

Research Article

Demographic Characteristics and Clinical–Radiological Profiles in Molecular Detection of Pulmonary Tuberculosis

Kalpesh Khutade¹, Sandip Wagh², Harshada Shah³, Ronit Kumar⁴

^{1,2}Department of Biological Sciences, Sandip University, Nashik, India

³Department of Microbiology, Vedantaa Institute of Medical Sciences and Research Centre, Dhundalwadi, Dahanu, Palghar, Maharashtra, India

⁴Department of Respiratory Medicine, Vedantaa Institute of Medical Sciences and Research Centre, Dhundalwadi, Dahanu, Palghar, Maharashtra, India

DOI: <https://doi.org/10.24321/0019.5138.202653>

I N F O

Corresponding Author:

Sandip Wagh, Department of Biological Sciences,
Sandip University, Nashik, India

E-mail Id:

sandipwagh60@gmail.com

Orcid Id:

<https://orcid.org/0000-0002-5889-6220>

How to cite this article:

Khutade K, Wagh S, Shah H, Kumar R. Demographic Characteristics and Clinical–Radiological Profiles in Molecular Detection of Pulmonary Tuberculosis. J Commun Dis. 2026;58(3):33-42.

Date of Submission: 2026-01-11

Date of Acceptance: 2026-08-27

A B S T R A C T

Aim: This study evaluated PTB demographics, clinical/radiographic features, and the diagnostic accuracy of chip-based PCR techniques in suspects. **Methods:** This cross-sectional WHO-aligned PTB study collected patient data, standardized chest X-rays, and evaluated sputum micro real-time PCR to their reference standard Middlebrook 7H9 culture.

Results: PTB burden was highest in men aged 51–60 with moderate-to-high incomes, with heavy smoking as the main risk factor. Higher bacterial loads correlated with worse clinical severity, and reticulonodular opacities were the most common radiological finding (41.1%; $p < 0.0001$). Bacterial (40.1%) and fungal (36.7%) co-infections were more frequent than diabetes or HIV ($p < 0.001$). TrueNat showed the highest diagnostic accuracy (98.2%), whereas chest radiography was significantly less accurate.

Conclusion: PTB risk was driven by demographics and behavior, while TrueNat far outperformed radiology in diagnostic accuracy.

Keywords: Bacterial load, chest radiography, co-infection, TrueNat

Introduction

India's TB incidence (new cases every year) slashed by 21%—from 237 per lakh population in 2015 to 187 per lakh in the population—at nearly double the pace of the global decrease rate recorded at 12%, according to the World Health Organization's Global TB Report 2025.¹ This represents one of the largest decreases in TB incidence worldwide, steeper than seen in other high-burden countries.² The novel case-finding strategy adopted by India, coupled with rapid adoption of advanced technologies,

decentralization, and extensive community involvement, has resulted in 26.18 lakh patients being diagnosed for TB during 2024, against an estimated incidence of 27 lakh. This has led to a reduction in the “missing cases”—defined as having TB but not getting reported—from about 15 lakhs in 2015 to less than one lakh by 2024.^{1,3-5} Conventional diagnostic modalities, sputum smear microscopy and culture continue to be the mainstay in TB diagnostics in several resource-poor settings.^{6,7} Though smear microscopy is cheap and affordable, it is less sensitive particularly in paucibacillary cases, children and patients

