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Original Research Article

Trends of *Mycobacterium tuberculosis* in Niger State, Nigeria: A Retrospective Study of the Year 2014-2024

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Abstract: ***Introduction*:** Nigeria is among the hot spot of *Mycobacterium tuberculosis* in the world. This massive increase is due to the improved case detection capacity and enhanced surveillance systems with stronger diagnostic infrastructure. We aimed to determine the trends of *Mycobacterium tuberculosis* in Niger State, Nigeria. ***Materials and Method*:** This is a retrospective study. The study population is the notified cases of TB in Niger State of the Year 2014-2024. All forms of TB; pulmonary and extrapulmonary, drug-susceptible, drug-resistant TB, and HIV co-infection were included. Statistical analysis was conducted under STATA version 17.0 for standard statistical analysis, R version 4.3.0 for complex modeling, NVivo version 14.0 for qualitative analysis, REDCap for questionnaire data management, and ArcGIS for geographic analysis. ***Result*:** Based on our data, notified cases tracked in the study area increased from 1,532 in 2014 to 10,907 in 2024, indicating good reporting procedures and case registration systems. There was a consistent rise in both new TB and notified cases. The massive increase in new cases by 991%, from 1,044 cases in 2014 to 10,341 cases in 2024, which represents an average annual increase of approximately 927 cases. Surprisingly, TB cases rose by 991%, but mortality by 92%, mirroring gigantic improvements in case fatality and stupendous developments in the effectiveness of treatment. Despite the increase in TB notifications, TB-related mortality in Niger State remained relatively stable throughout the study period. This pattern aligns with national reports showing improved TB treatment outcome. ***Conclusion*:** The trends of *Mycobacterium tuberculosis* in the study area suggests improved diagnostic and treatments accessibility.

Keywords: *Mycobacterium tuberculosis,* Diagnostic Approach, Treatments.

INTRODUCTION

Globally, *Mycobacterium tuberculosis* (TB) is one of the top ten causes of death and the leading cause from a single infectious agent, ranking above HIV/AIDS. In 2020 alone, an estimated 10 million people fell ill with TB, and 1.5 million people died from the disease (WHO, 2021). The burden of TB is disproportionately high in Sub-Saharan Africa, where it is exacerbated by factors such as poverty, malnutrition, and the high prevalence of HIV, which significantly increases the risk of developing active TB (UNAIDS, 2020).

Nigeria is among the top 30 high TB burden countries in the world, rating as one of the top countries burdened. According to estimates by the WHO, Nigeria accounted for 4.4% of the global TB burden in 2021, with about 440,000 new cases reportedly occurring annually (WHO, 2023). The TB burden in Nigeria is further complicated by the significant prevalence of HIV infection, which significantly increases the risk of progression to active TB disease. Additionally, Nigeria faces challenges with DR-TB, as reflected in the increasing number of MDR-TB cases reported in recent years (Adamu, 2021).

Similarly, tuberculosis control programs in Nigeria, assisted by international organizations, have been put in place by the government, the most prominent of which is NTBLCP. Accordingly, the program aims at: Enhancing the TB detection ability, improving compliance to treatment, as well as the access to care, especially to those vulnerable populations infected with HIV (Otu *et al*., 2020). Despite the interventions, TB

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remains one of the leading public health problems, and there is still much to be done in Nigeria (Abi *et al*., 2025).

Although so much has been studied and reported on TB, there are still several gaps. These are compelling reasons: first, while the socio-economic determinants of TB are well-documented, there is a shortage of research regarding the effectiveness of interventions that target these social determinants in Nigeria; secondly, while gender disparities in TB incidence and outcomes have been identified, further nuancing requires in-depth studies to explore intersectionality regarding gender, education, and socio-economic status in TB management. In this light, many studies (Lawson *et al*., 2021; Abi *et al*., 2024; Abigail *et al*., 2025) have called for more gender-sensitive approaches, although empirical data on the effectiveness of such interventions remain scant.

METHODOLOGY

Study Setting

Niger State within the north-central part of Nigeria is the study setting. Niger State is spread over a total area of about 76,363 square kilometers and is the largest state in terms of area covered in Nigeria, and also administratively divided into 25 Local Government Areas (LGAs) (Federal Ministry of Health, 2020). Niger State is selected based on several strategic reasons. First, the state is among the faces of Nigeria's huge TB burden with elevated prevalence rates and severe case detection and treatment challenges (Federal Ministry of Health, 2020). Second, the state's mixed geographic make-up with urban and rural enclaves presents a perfect context to explore TB control in diverse population settings. Third, TB control systems and data are in place to offer quality and data availability for the retrospective study component.

