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Original Research Article

Association of Glycemic Status, Lipid Profile, Smoking, and Occupational Exposure with Microbiologically Confirmed Pulmonary Tuberculosis: A Prospective Observational Study.

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Abstract: ***Background:*** Tuberculosis (TB) continues to be a major public health concern, particularly in low- and middle-income countries. Metabolic disorders such as diabetes mellitus and dyslipidemia, along with smoking and occupational exposure, may increase susceptibility to active TB; however, their combined association has not been fully elucidated. ***Objectives:*** To evaluate the association of HbA1c, lipid profile, smoking history, and occupational exposure with microbiologically confirmed pulmonary TB in adults attending a tertiary care teaching hospital. ***Methods:*** This prospective observational study included 153 adults (20–60 years) with clinically suspected pulmonary TB. Diagnosis was confirmed by Ziehl–Neelsen smear microscopy, GeneXpert MTB/RIF assay, and culture where indicated. Fasting HbA1c and lipid profile were measured using standardized laboratory methods. Associations between clinical variables and confirmed TB were analyzed using univariate and multivariate logistic regression. ***Results:*** Pulmonary TB was microbiologically confirmed in 29 (19.0%) participants. Compared with TB-negative individuals, TB patients had significantly higher HbA1c (6.8±1.4 vs. 5.6±0.9%), total cholesterol, triglycerides, and LDL-cholesterol, with lower HDL-cholesterol (all $p<0.01$). Smoking history (62.1% vs. 33.9%; $p=0.006$) and high-risk occupation (48.3% vs. 25.0%; $p=0.015$) were also significantly more common among TB-positive participants. Multivariate analysis identified HbA1c ≥6.5% (adjusted OR 3.2), triglycerides ≥150 mg/dL (adjusted OR 2.4), smoking (adjusted OR 3.8), and high-risk occupation (adjusted OR 2.9) as independent predictors of pulmonary TB. ***Conclusions:*** Poor glycemic control, dyslipidemia, smoking, and occupational exposure are independently associated with microbiologically confirmed pulmonary TB. Integrating metabolic assessment and behavioral risk-factor screening into routine TB evaluation may improve early diagnosis and support comprehensive TB control strategies in high-burden settings.

Keywords: Pulmonary tuberculosis; HbA1c; Dyslipidemia; Lipid profile; Diabetes mellitus; Smoking; Occupational exposure; GeneXpert; Biomarkers.

INTRODUCTION

Tuberculosis (TB) continues to be one of the leading causes of death from a single infectious agent worldwide. Caused by Mycobacterium tuberculosis, it primarily affects the lungs but can involve virtually any organ system. Despite advances in diagnosis, treatment, and global TB control programmes, the disease continues to pose a substantial public health burden, particularly in low- and middle-income countries (World Health Organization, 2025; Global Tuberculosis Report, 2024; Pai et al., 2016). Clinical manifestations range from latent infection to active pulmonary or extrapulmonary disease and commonly include chronic cough, hemoptysis, fever, weight loss, and night sweats (Furin et al., 2019; Barry et al., 2021; Seung et al., 2022).

Diabetes mellitus has emerged as an important comorbidity influencing the epidemiology and clinical outcomes of tuberculosis. Persistent hyperglycemia compromises both innate and adaptive immune responses, thereby increasing susceptibility to M. tuberculosis infection and progression to active disease (Jeon and Murray, 2008; Baker et al., 2021; Al-Rifai et al., 2022; Lee et al., 2019). Glycemic status, commonly assessed using glycated hemoglobin (HbA1c), has been linked to increased TB incidence, delayed sputum conversion, and poorer treatment outcomes (Critchley et al., 2017; Dooley et al., 2024; Lin et al., 2021).

Alterations in lipid metabolism have also attracted considerable attention in tuberculosis research. Elevated triglyceride levels and reduced HDL-cholesterol influence host immune responses and facilitate the intracellular survival of M. tuberculosis within macrophages (Sinha et al., 2020; Martens et al., 2023; Kumar et al., 2022). Tobacco smoking and occupational exposure further increase the risk of active TB. Smoking impairs mucociliary clearance and macrophage function, whereas occupations such as mining, construction, and healthcare increase exposure to silica dust and infectious aerosols (Bates et al., 2007; Slama et al., 2007; World Health Organization, 2023; Harries et al., 2022).

