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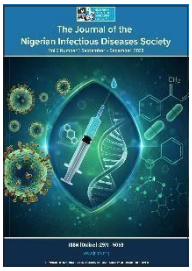

Original Article

Risk Factors and Patterns of Drug-Resistant Tuberculosis in Kaduna State, Nigeria: A Case–Control Study

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ABSTRACT

Background: Drug-resistant tuberculosis (DR-TB) threatens global TB control. Nigeria bears a high burden of TB and resistance, yet local data to guide interventions remain limited. We aimed to determine patterns and predictors of DR-TB in Kaduna State, Nigeria.

Methods: We conducted a matched case– control study in TB treatment centers across Kaduna State from January to December 2022. Cases were patients with microbiologically confirmed DR- TB. Each case was matched to two drug-susceptible TB (DS-TB) control s. Data were extracted from medical records and supplemented by interviews where necessary. Multivariable logistic regression identified independent risk factors. Model performance was assessed by receiver operating characteristic (ROC) analysis.

Results: We included 399 participants, with 133 DR- TB cases and 266 DS- TB controls. Prior TB treatment was strongly associated with DR-TB (adjusted odds ratio [aOR] 3.70; 95% confidence interval [CI] 2.10 to 6.80). Smear- positive disease (aOR 4.85; 95% CI 2.81 to 8.36) and alcohol use (aOR 5.81; 95% CI 1.80 to 18. 70) were independent risk factors. Higher socioeconomic status was protective (aOR 0.54; 95% CI 0.33 to 0.88). DR-TB was more likely to present as pulmonary disease. Rifampicin monoresistance was the most common resistance pattern, observed in 76. 1% of DR- TB cases. The ROC curve showed excellent discrimination (area under the curve 0.90).

Conclusion: In Kaduna State, DR-TB is driven by prior treatment, alcohol use, and socioeconomic disadvantage. The predomi nance of rifampicin monoresistance highlights the limitations of current diagnostics. Expanded drug- susceptibility testing and socioeconomic interventions are crucial to curtail DR- TB and improve outcomes.

Keywords: Drug Resistant Tuberculosis, Multidrug Resistant, Risk Factors, Case-Control Study, Kaduna State

Introduction

Tuberculosis (TB) remains one of the most persistent and deadly infectious diseases globally, despite sustained international control efforts under the initiatives such as the WHO End TB Strategy and the Sustainable Development Goals (SDGs).[1,2] Caused by *Mycobacterium tuberculosis*,[3] TB continues to exert a heavy burden, particularly in low- and middle-income countries. In 2022, TB caused an estimated 1.3 million deaths worldwide, making it the second leading infectious killer after COVID-19 and exceeding deaths from HIV and AIDS.[4]

Nigeria ranks among the top ten countries with the highest TB burden and accounts for a significant share of global incidence.[5] An estimated 479,000 people developed TB in Nigeria in 2022, representing about 4.5 percent of the global total.[4] Although TB is curable with appropriate therapy, the emergence and propagation of drug-resistant strains, especially multidrug resistant TB (MDR-TB) and rifampicin resistant TB (RR-TB), threatens to reverse the progress achieved over recent decades. Globally, more than 410,000 people were diagnosed with MDR or RR TB in 2022, and Nigeria alone reported over 12,000 such cases.[4]

MDR-TB and RR-TB require prolonged treatment with more toxic and costly drug regimens, which are associated with lower treatment success rates and increased mortality compared to drug-susceptible TB (DS-TB).[6] Factors such as delayed diagnosis, inadequate treatment adherence, and ongoing community transmission contribute to the persistence and spread of drug-resistant TB (DR-TB), particularly in settings with constrained health system capacity.[7-9] Despite the recognized importance of context-specific data, local determinants of drug resistance remain insufficiently characterized in many high-burden areas.

Kaduna State, situated in northwestern Nigeria, represents one such high-burden setting, characterized by significant healthcare delivery constraints and a substantial TB burden. However, there is a paucity of data delineating the patterns and risk factors associated with drug-resistant TB within this region. Elucidating these factors is critical for guiding targeted interventions and strengthening TB control efforts as Nigeria strives toward achieving the End TB targets by 2030. This study, therefore, aims to characterize the patterns and identify the predictors of drug-resistant TB in Kaduna State.