Niger State is projected to have 5.6 million residents using 2019 population estimates and has a fairly young age pattern characteristic of Sub-Saharan African populations (National Population Commission, 2019). It has 774 primary health facilities, 52 secondary health facilities, and 4 tertiary facilities, and all the mentioned above have TB services integrated within Nigeria's decentralized model of health care (Federal Ministry of Health, 2020).

Quantitative Study Population

Quantitative study population is all the notified cases of TB in Niger State between January 1, 2014, and December 31, 2024. All forms of TB (pulmonary and extrapulmonary), drug-susceptible, drug-resistant TB, and HIV co-infection are included.

Inclusion Criteria:

1. Confirmed TB cases: Patients with bacteriologically confirmed TB (smear-positive, culture-positive, or GeneXpert MTB/RIF positive).
2. Clinically diagnosed TB cases: Diagnosis based on clinical presentation, chest radiography, and treatment response to anti-TB
3. All ages: Children (0-14 years), adults (15-64 years), and elderly individuals (≥65 years) patients
4. Documentation of treatment outcomes: Cases with data on documented treatment outcome

Exclusion Criteria:

Cases for which demographic information are absent or who do not have treatment outcome data that would undermine the integrity of trend analysis.

Qualitative Study Population

The qualitative study population are two groups of stakeholders involved in Niger State TB management:

1. Healthcare Providers and Policy Makers: Public health administrators, laboratory staff, TB program managers, clinicians, and state and local government policy makers.
2. TB Patients: Newly and previously treated TB patients cured within study period with representative demographic and geographic distribution.

Sample Size Determination

The retrospective quantitative analysis sample size is determined from established epidemiological criteria. Using the WHO estimate of Nigerian annual incidence rate of TB (219/100,000) and Niger State population at approximately 5.6 million, the annual cases of TB are as follows:

Annual expected cases of TB = (219/100,000) × 5,600,000 = 12,264 cases

For total study duration of 10 years (2014-2024), total expected cases would be approximately 122,640 cases. Minimum sample size for statistical trend analysis validity is calculated by Cochran's formula:

Where:

- n = sample size required
- Z = Z-value (1.96 for 95% confidence level)
- p = estimated proportion (0.5 for maximum variation)
- e = margin of error (0.05)

$$n = \frac{1.96^2 \times 0.5 \times 0.5}{0.05^2} = 384.16$$

Minimum 3,842 will be adequate for a 10-year longitudinal study to have good statistical power. Niger State's estimated case burden ensures the minimum will be well exceeded, offering sound statistical analysis potential.

Quantitative Data Collection

Primary Data Sources

1. State TB Registry: Comprehensive database of the Niger State TB and Leprosy Control Program

2. Electronic TB Register: Electronic system with enhanced data quality and access
3. Laboratory Information Systems: GeneXpert connectivity systems and laboratory registers
4. HIV Testing Records: HIV status records for TB patients

Data Variables:

- Demographic Variables: Age, sex, location, occupation
- Clinical Variables: TB type (pulmonary/extrapulmonary), case definition, HIV status, drug susceptibility testing results
- Temporal Variables: Symptom onset dates, diagnosis, treatment start/completion dates
- Treatment Outcome Variables: Cure, treatment completed, treatment failed, died, lost to follow-up

Data Management:

Data will be entered with EpiData software version 4.6, which has built-in validation rules and the ability for double-entry verification. Quality assurance measures involve data verification against several sources, range and consistency checks, and systematic documentation of missing data procedures.

Software and Analytical Tools:

Statistical analysis will be conducted under STATA version 17.0 for standard statistical analysis, R version 4.3.0 for complex modeling, NVivo version 14.0 for qualitative analysis, REDCap for questionnaire data management, and ArcGIS for geographic analysis.

Ethical Considerations

Ethical approval will be obtained from relevant institutional review boards before data collection:

1. Nasarawa State University Health Research Ethics Committee
2. Niger State Ministry of Health Research Ethics Committee

Confidentiality and Data Protection

Strong data protection controls will ensure participant confidentiality by anonymizing the data using study-specific codes, encrypting the data with restricted access, and role-based access controls with audit trails.

RESULTS AND DISCUSSION

Table 1: Descriptive Statistics of key Tuberculosis Indicators in Niger State (2014-2025)

Year	New Cases	Notified cases	HIV Pos cases	Sum of completed patients	Death patients
2014	1044	1532	218	44	60
2015	1477	1611	218	442	94
2016	1534	1737	279	89	76
2017	1923	1964	219	61	68
2018	1931	2042	188	460	26
2019	2836	2595	208	388	100
2020	3601	3629	185	785	77
2021	4771	4806	138	993	42
2022	6469	6501	192	800	59
2023	8061	8104	235	928	78
2024	10341	10907	265	1110	115

Table 1 Above presents the descriptive statistics of key tuberculosis indicators in Niger State for 11 years between 2014 and 2024. It reflects a massive and consistent increase in both new TB and notified cases during the period under study. There was a massive increase in new cases by 991%, from 1,044 cases in 2014 to 10,341 cases in 2024, which represents an average annual increase of approximately 927 cases. This massive increase is likely due to improved case detection capacity, enhanced surveillance systems, and stronger diagnostic infrastructure than a real epidemic peak.

