with an average of 17 patients per facility being lost to follow-up, underscoring the need for improved patient tracking and retention strategies. The high viral load suppression rate (mean = 92.4%, SD = 2.07) across all facilities indicates that the majority of patients on ART are achieving viral suppression, a critical outcome in HIV management. From a policy perspective, these findings have significant implications for resource allocation and intervention design. Facilities with high LTFU and low retention rates may require targeted interventions such as enhanced patient counseling, community-based adherence support, and digital tracking systems to improve retention. The relatively lower numbers of pediatric patients on ART suggest a potential gap in early HIV diagnosis and treatment initiation for children, necessitating increased efforts in pediatric HIV testing and linkage to care. Additionally, the disparities in PMTCT enrollment highlight the need for strengthened maternal HIV programs to prevent mother-to-child transmission more effectively.

Overall, these statistics provide a roadmap for optimizing HIV/AIDS treatment and care in Kebbi State. Addressing disparities in ART uptake, retention, and viral suppression will be essential in achieving epidemic control. The findings underscore the importance of strengthening facility-based and community-driven interventions to enhance treatment adherence, reduce LTFU, and sustain high viral load suppression rates. Future research should explore underlying factors contributing to the observed variations, such as healthcare accessibility, patient socioeconomic status, and the effectiveness of facility-level HIV management strategies.





#### Figure 1: The trend analysis line chart illustrates the variation in HIV/AIDS treatment indicators over time across different healthcare facilities.

The trend analysis line chart illustrates the variation in key HIV/AIDS treatment indicators over time across different healthcare facilities. A general upward trend in ART enrollment for adults, adolescents, and pediatric patients suggests an increasing number of people accessing treatment, which aligns with national and global efforts to enhance ART coverage. However, fluctuations in the data indicate that while some facilities experience consistent patient enrollment and retention, others may face periodic declines due to factors such as stockouts, migration, or adherence challenges. The trend for PMTCT mothers and exposed infants follows a similar pattern, indicating that efforts to prevent mother-to-child transmission (PMTCT) are yielding results, but inconsistencies suggest possible gaps in service delivery or patient follow-up. The line chart also shows variations in PrEP and PEP patients, highlighting the fluctuating demand for HIV prevention measures. These fluctuations may be linked to periodic awareness campaigns, healthcare access barriers, or seasonal variations in risk behaviors. The retention rate trend highlights the stability of patient adherence over time, with some facilities maintaining a consistently high retention rate, while others exhibit slight declines. This finding underscores the importance of strengthening adherence support systems to ensure continuous patient engagement in treatment programs. The viral load suppression rate remains relatively stable across all facilities, which is a positive indicator of effective ART regimens and patient adherence.

However, occasional dips in suppression rates may indicate emerging adherence issues or drug resistance concerns, necessitating periodic regimen reviews and enhanced patient monitoring. The observed trends in lost-to-follow-up (LTFU) rates reinforce the need for targeted interventions to improve patient retention, especially in facilities with recurrent spikes in LTFU cases. Addressing these inconsistencies through robust community engagement, digital tracking, and adherence counseling can significantly enhance long-term treatment success. These insights emphasize the need for strategic policy interventions, including improved ART accessibility, enhanced PMTCT programs, and continuous evaluation of patient retention strategies to sustain and improve HIV/AIDS treatment outcomes.

Facility Name	Retention Rate (%)	Lost to Follow-Up (LTFU)
Sir Yahaya Memorial Hospital	85%	28
Federal Medical Center	88%	20
General Hospital Jega	82%	15
Yauri Specialist Hospital	80%	12
General Hospital Koko	78%	10

Table 5. Survival Analysis (Fatient Retention & LTFU Ra	ient Retention & LTFU F	atient Retention & LTFU R	Table 3: Survival Analysis
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The survival analysis of patient retention and lost-to-follow-up (LTFU) rates across the five healthcare facilities provides crucial insights into the effectiveness of HIV/AIDS treatment programs. Federal Medical Center (FMC) has the highest patient retention rate at 88%, followed closely by Sir

Yahaya Memorial Hospital (85%). These figures suggest that these facilities have well-established adherence support mechanisms, such as counseling services, medication adherence tracking, and patient follow-up strategies. High retention rates imply that a majority of patients are consistently engaged in treatment, reducing the risks of disease progression, opportunistic infections, and viral resistance. Conversely, General Hospital Koko exhibits the lowest retention rate at 78%, which could indicate potential challenges such as inadequate follow-up systems, limited healthcare infrastructure, or socioeconomic barriers that hinder continuous treatment engagement. These variations highlight the importance of identifying facility-specific barriers and developing tailored interventions to optimize retention outcomes. The lost-to-follow-up (LTFU) rates further emphasize disparities in patient engagement and continuity of care across these healthcare centers. Sir Yahaya Memorial Hospital has the highest LTFU cases at 28, while Federal Medical Center has a comparatively lower number at 20, suggesting that FMC has stronger patient tracking mechanisms. General Hospital Jega, Yauri Specialist Hospital, and General Hospital Koko report LTFU cases of 15, 12, and 10, respectively, indicating a gradual decline in LTFU as retention rates decrease. This trend suggests a direct correlation between high retention rates and lower LTFU cases, reinforcing the significance of effective patient retention strategies. Factors contributing to LTFU may include stigma, financial constraints, long travel distances, and side effects of antiretroviral therapy (ART). Addressing these factors through targeted interventions, such as decentralized ART services, peer support programs, and mobile health technologies for tracking and reminders, could significantly improve patient follow-up rates and reduce LTFU cases.