Materials and Methods

Study Setting

This study was conducted in TB treatment facilities across Kaduna State, northwestern Nigeria. Kaduna State spans 46,053 square kilometers and comprises 23 local government areas. The state has an estimated population of about 6 million, characterized by significant ethnic diversity, including Hausa-Fulani, Bajju, Atyap, Jaba, Gbagyi, and several other groups.[10] Participating facilities included Barau Dikko Teaching Hospital (BDTH), Primary Health Centre (PHC) Narayi, PHC Jaji, General Hospital Kafanchan, the National Tuberculosis and Leprosy Training Centre Zaria, and several other designated Directly Observed Treatment, Short-course (DOTS) clinics within the metropolis.

Study Design

A matched case–control study was conducted between January 1 and December 31, 2022, involving patients from TB treatment centers in Kaduna State. Each case was matched to two controls diagnosed within the same period, using a 1:2 ratio.

Study Population

Eligible participants comprised DR-TB patients and matched DS-TB controls enrolled at the participating facilities. Inclusion criteria encompassed newly diagnosed TB cases, patients who had completed treatment or been declared cured, TB/HIV co-infected individuals, and those who had defaulted but subsequently resumed therapy. Patients who resided in Kaduna State but received treatment outside the state were excluded from the study.

Data Collection

Data were abstracted from TB registers and patient case notes at each participating center. Collected variables included demographic characteristics, clinical details, and known TB risk factors. Where data were missing or unclear, a structured, investigator-administered questionnaire was employed during patient interactions whenever feasible.

Sampling Technique

A total population sampling strategy was used for case selection, including all eligible drug-resistant DR-TB patients diagnosed during the study period across the participating facilities. For controls, simple random sampling was performed among DS-TB patients at each center.

A 1:2 matching ratio was maintained, with the number of controls at each facility calculated as follows:

Number of Controls from each facility:
= *2 × Number of Case at the facility*

A sampling frame was created at each center, listing all DS-TB patients who met the inclusion criteria. Balloting was used to randomly select controls from this frame.

Definition of Terms

Cases: Cases were defined as individuals with microbiologically confirmed DR-TB, characterized by infection with *Mycobacterium tuberculosis* strains resistant to one or more first-line anti-tuberculosis drugs, namely rifampicin, isoniazid, pyrazinamide, or ethambutol.[11]

Controls: Controls were patients diagnosed with DS-TB, confirmed by susceptibility to all four first-line agents based on drug susceptibility testing.

Multidrug-Resistant Tuberculosis: Multidrug-resistant tuberculosis (MDR-TB) was specifically defined as resistance to at least both rifampicin and isoniazid.[11]

Socioeconomic Status: Socioeconomic status (SES) was assessed using the income-needs ratio (INR), defined as the ratio of a household's annual income to its estimated annual basic needs. The basic needs threshold was calculated by multiplying the 2020 national poverty line of ₦137,430 per person by the household size.[12] INR values were classified into four categories: below needs (<1.0), marginally sufficient (1.0 – 1.49), sufficient (1.5 – 2.99), and above needs (≥3.0).[13]

Statistical Analysis Plan

All data were reviewed for completeness, entered into Stata version 14.1 (StataCorp, College Station, TX), and cleaned prior to analysis. Continuous variables were assessed for normality using the Shapiro–Wilk test. Because most continuous data were not normally distributed, they were summarized as medians with interquartile ranges (IQRs), while categorical variables were presented as frequencies and percentages.

Bivariate analyses were performed using the Mann–Whitney U test for continuous variables and either the Chi-square test or Fisher's exact test for categorical variables, as appropriate. Variables demonstrating a p-value ≤ 0.20 in bivariate analysis were included in a multivariable logistic regression model to identify independent predictors of DR-TB.

Results from the multivariable model were expressed as adjusted odds ratios, along with corresponding 95% confidence intervals (CIs).