Although diabetes, dyslipidemia, smoking, and occupational exposure have each been investigated individually, comparatively few studies have evaluated their combined influence on microbiologically confirmed pulmonary tuberculosis, particularly in high-burden settings (Lin et al., 2021; Dooley et al., 2024; Harries et al., 2022; Kumar et al., 2022). A comprehensive assessment of these metabolic, demographic, and behavioural factors may improve the identification of individuals at increased risk and strengthen integrated screening and prevention strategies.

The present prospective observational study was undertaken to evaluate the association of HbA1c and lipid profile with microbiologically confirmed pulmonary tuberculosis among adults aged 20–60 years of both sexes, while simultaneously examining the influence of age, gender, smoking history, and occupational exposure. This study provides additional evidence regarding the contribution of metabolic abnormalities to pulmonary TB and supports the development of integrated diagnostic, screening, and management strategies (Seung et al., 2022; Barry et al., 2021; Critchley et al., 2017; Al-Rifai et al., 2022).

Study Objectives Primary Objective: To determine the association between biochemical parameters (HbA1c, lipid profile) and microbiologically confirmed TB.

Secondary Objectives: To assess the influence of age, gender, occupation, and smoking history on these associations.

MATERIALS AND METHODS

Study Design: this was a prospective observational study conducted in the Department of Respiratory Medicine and Biochemistry at a tertiary care teaching hospital in Eastern India. The study was carried out over a period of 12 months (January 2024 to December 2024).

Study Population: A total of 153 adult patients aged 20–60 years of both genders with clinically suspected pulmonary tuberculosis were enrolled consecutively.

Inclusion Criteria

- Age 20–60 years.
- Both genders.
- Clinical suspicion of pulmonary TB (cough >2 weeks, fever, weight loss, hemoptysis).
- Willingness to provide informed consent.

Exclusion Criteria

- Known HIV infection or other immunosuppressive conditions.
- Already on anti-TB treatment for >7 days.
- Incomplete clinical or laboratory data.
- Pregnancy.

Ethical Consideration: The study protocol was approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrolment.

Data Collection: A structured proforma was used to record demographic details (age, gender), occupation (categorized as high-risk: mining/construction/healthcare vs low-risk), smoking history (current/former/never smoker, pack-years), and clinical symptoms.

Microbiological Diagnosis: Sputum samples (two consecutive early morning samples) were collected under supervision.

I. Smear microscopy for acid-fast bacilli (AFB) using Ziehl-Neelsen staining.

II. GeneXpert MTB/RIF assay for rapid detection of M. tuberculosis and rifampicin resistance.

III. Culture on Lowenstein-Jensen medium where indicated. Microbiologically confirmed TB was defined as positive smear, GeneXpert, or culture.

Biochemical Parameters Fasting venous blood samples were collected at the time of enrolment for:

a) HbA1c (high-performance liquid chromatography).

b) Lipid profile: Total cholesterol, triglycerides, HDL-cholesterol, LDL-cholesterol (enzymatic colorimetric method on automated analyzer).

All biochemical tests were performed using standardized, quality-controlled procedures.

Statistical Analysis Data were entered into Microsoft Excel and analyzed using SPSS software version 26.0.

I. Descriptive statistics: mean ± standard deviation for continuous variables, frequencies and percentages for categorical variables.

II. Inferential statistics: Chi-square test or Fisher's exact test for categorical variables; independent t-test or Mann-Whitney U test for continuous variables.

III. Multivariate logistic regression was used to assess independent associations of HbA1c and lipid parameters with TB, adjusting for age, gender, occupation, and smoking history.

IV. A p-value of < 0.05 was considered statistically significant.

Sample Size: The sample size was calculated based on expected prevalence of diabetes (HbA1c ≥6.5%) in TB patients (approximately 20–25% in Indian settings), with 80% power and 5% significance level, yielding a minimum of 153 participants.

RESULTS

A total of 153 participants (mean age 38.4 ± 11.2 years) with clinically suspected pulmonary tuberculosis were enrolled. Of these, 92 (60.1%) were males and 61 (39.9%) were females.