with concurrence of HIV.⁸ Culture, a gold standard for TB diagnosis, provides the greatest sensitivity and allows for drug susceptibility testing, but is technically difficult to perform and time-consuming taking weeks to achieve growth of mycobacteria and usually not available in primary health care.^{9,10} In order to address these diagnostic needs, molecular tests for detection of tuberculosis have proved transformative tools in the global campaign against TB.¹¹ The nucleic acid amplification tests (NAATs) enable rapid, highly sensitive, and specific detection of *Mycobacterium tuberculosis* directly in clinical samples avoiding the constraints with respect to traditional testing methods.¹² Of the molecular diagnostic platforms, TrueNat tests have evolved as promising technologies that can be potentially used in decentralized and resource-constrained healthcare facilities.^{13,14} The indigenous chip-based real-time PCR assay-TrueNat for diagnosis of tuberculosis has been recommended by WHO for rapid TB detection and rifampicin resistance. It has the benefits of portability, low infrastructure needs, and a short turnaround time that is less than two hours and can be deployed in a point-of-care manner such as remote regions.¹⁵⁻¹⁷ Chest X-ray (CXR) is a common TB screening tool in many health systems. Automatic detection of TB signs in such X-rays using deep learning has become a major and increasing field of research.¹⁸ Although the use of molecular diagnostics has increasingly been implemented, correlation between patient-level demographics, clinical characteristics, and radiology have been reported. Furthermore, radiographic presentations of PTB are vital to diagnosis and prognosis determination in patients, as evaluated by CXR.¹⁹ Therefore, this study aimed to analyze the demographic profile, clinical presentations, radiological features, and diagnostic accuracy, specifically addressing the TrueNat assays.

Materials and Methods

This cross-sectional observations study was carried out at the Vedantaa Institute of Medical Sciences and Research Centre from September 2025 to December 2025 to correlate the demographic, clinical, and radiological profile with molecular methods for the detection of PTB suspects. The study was approved by the Institutional Ethics Committee (IEC) (approved number EC/OA/03/25) and adhered to the Declaration of Helsinki. The study subjects are selected from patients attending the OPDs of the Departments of Tuberculosis and Chest, General Medicine, and Paediatrics. Patients are evaluated through clinical, radiological, pathological, and microbiological investigations, followed by consultation with the chest physician and paediatrician, as appropriate, for suspected pulmonary tuberculosis (PTB). The routine protocol, including reporting to the National Tuberculosis Elimination Programme (NTEP) through the Nikshay ID, is followed regularly. The Department of

Microbiology routinely reports the relevant microbiological findings on the Nikshay portal. Written informed consent was obtained from all the participants before enrolling in the study. Eligible patients according to WHO criteria who presented with symptoms suggestive of PTB, such as cough for more than two weeks, haemoptysis, fever, night sweats or weight loss, were included in the study. Patients that received antituberculosis therapy in the preceding six months or those with incomplete clinical data were excluded.

Demographic and clinical data such as age, sex, occupation (agricultural, non-agricultural, housewife, or other), socio-economic status (poor/middle class/rich), comorbidity with Diabetes Mellitus (DM), HIV/AIDS, and TB co-infection and fungal co-infections were noted by using a pre-designed form along with detailed symptomatology. Radiological findings were classified according to patchy infiltration, cavity formation, consolidation, nodules, miliary alterations, reticulonodular opacities, and fibrosis. An early morning sputum sample was collected under standard biosafety procedures for molecular testing. The molecular diagnosis of *Mycobacterium tuberculosis* was carried out by micro real-time PCR following the manufacturer's manuals. Middlebrook 7H9 was used as the gold standard for mycobacterial culture.

Data were graphically illustrated by Microsoft Excel and GraphPad Prism software programs as well as Microsoft design graphics. Associations between demographic, clinical, and radiological parameters and molecular detection results were analysed using the chi-square test for categorical variables, which was considered statistically significant at $p < 0.05$. The performance of molecular tests in terms of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy was determined using culture as the reference standard with standard techniques (<https://www2.ccrb.cuhk.edu.hk/stat/ConfidenceInterval.htm>).

Results

The occupation-wise distribution of the study participants showed that among the TB-positive cases, agricultural workers represented the largest group, with 47/108 (17.4%), followed by housewives with 40/99 (14.8%). Non-agricultural workers and participants in other occupations contributed 16/43 (5.9%) and 9/20 (3.3%) TB-positive cases, respectively. Among the TB-negative cases, agricultural workers accounted for 61/108 (22.5%), followed by housewives with 59/99 (21.8%), non-agricultural workers with 27/43 (10.0%), and those in other occupations with 11/20 (4.0%) (Figure 1).