Model calibration was evaluated using the Hosmer–Lemeshow goodness-of-fit test, and model discrimination was assessed by calculating the area under the receiver operating characteristic (ROC) curve. Statistical significance was set at $p < 0.05$.

Ethical Consideration

Ethical approval for this study was obtained from the Kaduna State Ministry of Health and Human Services Ethics Committee. Written informed consent was secured from all participants or their caregivers after thorough explanation of the study objectives and procedures.

Confidentiality was ensured by anonymizing all data prior to analysis. Similar ethical considerations were extended to the heads of health facilities and managers of Health Management Information System units, who provided authorization to access patient medical records.

Results

Sociodemographic characteristics of the study population

A total of 399 participants were enrolled in the study, comprising 133 DR-TB cases and 266 DS-TB controls. The median age was 33.5 years (IQR: 25 – 43 years). Most participants were male (63.2%, n = 252), while females accounted for 36.8% (n = 147). Regarding marital status, 52.4% (n = 209) were married, and 47.6% (n = 190) were single.

Educational attainment varied, with 21.6% (n = 86) having only Qur'anic or no formal education, 55.4% (n = 221) completing basic education (primary or secondary), and 23.1% (n = 92) attaining tertiary education. Ethnically, the majority were Hausa/Fulani (67.2%, n = 268), followed by other northern ethnic groups (18.3%, n = 73), and southern Nigerian ethnicities, including Yoruba and Igbo (14.5%, n = 58). Employment status showed that 57.1% (n = 228) were employed, while 42.9% (n = 171) were unemployed. Most participants resided in urban areas (89.5%, n = 357), with only 10.5% (n = 42) living in rural locations. Proximity to treatment centers varied: 78.7% (n = 314) lived within 5 kilometers of a treatment facility, 17.8% (n = 71) were 6 – 10 kilometers away, and 3.5% (n = 14) resided more than 10 kilometers from a center.

The median monthly household income was ₦30,000 (IQR: ₦20,000 – ₦50,000). The median number of household dependents was four (IQR: 2 – 4). Based on the INR, 48.7% of participants lived below the basic needs threshold, 23.4% were marginally sufficient, 21.6% had sufficient income, and 6.3% reported income levels considered above basic needs. Regarding lifestyle factors, alcohol consumption was reported by 11.3% (n = 45), while 9.0% (n = 36) reported tobacco use, with the majority abstaining from both alcohol (88.7%, n = 354) and tobacco (91.0%, n = 363).

Table 1: Sociodemographic and lifestyle characteristics of participants (N = 399)

Characteristic	Category	Frequency (%) or Median (IQR)
Age (years)	—	33.5 (25 – 43)
Sex	Female	145 (36.4)
	Male	254 (63.6)
Marital Status	Single	188 (47.2)
	Married	211 (52.8)
Tribe	Hausa/Fulani	268 (67.4)
	Other northern tribes	72 (17.8)
	Southern tribes	59 (14.8)
Educational Status	Quaranic	85 (21.4)
	Basic	223 (56.0)
	Tertiary	91 (22.6)
Occupation	Unemployed	171 (43.0)
	Employed	228 (57.0)
Family Income/Month (₦)	—	30,000 (20,000 – 50,000)
Number of Dependents	—	4 (2 – 4)
Income-Needs Ratio	—	1.1 (0.58 – 1.75)
SES by INR	Below basic needs	194 (48.7)
	Marginally sufficient	93 (23.4)
	Sufficient	86 (21.6)
	Above basic needs	26 (6.3)
Alcohol Use	No	356 (89.4)
	Yes	43 (10.6)
Tobacco Use	No	365 (91.7)
	Yes	34 (8.3)
Area of Residence	Rural	43 (10.6)
	Urban	356 (89.4)
Distance to Treatment Center	≤ 5 km	316 (79.4)
	6–10 km	72 (18.1)
	> 10 km	11 (2.5)

SES = Socio-economic status; Income Needs Ratio (INR)