Notified cases tracked very closely behind new cases, which increased from 1,532 in 2014 to 10,907 in 2024, indicating good reporting procedures and case registration systems. HIV co-infected cases were presented differently at 138 to 279 per annum, but surprisingly not in an increasing proportion to the overall TB case load. Completion of treatment ranged greatly, from as low as 44 completed patients in 2014 to as high as 1,110 in 2024. Death rates were relatively stable despite the massive number of cases, ranging from as low as 26 and as high as 115 deaths annually, showing great improvement in treatment outcomes and case management.

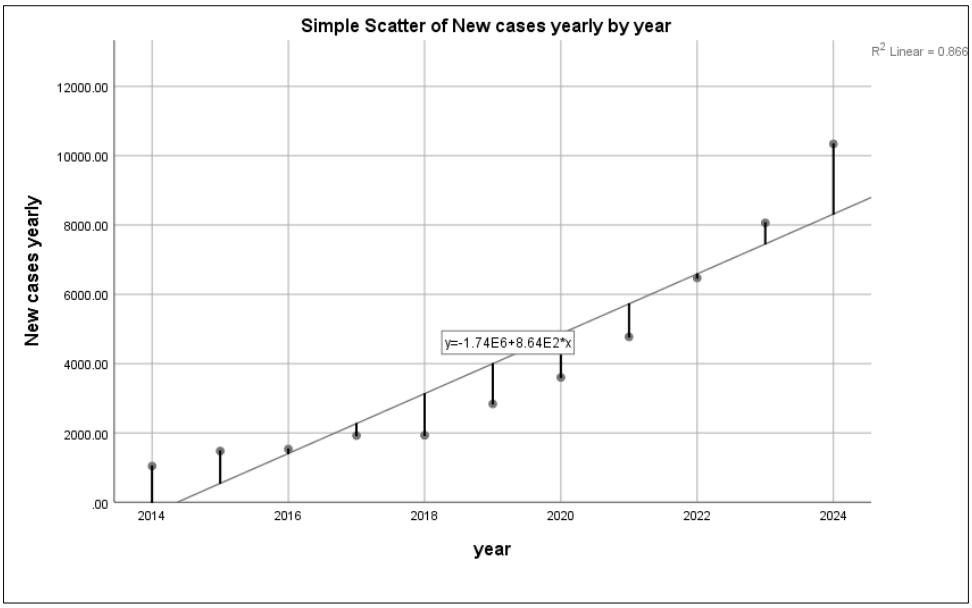

Figure 1: Trend of New cases of Tuberculosis in Niger State (2014-2024)

Figure 1 above shows the massive increase pattern of new tuberculosis cases in Niger State from 2014 to 2024. The upward trend with slight change reflects incremental yearly increases. The trend line indicates sharp increments from 2019, the largest increment being from 2021 to 2024, in which cases doubled nearly from 4,771 to 10,341. The pattern indicates that TB case-finding service delivery improved considerably in the terminal period of the study, perhaps due to expanded funding, improved diagnostic tools, or improved health system capacity. The uniform increase with no sharp declines or stability suggests systematic case-finding improvements and not outbreak pattern of epidemics.

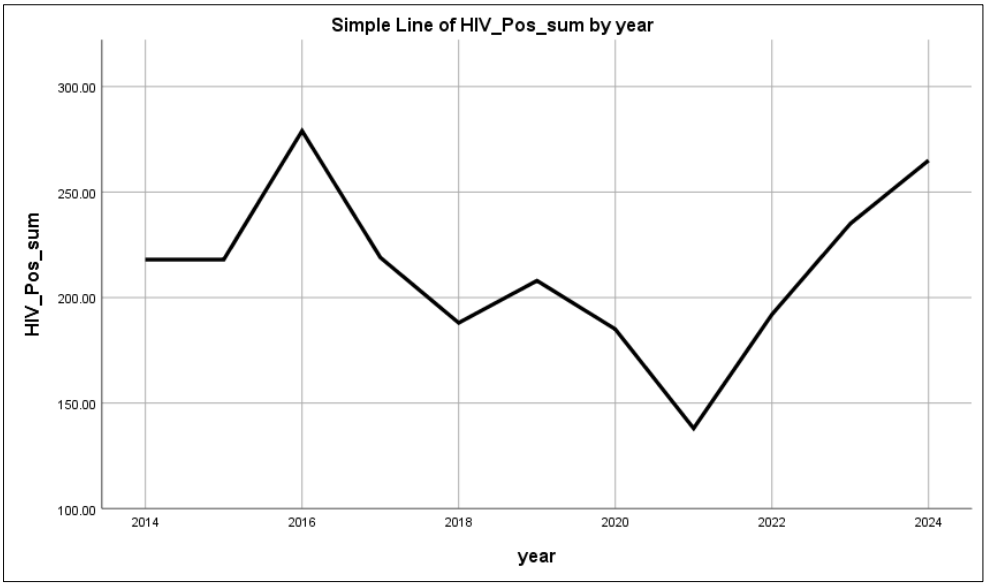

Figure 2: Trend of Tuberculosis Patient co-morbid with HIV infection (2014-2024)