The association between occupation and TB status was tested using the chi-square test of independence. The

distribution of TB-positive and TB-negative cases by occupational categories (agriculture, non-agriculture, housewife, and others) showed no significant difference from what would be expected under the independence assumption ($\chi^2 = 0.649$, $df = 3$, $p > 0.05$). This suggests that TB status in this group was statistically unrelated to occupation and that the risk of TB was not influenced by occupational class in the study group.

The distribution of TB-positive patients showed an age-specific pattern, as well as income category-specific. The distribution of TB-positive participants demonstrated variation according to age, sex, and income category. Among males, the highest proportion of TB-positive participants was observed in the 51–60-year-old age group (17; 15.2%), corresponding to the very high income category (₹80,000–89,999). This was followed by males aged 41–50 years (15; 13.4%) and 31–40 years (14; 12.5%), both belonging to the high-income category. Among females, the highest proportion was observed in the 21–30-year-old age group (19; 17.0%), corresponding to the high-income category (₹60,000–79,999). Female participants aged 31–40 years (9; 8.0%) and 41–50 years (4; 3.6%) were also classified as high income. In contrast, females aged 51–60 years accounted for only 2 (1.8%) participants and were classified as low income (Figure 2). Among pediatric patients up to 13 years of age, the parents' income was considered to assess the prevalence of pulmonary tuberculosis in relation to the socioeconomic status of the family. Distributions of male and female TB cases at all age groups: the rate of TB was higher in males than in females overall, indicating that occupational exposure, social interaction such as sharing resources (i.e., income), and socioeconomic level could be closely related to TB susceptibility.

The risk factors observed among the study persons ($n=112$) were tobacco and alcohol-consuming habits, which comprised 22 (19.6%) heavy smokers, 16 (14.3%) moderate smokers, 11 (9.8%) light smokers, 8 (7.1%) non-smokers, and 14 (12.5%) chewing tobacco. The alcohol-consuming persons comprised 11 (9.8%) occasional heavy alcohol drinkers, 16 (14.3%) frequent alcohol drinkers, and 5 (4.5%) moderate alcohol drinkers, while 2 persons (1.8%) were found to be abstainers, who hardly had any involvement in alcohol consumption. 7 persons (6.3%) had both smoking and alcohol consumption habits (Figure 3). It is apparent from the data that the tobacco users (62.6%) outnumbered the alcohol users (34.8%). The mean frequency of habits in this population, with a frequency of 11.2 (standard deviation = 5.67) of the habits considered, and heavy smoking at 22.01 and a z-score of +1.91 were found to be very significant. In contrast, small and non-significant differences were observed for the frequency of moderate drinking (5, $z \approx -1.09$) and no drinking at all (2, $z \approx -1.63$), suggesting protective or low-risk use may not be widespread in this population.

In the clinical profile of subjects under study, the most persistent clinical symptoms were associated with the highest bacterial load (averaging 1.0×10^6 to 5.6×10^7 CFU/mL). These high-load cases usually had cough, fever, and weight loss in combination. There was an increase in the size of the symptomatic complex and severity of illness with increasing bacterial load; symptomatic groups were mostly multi-syndromic in higher-burden categories. The medium bacterial load group (1.1×10^3 , 2.3×10^4 , 8.7×10^4 , and 9.3×10^4 CFU/mL) was linked with the combination of fever, fatigue, and cough, while it showed almost no relation to weight loss. Medium bacterial loads accounted for moderate, less complex disease (an intermediate stage between early infection and advanced post-primary TB). The lowest bacterial burdens, 8.9×10^1 , 1.7×10^2 , and 2.1×10^2 , were mainly those with fever and fatigue but only occasional mild coughing. Thus, low bacterial burden was associated with mild, relatively nonspecific clinical symptoms consistent with early or contained MTB infection (Table 1).