Bivariate Analysis of Risk Factor for Drug-resistant Tuberculosis

Table 2 summarizes the bivariate analysis comparing patients with DR-TB and those with DS-TB. There was no significant difference in age between groups, with median ages of 35.0 years (IQR: 25.0 – 43.0) for DR-TB cases and 33.0 years (IQR: 25.0 – 43.0) for DS-TB controls (p = 0.98). Sex distribution was also similar, with males representing 61.7% of DR-TB cases and 63.1% of DS-TB controls (p = 1.00). Educational attainment, marital status, ethnic composition, employment status, and area of residence showed no significant differences between the groups. For instance, 23.3% of DR-TB cases had only Qur'anic education compared to 20.7% of controls, while 50.4% of cases were single versus 46.2% of controls. Ethnically, the Hausa/Fulani group predominated in both cohorts (p = 0.80). The proportion of unemployed participants was similar (39.8% among cases vs. 44.4% among controls; p = 0.45), as was urban residence (86.5% vs. 91.0%; p = 0.36). The median number of dependents was marginally higher among DR-TB cases (4 [IQR: 2 – 5]) than among controls (3 [IQR: 2 – 4]), though this difference was not statistically significant (p = 0.08).

In contrast, significant disparities emerged in socioeconomic and clinical factors. Median household income was lower among DR-TB cases (₦20,000 [IQR: ₦15,000 – ₦40,000]) compared to DS-TB controls (₦30,000 [IQR: ₦25,000 – ₦50,000]; p < 0.001), as was the income-to-needs ratio (0.6 [IQR: 0.4 – 1.2] vs. 1.2 [IQR: 0.8 – 1.7]; p < 0.001). Clinically, prior tuberculosis treatment was far more frequent among cases (55.6%) than controls (3.4%; p < 0.001). Smear-positive disease (71.4% vs. 33.1%; p < 0.001) and pulmonary TB (93.2% vs. 85.3%; p < 0.001) were also significantly more common in DR-TB cases. Notably, a higher proportion of DR-TB patients received care in private facilities (24.1% vs. 2.6%; p < 0.001). Lifestyle factors differed markedly, with alcohol use reported by 27.8% of DR-TB cases compared to 3.0% of controls (p < 0.001), and tobacco use by 22.6% of cases versus 2.3% of controls (p < 0.001). Although HIV co-infection was more common in DR-TB patients (28.6% vs. 21.1%), this difference did not reach statistical significance (p = 0.08).

Table 2: Bivariate Analysis of Risk Factors for Drug-Resistant Tuberculosis Among Participants

Characteristics	Cases (n = 133)	Controls (n = 266)	p-value
Age, years	35.0 (25.0 – 43.0)	33.0 (25.0 – 43.0)	0.98
Sex			1.0
Female	51 (38.3)	96 (36.1)	
Male	82 (61.7)	170 (63.1)	
Educational status			0.39
Quaranic	31 (23.3)	55 (20.7)	
Basic	76 (57.2)	145 (54.5)	
Tertiary	26 (19.5)	66 (24.8)	
Marital status			0.43
Single	67 (50.4)	123 (46.2)	
Married	66 (49.6)	143 (53.8)	
Tribe			0.80
Hausa/Fulani	90 (67.7)	178 (66.9)	
Other northern tribes	22 (16.5)	51 (19.2)	
Southern tribes	21 (15.8)	37 (13.9)	
Occupation			0.45
Unemployed	53 (39.8)	118 (44.4)	
Employed	80 (60.2)	148 (55.6)	
Family income/month (₦)	20000 (15000 – 40000)	30000 (25000 – 50000)	0.000*
Number of dependents	4 (2 – 5)	3 (2 – 4)	0.08
Income-needs-ratio	0.6 (0.4 – 1.2)	1.2 (0.8 – 1.7)	0.000*
SES by INR			0.000*
Below basic needs	86 (64.7)	108 (40.6)	
Marginally sufficient	16 (12.0)	77 (29.0)	
Sufficient	14 (10.5)	66 (24.8)	
Above basic needs	17 (12.8)	15 (5.6)	
Area of residence			0.36
Rural	18 (13.5)	24 (9.0)	
Urban	115 (86.5)	242 (91.0)	