The implications of these findings extend beyond individual patient outcomes to the broader public health landscape. Facilities with high retention rates contribute significantly to achieving the global HIV/AIDS treatment targets by ensuring sustained viral suppression and reducing transmission risks within communities. Conversely, high LTFU rates pose a serious public health challenge, as patients who discontinue treatment are at greater risk of disease progression and may contribute to increased HIV transmission. Policymakers and healthcare providers must prioritize resource allocation to facilities with lower retention rates by strengthening healthcare infrastructure, increasing staff training on patient retention strategies, and leveraging community-based approaches to encourage long-term adherence. By addressing the gaps in patient retention and follow-up, healthcare systems can enhance treatment outcomes, reduce HIV/AIDS-related morbidity and mortality, and work towards the ultimate goal of epidemic control.

#### 4. Discussion of Findings

The examination of HIV/AIDS treatment data from five medical institutions in Kebbi State offers important new information on viral load suppression, ART uptake, patient retention, and lost-to-follow-up (LTFU) rates. The number of patients on ART varies significantly, according to the descriptive data; the largest enrollment was among adult patients (mean = 546.6), followed by adolescents (mean = 121.0) and pediatric patients (mean = 19.8). In order to guarantee better health outcomes, these numbers emphasize the necessity of increased efforts in early diagnosis and treatment beginning among younger patients. With a standard deviation of 36.12 and an average of 99 mothers recruited per institution, the PMTCT program data points to differences in program efficacy and reach. This variation is further supported by the number of exposed newborns (mean = 35.8), which calls for stronger maternal HIV interventions to stop transmission from mother to child. Potential gaps in HIV prevention understanding and accessibility are highlighted by the comparatively smaller numbers of PrEP (mean = 6.6) and PEP (mean = 13.6) patients. With an average of 82.6%, retention rates range from 78% to 88% across the facilities, suggesting that whereas some have efficient patient retention systems, others face difficulties with adherence. High LTFU rates, especially at Sir Yahaya Memorial Hospital (28 patients), suggest that there may be systemic issues such inadequate follow-up, stigma, and transportation hurdles. On the other hand, Federal Medical Center indicates that robust adherence support systems can reduce patient loss because of its greatest retention rate (88%) and comparatively low LTFU instances (20). With a mean of 92.4%, viral load suppression rates are comparatively high across all facilities, demonstrating the efficacy of ART regimens. Ongoing patient monitoring and regimen modifications are necessary, though, as sporadic variations may be a sign of adherence problems or new drug resistance. The trend analysis confirms an

#### 5. Conclusion

The inequalities and difficulties in managing and treating HIV/AIDS in Kebbi State are brought to light by this study. The differences in patient retention, LTFU rates, and PMTCT uptake suggest systemic impediments that require immediate attention, even though ART enrollment has typically improved. Better patient outcomes are correlated with higher retention rates, highlighting the significance of adherence support systems. Targeted interventions are necessary to enhance patient follow-up and long-term involvement in care in facilities with lower retention and higher LTFU rates. The results highlight the necessity of consistent efforts to suppress viral loads in order to guarantee treatment effectiveness and lower the risk of transmission.

# 6. Recommendations

Base on the outcome of the results the following the following recommendations were made to the government and other stakeholders.

- To increase engagement and lessen LTFU cases, facilities with poor retention rates could use mobile health tracking tools, peer support groups, and improved adherence coaching.
- More work is required to enhance pediatric patients' early diagnosis and ART initiation, including regular testing in maternal and child health facilities.

- Funds should be set aside by policymakers to improve maternal HIV interventions and guarantee that all facilities have fair access to PMTCT care.
- Patients' burdens can be lessened and retention rates raised by offering financial aid, transportation support, and community-based ART delivery.
- To lessen variations in treatment continuity, digital monitoring technologies should be used to better monitor patient follow-up, stock levels, and ART adherence.
- New infections can be decreased by bolstering HIV prevention measures with awareness campaigns and better access to PrEP and PEP therapies.

#### 7. Contribution to Knowledge

The study uses real-world patient data and mathematical modeling to evaluate HIV/AIDS treatment outcomes in Kebbi State. It identifies retention disparities, barriers to patient retention, and the effectiveness of ART regimens. The findings inform targeted interventions and validate predictive modeling for HIV control policies and resource allocation. The study also evaluates HIV/AIDS treatment data in Kebbi State, revealing improvements in ART coverage and viral suppression but highlighting gaps in patient retention and PMTCT uptake, requiring targeted interventions.

#### Acknowledgement

We gratefully acknowledge the support of the Tertiary Education Trust Fund (TETFund), Nigeria, for providing the financial assistance for this study through the 2024 TETFund Research Grant. This support was instrumental in facilitating data collection, analysis, and the overall success of this research project. We deeply appreciate TETFund's commitment to advancing research and innovation in Nigerian tertiary institutions.

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