The radiological findings of persons under study that reflected reticulonodular opacities were the most common abnormality, 46/112 (41.1%), and more frequently observed in males, 29/112 (25.9%), than in females, 17/112 (15.2%). Cavitory lesions were observed in 27/112 (24.1%) patients, 18 (16.1%) men, and 9 (8.0%) females. Patchy infiltration was observed in 19/112 (17.0%) patients, while consolidation was present in 9/112 (8.0%). Nodules were seen in 7 (6.3%) patients, miliary disease in 3 (2.7%) patients, and fibrosis in 1 (0.9%) patient (Table 2). The chi-square test revealed a very significant difference in radiological findings distribution ($\chi^2 = 97.11$, $df = 6$, $p < 0.0001$).

Associated conditions in the plain (no co-infection): fungal co-infection was detected in 41/112 (36.6%) patients. Diabetes mellitus was present in 22/112 (19.6%) patients, while HIV co-infection was identified in 4/112 (3.6%) patients. Of the patients with fungal co-infection, 15 had neither diabetes mellitus nor HIV co-infection. Among the fungal isolates, *Aspergillus niger* was the most frequently identified species (7; 10.4%), followed by *Aspergillus fumigatus* (5; 7.5%), *Aspergillus flavus* (2; 3.0%), and *Aspergillus terreus* (1; 1.5%) (Figure 4). The 95% confidence intervals for the proportion of each co-infection category were calculated. Diabetes mellitus varied from 12.3% to 27.0%, HIV/AIDS from 0.14% to 7.00%, and fungal co-infection from 27.7% to 45.5%, while plain cases were seen in between 31.1% and 49.2%. A chi-square goodness-of-fit test also indicated a significant deviation from a uniform distribution between categories ($\chi^2 = 38.21$, $df = 3$, $p < 0.001$). These findings suggest that co-infections are not randomly distributed and are significantly more likely to occur.

Among all diagnostic methods tested, TrueNat showed the highest sensitivity, 98.2% (95% CI: 95.4 to 100), with correct identification of true positive cases, while the CXR performed significantly poorer with a sensitivity of 75.2% (67.1–83.3), indicating an increased risk of false negatives. The molecular tests exhibited perfect specificity: TrueNat had 100% (95% CI: 29.2-100). For a lower specificity of the CXR at 66.7% (9.4–99.1), false positives were more likely to occur. The PPV for TrueNat was 100%, thereby qualifying them for having high validation ability in diagnosing disease

presence. The CXR's PPV was marginally lower but still high at 98.8% (96.5–100). The NPV was more variably distributed: TrueNat displayed the highest value of 60% (12–100), which expressed a relatively better sensitivity to exclude disease in negative patients, whose NPV approached 37.5% (4.2–70.8). CXR was a poor NPV in this respect: 6.9% (0–16.1). The accuracy reflected this trend, with TrueNat achieving an overall accuracy of 98.2% and CXR being significantly lower, dropping to about 75% (Figure 5).

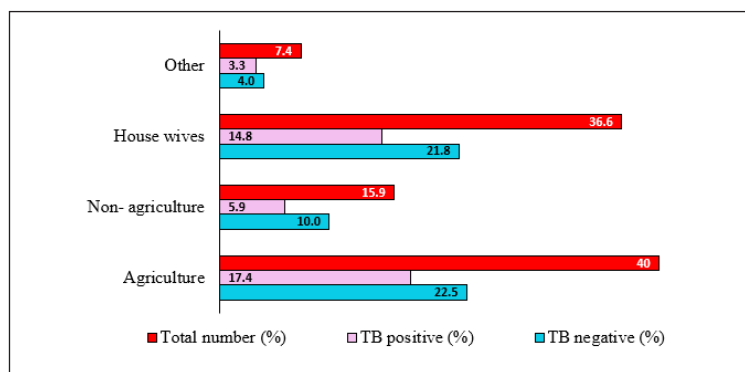


Figure 1. Proportion of tuberculosis-positive cases across different occupational categories (n=112). These profiles were consistent with the higher load of TB on groups with occupational exposure and socio-environmental vulnerabilities related to farming work.