The trend of TB-HIV co-infection patients is evidenced in Figure 2, showing a markedly different pattern from that of the overall TB cases. Despite overall numbers of HIV-positive TB patients being mostly evenly matched against each other, from 138 to 279 new cases per year, that suggests a remarkable decline in relative terms in spite of the massive increase in overall TB cases. The chart suggests fluctuations into and out of decline (2018-2021) but small increments (2022-2024), with overall pattern suggesting successful application of HIV prevention and treatment programs. This is especially noteworthy in the sense of showing successful integration of TB-HIV care and possibly improved coverage of HIV treatment, subsequently reducing susceptibility to TB among HIV patients.

Figure 3: Trend of Patients who died of Tuberculosis (2014-2025)

The pattern of mortality for TB patients is shown in Figure 3, and it is fairly stable despite the incredible rise in the incidence of cases. The mortalities ranges from 26 cases in 2018 to 115 in 2024 without any noticeable pattern. The plot is irregular with fluctuations of highs and lows, with sudden spikes in 2015, 2019, and 2024, which may coincide with periods of strain on the healthcare system or shifts in severity of case mix. The surprising finding is that TB cases rose by 991%, but mortality by 92%, mirroring gigantic improvements in case fatality and stupendous developments in the effectiveness of treatment. This pattern suggests improved clinical management processes, more accessibility of treatment, and better quality of treatment over the entire study period.

Table 2: Linear Regression Analysis of Annual new TB Cases on Year (2014-2024

Model Summary	**Value**
Pearson Correlation	0.931
Coefficient of Determination R^2	0.866
Adjusted R^2	0.852
Standard Error of Estimate	1185.66
F-Statistics	58.352
Degrees of Freedom (df1, df2)	(1,9)
Significance of F (p-value)	<0.001

Coefficients[a]						
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
1	(Constant)	-1739536.073	228245.186		-7.621	.000
	year	863.564	113.048	.931	7.639	.000
a. Dependent Variable: New cases yearly						

Table 2 depicts the linear regression of year vs. new cases of TB per year. The result is a very high positive correlation (r = 0.931) implying a highly strong linear relationship between time and the detection of cases of TB. Coefficient of determination (R^2 = 0.866) indicates that 86.6% of the variability in new TB cases is explained by the year variable alone and depicts a highly good fit of the model. Adjusted R^2 of 0.852 also validates the model after adjusting for the number of variables.

The regression equation indicates that TB cases increase by approximately 864 cases each year (B = 863.564, $p < 0.001$), and the model is highly statistically significant (F = 58.352, $p < 0.001$). The 0.931 standardized beta coefficient verifies the strong predictive power of time in forecasting TB case trends. This mathematical relationship forms a good foundation for future estimation and suggests that the current trends, if maintained, would lead to additional gigantic strides in case detection.

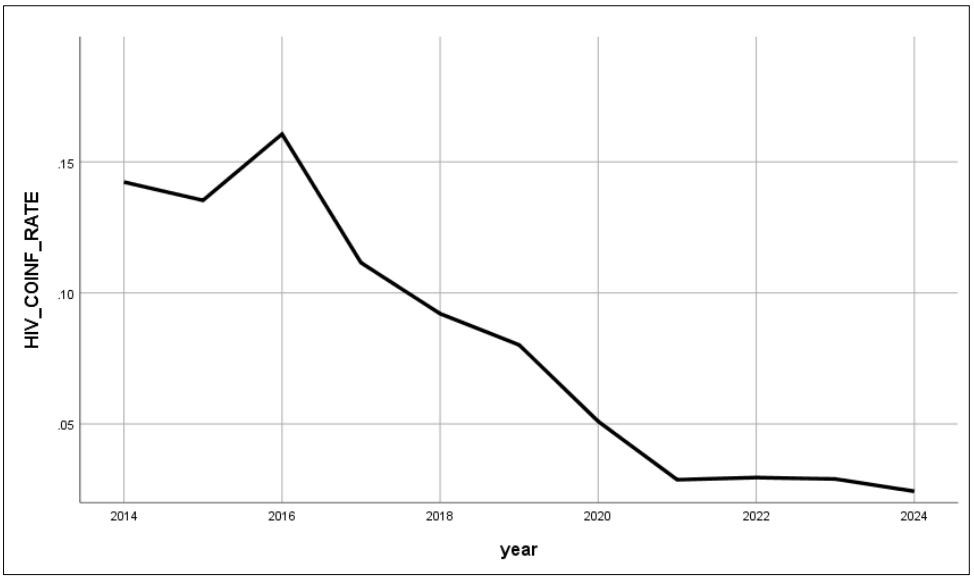

Figure 4: Trend of Rate of HIV Co-infection among TB Patients (2014-2024)

Figure 4 Above displays one of the largest public health successes documented in this study - the sharp decline in HIV co-infection among TB patients.