Distance to treatment center ≤ 5 km 6-10 km > 10km	 104 (78.2) 23 (17.3) 6 (4.5)	 210 (78.9) 48 (18.1) 8 (3.0)	0.32
Source of drugs Private Public	 32 (24.1) 101 (75.9)	 7 (2.6) 259 (97.4)	0.0004*
Site of Tuberculosis Pulmonary Extrapulmonary	 124 (93.2) 9 (6.7)	 227 (85.3) 39 (14.7)	0.000*
Co-infection with HIV No Yes	 95 (71.4) 38 (28.6)	 210 (78.9) 56 (21.1)	0.08
Previous tuberculosis treatment No Yes	 59 (44.4) 74 (55.6)	 257 (96.6) 9 (3.4)	0.0004*
Microbiological class Smear negative Smear positive	 38 (28.6) 95 (71.4)	 178 (66.9) 88 (33.1)	0.0004*
Alcohol use No Yes	 96 (72.2) 37 (27.8)	 258 (97.0) 8 (3.0)	0.0004*
Smoking No Yes	 103 (77.4) 30 (22.6)	 260 (97.7) 6 (2.3)	0.0004*
*Values are median (interquartile range) for continuous variables and frequency (percentage) for categorical variables. *Statistical significance set at p < 0.05. Chi-square or Fisher's exact test used for categorical variables; Mann–Whitney U test for continuous variables.*			

Multivariate Analysis of Independent Predictors of Drug-Resistant Tuberculosis

Table 3 summarizes the multivariable logistic regression analysis identifying independent predictors of DR-TB. Microbiological classification emerged as the strongest predictor in the model. Patients with smear-positive disease had nearly five times the odds of DR-TB compared with those who were smear-negative (OR: 4.85; 95% CI: 2.81 – 8.36; p < 0.001). A history of prior tuberculosis treatment was also significantly associated with resistance, with previously treated individuals exhibiting more than threefold higher odds of developing DR-TB compared to treatment-naïve patients (OR: 3.70; 95% CI: 2.10 – 6.80; p < 0.001).

Alcohol use was independently linked to increased risk. Participants reporting alcohol consumption had significantly higher odds of DR-TB than those who abstained (OR: 5.81; 95% CI: 1.80 – 18.70; p = 0.003). SES demonstrated a protective association, as individuals in higher SES categories had significantly lower odds of resistance compared to those in lower SES groups (OR: 0.54; 95% CI: 0.33–0.88; p = 0.013), suggesting the mitigating influence of improved living conditions and resources.

The anatomical site of tuberculosis was another significant factor. Patients diagnosed with extrapulmonary TB had markedly lower odds of resistance compared to those with pulmonary disease (OR: 0.098; 95% CI: 0.013 – 1.02; p = 0.028), indicating that DR-TB was more likely to present as pulmonary infection. Other variables, including monthly household income, number of dependents, income-needs ratio, HIV co-infection, and tobacco use, did not show statistically significant associations with DR-TB (p > 0.05 for all). Although some variables suggested trends toward risk or protection, their confidence intervals included unity, and none met criteria for significance.

Overall, the multivariable model demonstrated good fit and explanatory power (Likelihood Ratio $\chi^2 = 141.39$; $p < 0.001$; Pseudo $R^2 = 0.28$). The model's ability to discriminate between DR-TB and drug-susceptible TB was further supported by the receiver operating characteristic (ROC) curve, which yielded an area under the curve (AUC) of 0.9009. *Figure 1* illustrates this ROC curve, confirming robust predictive performance and underscoring the model's relevance for identifying high-risk groups and informing targeted TB control strategies.

Pattern of Drug Resistance Among Cases

Among the 133 participants diagnosed with DR-TB, rifampicin mono-resistance was the most common pattern, identified in 101 cases (76.1 percent). MDR-TB was observed in 26 cases (19.6 percent). Less frequent patterns included isoniazid mono-resistance, which occurred in 3 cases (2.2 percent), and pan-resistance, found in 1 patient (0.7 percent), indicating resistance to all first-line anti-TB drugs. In addition, two MDR-TB cases showed resistance to second-line drugs, with one case resistant to streptomycin and another to ethambutol, each representing 0.7 percent of the DR-TB case.