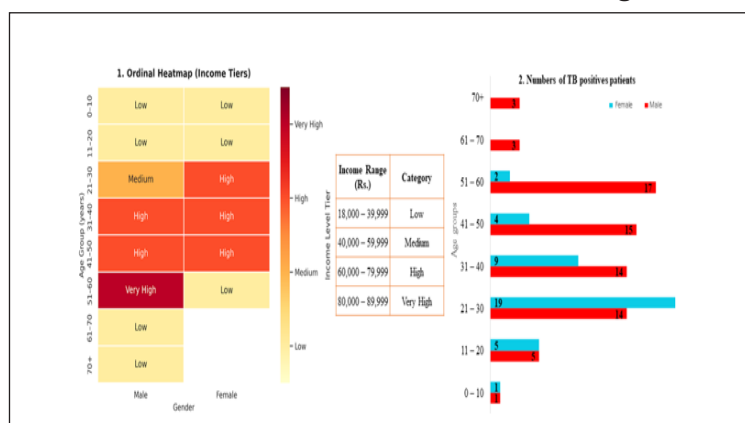


Figure 2. Socioeconomic and age determinants of TB susceptibility in male and female populations

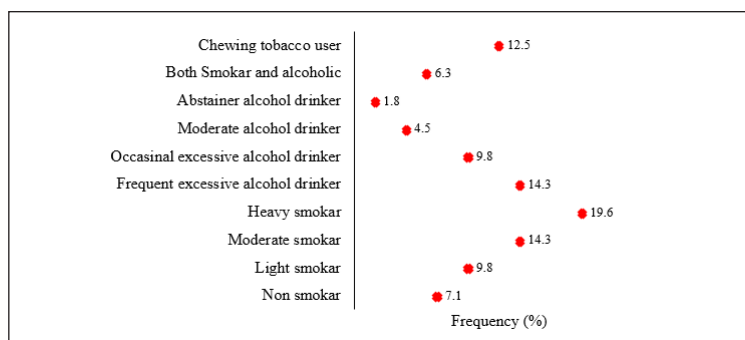


Figure 3. Habits with potential risk for tuberculosis and their prevalence. The population shows a large variety in smoking, alcohol, and tobacco habits, where heavy smoking was the most notable high-risk behavior. The prevalence of moderate drinking and non-use were both low, suggesting low rates for protective behavior