Table 1. Demographic and Risk Factor Characteristics of Study Participants

Characteristic	TB Positive (n=29)	TB Negative (n=124)	Total (n=153)	p-value
Age (years, mean ± SD)	41.2 ± 10.8	37.6 ± 11.4	38.4 ± 11.2	0.112
Male, n (%)	21 (72.4)	71 (57.3)	92 (60.1)	0.132
Female, n (%)	8 (27.6)	53 (42.7)	61 (39.9)	—
Smoking history (current/former), n (%)	18 (62.1)	42 (33.9)	60 (39.2)	0.006
High-risk occupation, n (%)	14 (48.3)	31 (25.0)	45 (29.4)	0.015

Microbiological Confirmation Pulmonary TB was microbiologically confirmed in 29 (19.0%) participants. Among the confirmed cases, 22 (75.9%) were smear-positive, 27 (93.1%) were GeneXpert-positive, and 18 (62.1%) were culture-positive. Rifampicin resistance was detected in 3 (10.3%) cases.

Biochemical Parameters

Table 2. Biochemical Parameters in TB-Positive versus TB-Negative Participants

Parameter	TB Positive (n=29)	TB Negative (n=124)	p-value
HbA1c (%)	6.8 ± 1.4	5.6 ± 0.9	<0.001
Total Cholesterol (mg/dL)	198.4 ± 32.6	172.3 ± 28.4	0.002
Triglycerides (mg/dL)	162.7 ± 45.1	128.5 ± 38.2	<0.001
HDL-Cholesterol (mg/dL)	38.2 ± 7.9	45.6 ± 9.3	0.001
LDL-Cholesterol (mg/dL)	128.5 ± 24.3	105.4 ± 22.1	<0.001

Participants with confirmed TB exhibited significantly poorer glycemic control and a more atherogenic lipid profile compared to TB-negative individuals.

Multivariate Logistic Regression Analysis After adjustment for age and gender, the following factors remained independently associated with confirmed TB:

Factor	Adjusted OR	95% CI	p-value
HbA1c ≥6.5%	3.2	1.7–6.1	<0.001
Triglycerides ≥150 mg/dL	2.4	1.4–4.2	0.002
Smoking history	3.8	2.0–7.2	<0.001
High-risk occupation	2.9	1.5–5.6	0.002

Subgroup Analysis

Table 3. Subgroup Analysis Among TB-Positive Cases

Comparison	Parameter	Results (Mean ± SD)	p-value
Smokers vs Non-smokers	HbA1c (%)	7.3 ± 1.5 vs 6.2 ± 1.1	0.024
High-risk vs Low-risk occupation	Triglycerides (mg/dL)	178.4 ± 48.2 vs 142.6 ± 39.8	0.008
Male vs Female	HbA1c (%)	7.1 ± 1.4 vs 6.3 ± 1.2	0.031

DISCUSSION

This prospective observational study demonstrated that poor glycemic control, dyslipidemia, smoking, and high-risk occupational exposure were significantly associated with microbiologically confirmed pulmonary tuberculosis (TB). Elevated HbA1c and triglyceride levels remained independent predictors of TB after

adjustment for demographic variables, suggesting that metabolic abnormalities contribute substantially to TB susceptibility.

The association between hyperglycemia and TB observed in this study is consistent with previous reports demonstrating that diabetes increases both the risk of developing active TB and adverse treatment outcomes. Chronic hyperglycemia impairs innate and adaptive immune responses, reducing the host's ability to control Mycobacterium tuberculosis. In addition, the altered lipid profile observed among TB patients supports emerging evidence that disturbances in lipid metabolism may influence mycobacterial survival and disease progression.

The higher prevalence of smoking among TB-positive participants observed in the present study is consistent with the well-established role of tobacco smoking as a risk factor for tuberculosis. Smoking impairs pulmonary immune defenses, reduces mucociliary clearance, and increases susceptibility to Mycobacterium tuberculosis infection. High-risk occupational exposure was also independently associated with microbiologically confirmed TB, likely reflecting increased exposure in crowded workplaces and environments containing silica dust. These findings support the integration of smoking cessation interventions and occupational health measures into routine tuberculosis prevention and control programs.

The strengths of this study include its prospective design, microbiological confirmation of TB using standardized diagnostic methods, and adjustment for important confounding variables. However, the study was conducted at a single center with a relatively small number of confirmed TB cases, which may limit the generalizability of the findings. Larger multicenter studies are warranted to validate these observations and further clarify the relationship between metabolic dysfunction and tuberculosis.

CONCLUSION

The present study suggests that elevated HbA1c, dyslipidemia, smoking, and high-risk occupational exposure are significant determinants of pulmonary TB. Incorporating metabolic assessment and risk-factor evaluation into routine TB screening may facilitate earlier diagnosis and improve disease management in high-burden settings.

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