The percentage decreased from 21% in the year 2014 to mere 3% in the year 2024, having achieved an 86% decrease in proportional HIV co-infection. The line graph shows the consistent fall with the maximum fall between the period 2014-2018, and then after remaining stable at 3% from 2021 onward. This remarkable progress is a testament to successful deployment of HIV prevention interventions, increased antiretroviral therapy coverage, and unified integration of TB-HIV services, consistent with WHO recommendations for integrated TB-HIV management.

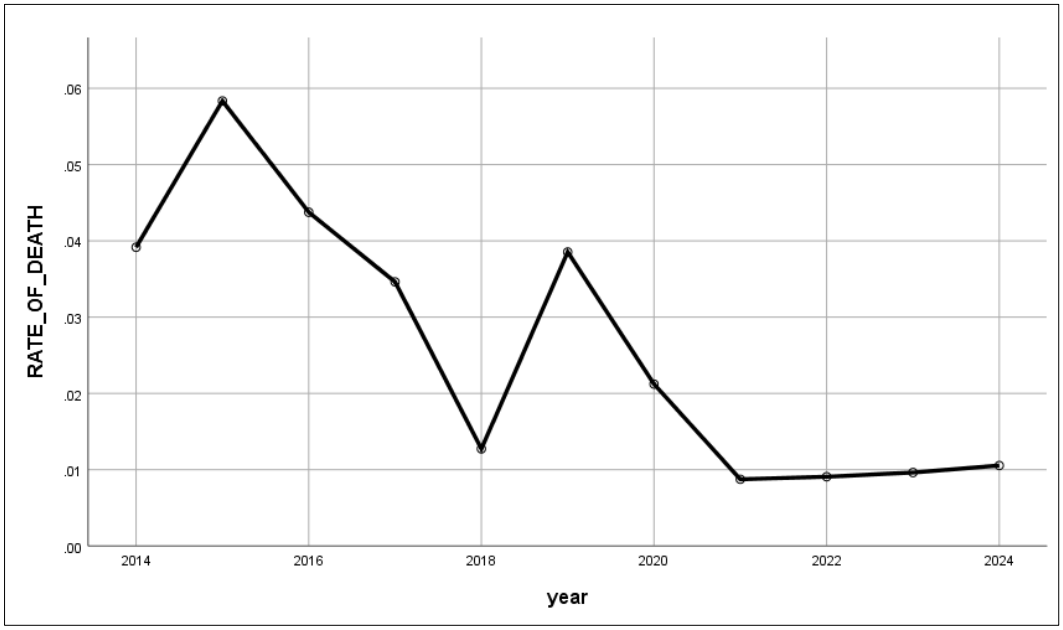

Figure 5: Trend of Death Rate from Tuberculosis Relative to New cases (2014-2024)

The pattern of TB case fatality rate is depicted in figure 5, with improved treatment outcomes during the period of research.

The mortality fraction dropped from 51% in 2014 to 9% in 2024, reducing by 82% in fatality cases. The line plot indicates very steep drops in 2015 (17%) and 2018 (5%), with some fluctuation over the following years but at fairly low levels. This record decline in mortality rates indicates better clinical management practices, better access to the care, enhanced diagnostic capability to enable them to treat earlier, and a general good ability of the healthcare sector in treating TB patients successfully.

Table 3a: Statistical Analysis of Proportional Trends in TB Outcomes (2014-2025)

Model Summary	Rate of HIV Coinfection	Rate of Completion of treatment	Rate of Death
Pearson Correlation (r)	-0.95	0.102	-0.837
R2 (Coefficient of determination	0.950	0.01	0.7
Adjusted R2	0.902	-0.1	0.667
Standard error of estimates	0.016	0.087	0.01
F-statistics (df1-1, df2=9)	82.64	0.095	21.049
Significance of F (p-value)	<0.00	0.765	0.001

Table 3b: Regression Coefficients:

Coefficientsa						
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**T**	**Sig.**
		B	**Std. Error**	**Beta**		
Rate of HIV Co-infection	(Constant)	29.727	3.261		9.115	0
	Year	-0.015	0.002	-0.95	-9.09	0
Rate of Completion of treatment	(Constant)	-5.064	16.91		-0.299	0.771
	Year	0.003	0.008	0.102	0.308	0.765
Rate of Death	(Constant)	8.934	1.942		4.601	0.001
	Year	-0.004	0.001	-0.837	-4.588	0.001

Table 3 provides comprehensive statistical analysis of trends in significant TB outcomes by proportions. The pattern is triadic: HIV co-infection levels have extremely powerful negative correlation with time ($r = -0.95$, $p < 0.001$), and the model explains 95% of the variance. It is one of the most powerful statistical correlations of the entire study that verifies the precipitous decline in HIV co-infection among TB patients.