Table 1. Symptom patterns stratified by quantitative MTB bacterial loads

Bacterial Load Category	Representative Bacterial Load Values (CFU/mL)	Primary Associated Symptoms	Clinical Interpretation
High Bacterial Load ($\geq 10^5 - 10^7$)	1.0×10^6 , 1.3×10^5 , 1.4×10^6 , 1.5×10^6 , 1.6×10^5 , 1.7×10^5 , 1.8×10^6 , 1.9×10^5 , 2.0×10^5 , 2.1×10^5 , 2.5×10^5 , 2.5×10^7 , 2.6×10^6 , 2.8×10^5 , 2.9×10^6 , 3.0×10^6 , 3.1×10^5 , 3.8×10^6 , 4.2×10^5 , 4.5×10^5 , 5.6×10^6 , 5.6×10^7 , 5.8×10^5 , 5.9×10^5 , 6.7×10^5 , 7.3×10^5 , 9.1×10^5	Cough, fever, weight loss (often combined)	Represents severe disease with extensive lung involvement and intense inflammatory response; multi-symptom presentations were most frequent in this group.
Medium Bacterial Load ($10^3 - 10^5$)	1.1×10^3 , 1.1×10^4 , 1.2×10^3 , 1.4×10^3 , 1.6×10^4 , 1.9×10^3 , 1.9×10^4 , 2.3×10^4 , 2.5×10^3 , 2.8×10^4 , 3.2×10^3 , 3.2×10^4 , 4.7×10^3 , 4.8×10^4 , 6.4×10^3 , 7.5×10^3 , 8.0×10^3 , 8.7×10^4 , 9.3×10^4 , 9.6×10^4	Fever, fatigue, cough + fever; rarely weight loss	Corresponded to moderate disease activity; symptoms less complex, reflecting partial lung involvement and moderate immune activation.
Low Bacterial Load ($< 10^3$)	1.3×10^2 , 1.5×10^2 , 1.7×10^2 , 2.1×10^2 , 2.9×10^2 , 3.3×10^2 , 3.5×10^2 , 3.6×10^2 , 5.8×10^2 , 7.5×10^2 , 9.7×10^2 , 8.9×10^1	Fever, fatigue, occasional mild cough	Indicated early or paucibacillary TB; mild, nonspecific symptoms consistent with limited bacterial replication and minimal tissue damage.

Table 2. Distribution of radiological findings among PTB patients

Sr. No.	Radiological finding	Number of patient	Total χ^2 value	Degrees of freedom (df)	p-value
1	Reticulonodular opacities	46 (41.1%)	97.11	6	< 0.0001
2	Cavity	27 (24.1%)			
3	Patchy infiltration	19 (17.0%)			
4	Consolidation	9 (8.0%)			
5	Nodules	7 (6.3%)			
6	Miliary change	3 (2.7%)			
7	Fibrosis	1 (0.9%)			

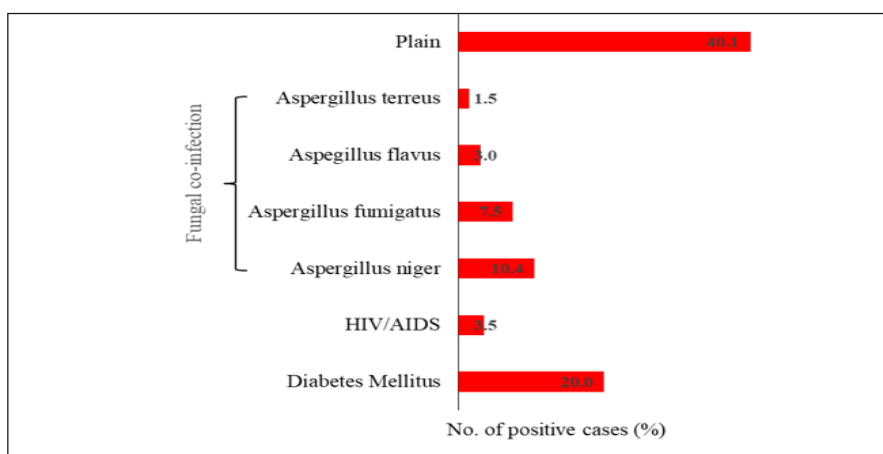


Figure 4. Distribution of positive cases by co-infection type.