Table 3: Multivariate Logistic Regression of Risk Factors for Drug-Resistant Tuberculosis

Risk Factor	OR	95% CI	z	p - value	Interpretation
Family income/month	0.99	0.99 – 1.00	0.01	0.452	NS
Number of dependents	1.12	0.93 – 1.36	0.53	0.242	NS
Income-needs-ratio	1.74	0.89 – 3.4	– 0.14	0.11	NS
SES	**0.54**	**0.33 – 0.88**	**– 2.49**	**0.013**	**Significant**
Site of tuberculosis	**0.098**	**0.013 – 1.02**	**– 2.20**	**0.028**	**Significant**
HIV Co-infection	1.37	0.72 – 2.58	0.96	0.336	NS
Microbiological class	**4.85**	**2.81 – 8.36**	**5.68**	**0.000**	**Significant**
Alcohol use	**5.81**	**1.8 – 18.7**	**2.94**	**0.003**	**Significant**
Smoking	1.8	0.50 – 6.4	0.91	0.365	NS
Previous TB treatment	**3.7**	**2.1 – 6.8**	**4.35**	**0.000**	**Significant**
Constant	0.052	0.018 – 0.15	– 5.52	0.000	—

OR = Odds Ratio; CI = Confidence Interval; NS = Not Significant. Boldface indicates statistically significant predictors ($p < 0.05$). Reference groups: Pulmonary TB (vs. extrapulmonary); Smear-negative (vs. positive); No alcohol use; No prior TB treatment.

Table 4: Pattern of drug resistance

Drug resistance	Frequency (N = 133)	Percentage
Pan-resistant	1	0.7
INH mono-resistant	3	2.2
RH mono-resistant	101	76.1
MDR-TB (INH+ RH)	26	19.6
MDR-TB + Strep	1	0.7
MDR-TB + ETH	1	0.7

INH = Isoniazid; RH = Rifampicin; ETH = Ethambutol; Strep = Streptomycin

Discussion

This study examined risk factors and patterns of DR-TB among patients in Kaduna State, Nigeria. A key finding was that individuals with prior TB treatment had nearly fourfold higher odds of DR-TB (aOR 3.70, 95% CI 1.34 to 10.19, p = 0.012). This agrees with the WHO Global Tuberculosis Report 2023, which indicates that about 42% of MDR/RR-TB cases worldwide occur among previously treated patients.[4] Similar trends have been reported globally. Espinal et al. found an odds ratio of 18.5 for multidrug resistance among retreatment cases, while Sindani et al. documented an odds ratio of 23.0 in Somalia.[14] [15] Micheletti et al. observed a twelvefold increase in Brazil, and within Nigeria, Oladimeji et al. reported that 77% of DR-TB cases involved prior treatment.[16] [17] National data show MDR-TB rates of 6% among new cases compared with 32% among retreatment cases.[18] Our MDR-TB prevalence of 19.6% fits within this national range but is lower than earlier estimates, possibly reflecting progress in treatment adherence and programmatic management. These results highlight the importance of strengthening Nigeria's directly observed therapy strategy, ensuring consistent drug supplies, and improving adherence support to reduce retreatment-driven resistance.

Biological factors such as HIV infection may also contribute to DR-TB risk. Although HIV infection did not remain significant in our multivariate model, it showed a borderline association in bivariate analysis, consistent with WHO observations that HIV indirectly raises DR-TB risk through immunosuppression and higher bacillary loads.[4] [19] Espinal et al. similarly found no independent association after adjusting for confounders.[14] Other studies have linked HIV to poor drug absorption, frequent treatment interruptions due to opportunistic infections, and more hospitalizations, all of which may foster drug resistance.[15] [20] In Nigeria, Oyedeji et al. reported a higher prevalence of MDR-TB among HIV-positive patients at 12.6%.[21] The NTBLCP also recognises HIV as an important risk factor.[18] Although HIV was not significant in our final model, the observed trend supports integrating HIV services within DR-TB programmes.