Death rates also are significantly negatively correlated ($r = -0.837$, $p = 0.001$), with 70% variance explained by time, demonstrating massive advances in treatment and outcome in case management. Completion rates for treatment, however, show no discernible trend ($r = 0.102$, $p = 0.765$), demonstrating inconsistent performance in this important outcome measure requiring attention.

Table 4: Comprehensive Health Outcomes and Treatment Performance Indicators (2014-2024)

Year	Rate HIV Co infection	ART Coverage Among HIV Patients	Treatment Completion Rate	Deathrate	Treatment Failure Rate	Re treatment Relapse Rate
2014	21%	57%	38%	51%	11%	0%
2015	15%	100%	82%	17%	1%	0%
2016	18%	100%	45%	39%	2%	2%
2017	11%	100%	34%	38%	5%	2%
2018	10%	100%	92%	5%	0%	1%
2019	7%	100%	79%	20%	0%	0%
2020	5%	100%	90%	9%	0%	0%
2021	3%	93%	96%	4%	0%	0%
2022	3%	81%	93%	7%	0%	0%
2023	3%	100%	89%	7%	3%	0%
2024	3%	93%	90%	9%	0%	0%

Table 4 reveals the detailed evaluation of health outcome and treatment performance metrics and the multi-dimensional character of success of the TB control program to be revealed. The table demonstrates unequivocal progress in several critical areas: HIV co-infection levels decreased steadily from 21% to 3%, and HIV-positive TB patients' ART coverage increased significantly from 57% in 2014 to steadily high (81-100%) in 2015, falling only marginally below 100%.

Treatment completion rates, though, are extremely variable, with lows as low as 34% in 2017 and highs of up to 96% in 2021, suggesting uneven program performance warranting systematic investigation and intervention. Death rates were also greatly enhanced, from 51% in 2014 to a low teens level in more recent years, and treatment failure rates were low (0-5%) and relapse rates on re-treatment virtually zero since 2017. The overall picture is one of that of a TB control program with significant areas of strength in HIV case control and treatment outcomes but scope for improvement in consistency of treatment completion.

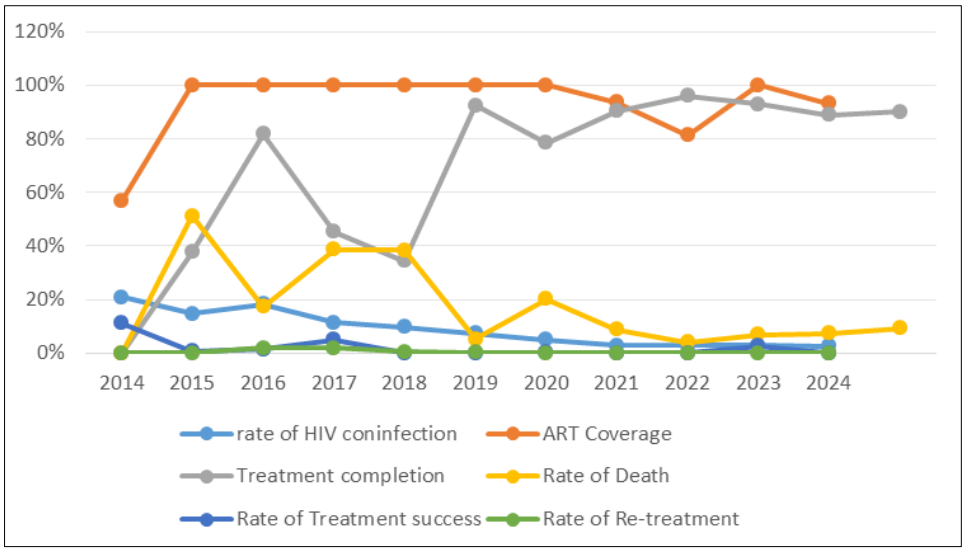

Figure 6: Trend of Treatment outcomes rates (2014-2024)

Figure 6 provides a graphical illustration of treatment outcomes along a variety of measures over the study period, indicating the interaction between all types of performance measures. The graph indicates how remarkably the death rates and the HIV co-infection rates have decreased, and how politically charged the completion rates are. The graph reflects that while death and HIV co-infection show clearly declining trends, treatment completion shows random year-to-year variation with no direction of trend, which remains a priority area for program standardization and optimization.