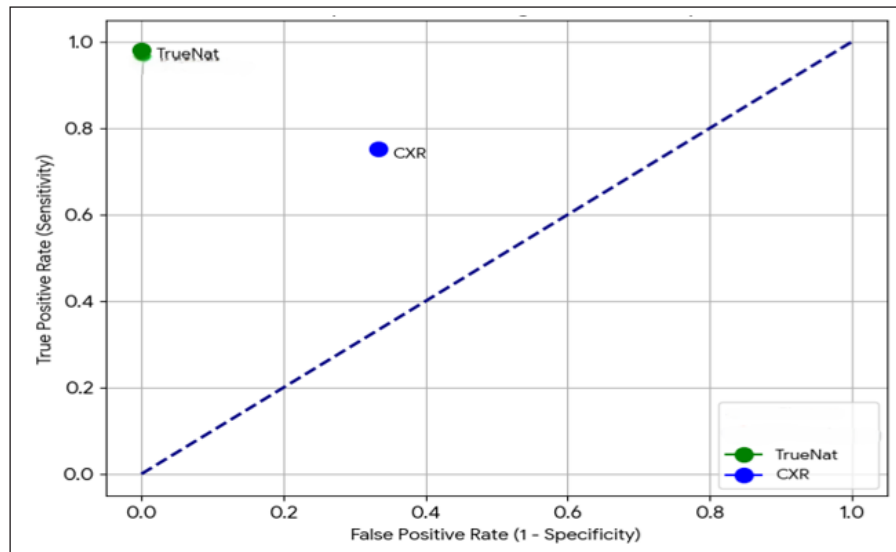


Figure 5. The ROC curve illustrates a test's performance, with the Y-axis indicating true positive detection and the X-axis representing false positive rates. The closer the curve moves toward the top-left corner, the stronger the test's accuracy becomes. The ideal point in this region reflects near-perfect identification of true cases with minimal false alarms

Discussion

This study evaluated the demographic and clinical-radiological profile of patients in this cohort according to the molecular diagnosis of PTB. Knowledge of the trends has implications for the recognition of high-risk groups and enables targeted diagnostic approaches. Combining clinical, radiological, and molecular data offers an overall approach to both optimizing TB detection and management.

Agriculture was the most prevalent occupation in our study, followed by housewives and non-agricultural laborers. A zoonotic pathogen recently causing great concern as a public health threat was *Mycobacterium tuberculosis*, also previously reported in 17 studies. 20 *Mycobacterium tuberculosis* infection poses a substantial risk in some occupational categories who have close contact with domestic/wild animals, including farmers of livestock, slaughterhouse workers, animal rearers, veterinary personnel, and butchers. 21 A High Burden of Tuberculosis among Dairy Farm Workers in Addis Ababa and the Surrounding Areas—A total of 256 subjects participated voluntarily, and from them there were 12 tuberculosis suspects and three tuberculosis cases. The TB prevalence found was 1.17%. A higher risk of specified symptom complex by participants who had consumed raw meat than those who consumed the cooked one (adjusted OR 0.8, 95% CI: 1.08-13.29).²²

Our finding also trends seen in TB distribution according to both age group and income level. The prevalence of TB was highest among males aged 51–60 years, who belonged to the very-high-income group, followed by males aged 31–50 years in the high-income group and those aged

21–30 years in the medium-income group. The remaining age groups, which predominantly belonged to the low-income category, showed a comparatively lower burden of TB. Income data showed that high-income cases were more common in 51 to 60 age groups, but this may reflect confounding factors such as stronger addictive habits and reduced immunity rather than true socioeconomic influence. Likewise, women concentrated in the 21–40 years of age and high income levels. Contrastingly, according to our data, the high-income stratum (PKR 25,001 - 40,000) has a nearly twofold risk for TB of those who make over PKR 40,000. This fits with the overall trend of increased exposure to middle-income and working-age participants—probably in part due to workplace contact, mobility, and shared social environments. Therefore, both datasets confirm the link between working age, moderate income, and risk of developing TB disease, emphasizing socioeconomic and exposure-related factors influencing the degree of risk for disease.²³⁻²⁶

In this investigation, heavy smokers (19.6%) and frequent harmful drinkers (14.3%) were the more prevalent habits, and light-drinkers and abstainers were rare. The chewing of tobacco and simultaneous smoking-alcohol use were also observed but were less common. Altogether, our findings suggest that high-risk lifestyle habits are common in our study sample. Previous studies have consistently demonstrated that smoking substantially elevates the risk of TB by affecting the host defence through impairment of mucociliary transport, stimulation of airway inflammation and pulmonary oxidation or damage, which subsequently may result in cavitation and recurrent TB.^{27,28}

The susceptibility is also enhanced by alcohol consumption and immune modulation.