Behavioural factors were also significant in our analysis. Alcohol consumption was identified as an independent risk factor for DR-TB (aOR 5.81, 95% CI 1.39 to 24.31, p = 0.016). Although alcohol use was not directly analysed in Zhao et al.'s meta-analysis, poor adherence, often linked to alcohol use, doubled the risk of DR-TB and increased MDR-TB risk fourfold in China.[8] WHO reports that substance use disrupts treatment adherence and diminishes pharmacologic effectiveness.[4] [18] Akinleye et al. found alcohol use to be a significant risk factor for MDR-TB in Nigeria.[23] Alcohol's impact on liver metabolism and its influence on social stability may further increase the risk of treatment interruption.[22] Cultural norms in northern Nigeria might contribute to underreporting of alcohol consumption, potentially hiding its true effect in our population.

Socioeconomic status played a clear role. Low socioeconomic status was a significant risk factor for DR-TB, while higher income-to-needs ratios were protective (aOR 0.54, 95% CI 0.30 to 0.97, p = 0.038). This agrees with WHO findings that poverty increases TB incidence, limits treatment access, and promotes resistance.[4] [19] Zhao et al. found poverty to be a major risk factor for MDR-TB in China with an odds ratio of 1.87.[8] Merza et al. reported similar findings in Iran.[20] In Nigeria, the NTBLCP has identified poverty as a key driver of DR-TB, particularly in rural areas with poor DOTS coverage.[19] Our results suggest that socioeconomic interventions should accompany biomedical strategies to control DR-TB.

Resistance patterns in our cohort have important implications for treatment. Rifampicin monoresistance accounted for 76.1% of DR-TB cases, while MDR-TB represented 19.6%. WHO surveillance has reported that greater use of GeneXpert has led to more detection of rifampicin resistance, while resistance to other drugs may remain hidden without expanded drug-susceptibility testing.[19] GeneXpert is the first-line diagnostic tool under NTBLCP guidelines, explaining the predominance of rifampicin monoresistance in our study.[19] Our MDR-TB prevalence is higher than the 1.25% rifampicin resistance reported by Olatunji et al. in Kaduna[24] but similar to rates reported in Osun State at 10.5% and in Iran at 15.1%.[20] [21] The detection of a single pan-resistant isolate in our study echoes WHO warnings about the emergence of extensively drug-resistant strains.[4] [19] This finding underscores the urgent need to expand phenotypic drug-susceptibility testing capacity in Nigeria.

Limitations

This study has limitations. The case-control design is prone to recall bias, especially for behavioural factors such as alcohol use. The sample size may have lacked power to detect rare resistance patterns like pan-resistance. Facility-based sampling might underrepresent community cases, leading to an underestimate of the true burden of DR-TB. GeneXpert primarily detects rifampicin resistance and may miss other resistance mutations. Important variables such as nutritional status, treatment adherence, and diagnostic delays were not comprehensively analysed but could affect the observed associations. Nonetheless, our findings provide important insights into DR-TB dynamics in northwestern Nigeria and align with national and global reports.

Conclusion and Implications

This study identifies prior TB treatment, alcohol use, and low socioeconomic status as important drivers of DR-TB in Kaduna State. The predominance of rifampicin monoresistance highlights both the progress and the gaps in Nigeria's current diagnostic strategies.

Policy priorities should include expanding drug-susceptibility testing services, integrating interventions for substance use within TB programmes, strengthening adherence support, and addressing socioeconomic barriers. Further longitudinal and mixed-methods research is needed to clarify causal pathways and inform programmatic responses.

Declarations

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: MAO, BOBO, and JOO conceptualized and designed the study. MAO, BOBO, JOO, SA, MSI, and BIA collected the data. JOO performed the statistical analysis. JOO, MAO, and BOBO interpreted the data and drafted the manuscript. SA, MSI, and BIA critically reviewed and revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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