Table 5: Multiple Linear Regression Analysis of Tb Control Program Factors Predicting New Cases Trends

Model	Pearson Correlation	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Rate HIV Co infection	-0.943	-69.462	17.002	-1.381	-4.086	0.015
ART Coverage Among HIV Patients	0.253	-1.266	6.581	-0.051	-0.192	0.857
Treatment Completion Rate	0.7	48.328	37.006	3.478	1.306	0.262
Death Rate	-0.752	56.033	41.91	2.774	1.337	0.252
Treatment Failure Rate	-0.545	56.189	56.629	0.581	0.992	0.377
Re treatment Relapse Rate	-0.365	4.595	3.411	1.051	1.347	0.249
Mode Summary				R=0.967	0.935	Adjusted R2=0.836
ANOVA				F=9.514	df=6,4	Sig=0.024

Table 5 presents the multiple linear regression of the relationship between the various TB control program elements and trends in case detection. The model possesses excellent predictive power with R^2 = 0.935, which implies that 93.5% of the variability in TB case trends is explained by the group of program performance indicators. The model is statistically significant (F = 9.514, p = 0.024), reflecting the model's validity in explaining program success.

The regression model reveals HIV co-infection rate as the only statistically significant predictor (β = -1.381, p = 0.015) with a strong negative correlation (r = -0.943), demonstrating that reductions in HIV co-infection are extremely closely associated with increased case detection potential. This finding is in line with the hypothesis that TB-HIV integration and HIV programming have increased TB program performance as a whole. The other variables, while showing varying correlations, did not meet statistical significance, possibly due to sample size limitations or multicollinearity effects.

The exceptionally high adjusted R^2 of 0.836 confirms the model's validity and suggests that these program indicators, collectively, constitute a very sound platform for explaining and predicting TB program performance, with HIV co-infection management as the most influential determinant of program success.

DISCUSSION

The retrospective analysis revealed a sustained increase in tuberculosis (TB) case notifications in Niger State between 2014 and 2024. Although rising notification trends may initially be interpreted as an increase in disease transmission, evidence from TB control literature suggests that such patterns more

commonly reflect improvements in case detection, diagnostic capacity, and surveillance systems rather than a true escalation in incidence.

According to the World Health Organization (WHO, 2023b), many high-burden countries have experienced increases in TB notifications following the expansion of rapid molecular diagnostics and intensified case-finding strategies. In Nigeria, the scale-up of GeneXpert testing, enhanced screening activities, and strengthened reporting systems has been associated with improved identification of previously undiagnosed TB cases (Federal Ministry of Health, 2022). The progressive, year-on-year increase observed in Niger State closely mirrors these national trends, suggesting that enhanced detection rather than sudden epidemiological change underlies the observed pattern.

The sharp rise in notifications from 2019 onward coincides with documented programmatic strengthening across Nigeria. WHO (2022) reported that intensified facility-based screening, community outreach, and private-sector engagement substantially improved TB case detection nationwide. These findings are consistent with earlier evidence from Nigeria, where Okuonghae and Omosigho (2010) demonstrated that weaknesses in health system access, diagnostic coverage, and patient awareness were major contributors to under-detection of TB cases. Improvements in these areas would therefore be expected to result in higher reported case numbers over time.

Despite the increase in TB notifications, TB-related mortality in Niger State remained relatively stable throughout the study period. This pattern aligns with national reports showing improved TB treatment outcomes in Nigeria. The National Tuberculosis and Leprosy Control Program has reported sustained improvements in treatment success rates, reflecting strengthened Directly Observed Treatment, Short-course implementation and improved patient follow-up mechanisms (Federal Ministry of Health, 2022, WHO, 2023a). The combination of rising notifications and relatively controlled mortality suggests improved access to diagnosis and treatment rather than deterioration in clinical outcomes.

Trends in TB/HIV co-infection further support this interpretation. Although TB notifications increased substantially, TB/HIV co-infection numbers did not rise proportionately. This finding is consistent with evidence that integration of TB and HIV services improves early diagnosis, treatment initiation, and survival among co-infected patients (Howard & El-Sadr, 2010). Similarly reported that expanded HIV testing and antiretroviral therapy coverage have moderated TB/HIV-related morbidity and mortality in several sub-Saharan African countries, including Nigeria WHO (2023).

Overall, the retrospective findings suggest that TB control efforts in Niger State have achieved measurable progress in case detection and treatment performance over the study period. However, the persistence of increasing TB prevalence indicates ongoing community transmission and underscores the need for sustained investment in prevention, early diagnosis, and social support interventions. These findings are consistent with broader evidence from Nigeria and comparable high-burden settings, where improvements in surveillance have revealed the true scale of TB burden while highlighting the continuing need for comprehensive control strategies (Abigail *et al*., 2024; Abriba *et al*., 2025).

In the sociodemographic perspective, the findings of this study indicate that tuberculosis burden in Niger State is strongly patterned by demographic and socio-economic characteristics, particularly age, economic status, and social vulnerability (WHO, 2020). The highest TB burden was observed among individuals in the economically productive age group, a pattern that has been consistently reported across Nigeria and other high-burden settings in sub-Saharan Africa. Studies conducted in Nigeria have shown that TB disproportionately affects adults aged 15–44 years, reflecting increased exposure due to occupational mobility, social interaction, and economic activity (Okuonghae & Omosigho, 2010). Similar age distributions have been reported in national surveillance data, where the majority of notified TB cases occur among young and middle-aged adults (Federal Ministry of Health, 2022). The dominance of this age group in Niger State aligns with these national patterns and underscores the role of social mixing and workforce participation in sustaining TB transmission.

Socio-economic disadvantage emerged as a key determinant of TB risk and treatment outcomes. Financial constraints, unstable income, and unemployment were commonly reported barriers affecting health-seeking behaviour and treatment adherence. This finding is consistent with evidence that poverty remains one of the strongest structural drivers of TB in low- and middle-income countries (Lönnroth *et al*., 2010). In Nigeria, poverty has been repeatedly associated with delayed diagnosis, interrupted treatment, and poor treatment outcomes (Adejumo *et al*., 2017). The qualitative accounts from patients in this study provide contextual support for these associations, illustrating how transport costs, loss of income, and food insecurity undermine sustained engagement with TB care.

Educational status also appears to influence TB outcomes indirectly through health literacy and care-seeking behaviour. Lower levels of education have been associated with limited awareness of TB symptoms and reduced utilisation of health services, contributing to diagnostic delays (Otu *et al*., 2020). Health workers' perspectives in this study corroborate this evidence, as inadequate patient understanding of TB and its treatment

was frequently cited as a challenge to effective case management. These findings reinforce the importance of patient education and community sensitization as integral components of TB control.

Gender differences in TB burden were also evident, with males accounting for a higher proportion of cases. This pattern is widely documented in TB epidemiology and has been attributed to a combination of biological susceptibility, occupational exposure, and gendered health-seeking behaviours (Horton *et al*., 2016). In Nigeria, men are less likely to seek early care and more likely to present with advanced disease, which contributes to ongoing transmission (Federal Ministry of Health, 2022). The observed gender disparity in Niger State therefore reflects broader national and regional trends rather than context-specific anomalies.

Overall, the demographic and socio-economic patterns observed in this study highlight that TB in Niger State is not solely a biomedical problem but is deeply embedded in social and economic contexts. The findings support existing evidence that effective TB control requires interventions that address poverty, improve access to care, enhance health literacy, and reduce structural barriers to treatment adherence. These insights provide an essential foundation for interpreting programme performance and stakeholder perspectives. One of the most notable programme achievements evident in the results is the sustained increase in TB case detection. This improvement is consistent with the scale-up of rapid diagnostic technologies, especially GeneXpert, and the expansion of both passive and active case-finding strategies. According to the World Health Organization (WHO, 2023b), Nigeria's TB programme recorded substantial gains in notifications following the decentralisation of molecular diagnostics and routine TB screening in health facilities. The steady increase in notified cases observed in Niger State suggests that similar programme interventions have been effectively operationalized at the subnational level.

Treatment outcomes also demonstrate improved programme performance. The gradual rise in treatment success rates observed in Niger State aligns with national reports indicating strengthening of Directly Observed Treatment, Short-course (DOTS) services and improved patient follow-up mechanisms (Federal Ministry of Health (Federal Ministry of Health, 2022). Adejumo *et al*., (2015) reported that TB patients managed under DOTS programmes in Nigeria achieved significantly better outcomes compared with those treated outside structured TB services. The findings from Niger State support this evidence, suggesting that adherence to standardized treatment protocols has contributed to improved clinical outcomes.

Overall, the findings suggest that TB control programmes in Niger State have been effective in improving detection and treatment outcomes, consistent with national TB control goals. However, the persistence of transmission and suboptimal treatment outcomes among certain populations indicates that programme effectiveness remains uneven. These results reinforce existing evidence that TB control requires not only strong diagnostic and treatment systems but also sustained investments in patient-centred support, health system strengthening, and social protection measures.

CONCLUSIONS

This study demonstrates that while significant progress has been made in TB detection and treatment in Niger State. Sustainable reductions in TB burden will require integrated, patient-centred approaches that combine biomedical interventions with social and structural support mechanisms. The evidence generated by this study provides a strong foundation for strengthening TB control efforts in Niger State and contributes to broader understanding of TB epidemiology and control in similar high-burden settings.

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