In the current research, significantly higher bacterial counts (1.0×10^6 to 5.6×10^7 CFU/mL) were found with severe multicomponent TB than those with cough, fever and weight loss. Moderate bacterial loads were associated with moderate disease (fever, fatigue and cough), but little weight loss. Low bacterial loads were associated with mild, nonspecific symptoms consistent with early or contained MTB infection. A previous study evaluated the relations between sputum microbial composition and TB manifestation, including mycobacterial load, CXR zoometries, an age of symptom onset and disease severity assessed by a TB disease score. Their interpretations showed the extent to which microbial profiles mirror disease load and stage, offering a conceptual model for TB severity.^{29,30}

Within this analysis, reticulonodular opacities were the most common CXR abnormality, followed by cavitary lesions, patchy infiltration, consolidation nodules, and miliary disease. In concordance with another study, the most frequent CXR finding was reticulonodular opacities, which were found in all patients with PTB.³¹ Four of these males were smokers; they all presented cavitary lesions. This helps to demonstrate that smoking plays a significant role in cavitary lung diseases, especially with malignancy.³²

In this work, the majority of the cases were plain (non-co-infected), followed by fungal co-infections (*Aspergillus niger* followed by *Aspergillus fumigatus*, *Aspergillus flavus*, and *Aspergillus terreus*) of life threatening invasive infections, compared to smaller numbers of DM and HIV/AIDS. Jeffrey D. Jenks and Ellis H. Tobin (2026)³³ published a study that, although hundreds of species exist, fewer than 40 cause human disease, most commonly *Aspergillus fumigatus*, followed by *Aspergillus terreus*, *Aspergillus flavus*, and *Aspergillus niger*. Jigan et al. (2026)³⁴ studied that *Aspergillus* was the next most common genus identified, with a total of 24 isolates (18.8% of fungal cases). Among these, *Aspergillus niger* was found in 10 cases, *A. fumigatus* in 9, and *A. flavus* in 5 cases. In one additional case, *Aspergillus niger* was co-isolated alongside a *Fusarium* species from the same patient's sputum sample. The presence of *Aspergillus*, especially *A. fumigatus* and *A. niger*, was often correlated with patients who had pre-existing lung cavities on imaging, as *Aspergillus* can colonize healed TB cavities.

In line with previous observations, individuals in our cohort who co-infected with fungi suffered from delayed sputum conversion and eal.)ibited more treatment failure and mortality, indicating the substantial influence of fungal coinfections on TB outcomes. These findings emphasize the importance of regular screening and treatment for mycotic infections in TB patients to enhance prognosis.³⁵

Diab2.0–2.3 fors (DM) is also a major risk factoDM,for TB because it negatively affects host immune responses, decreases IFN- γ production and impairs macomorbidityesen presentation; there are decreased IL-8 and IL-22 leading to defective phagocytosis and reduced clearance of TB by the host (Feng et al). Meta-analyses from 2007, 2017 and 2021 stated pooled risk estimates for TB among diabetic patients between 2.0 and 3.11 with high heterogeneity between trials. Individual cohort and case–control studies have demonstrated adjusted hazard ratios of approximately 2.0–2.3, for active TB in adults with type 2 DM attesting to the collaborative predisposing effects of lifestyle influences together with metabolic co morbidities on TB susceptibility. These results are consistent with our study, highlighting the combined effect of smoking, alcohol, and DM in TB risk.^{36–37}

We reported in our study that TrueNat tests showed very high sensitivity and perfect specificity compared with CXR, the sensitivity and specificity of which were relatively low. TrueNat classifiers obtained the best overall accuracy, which establishes it as the most reliable of the TB diagnosis methods. The World Health Organisation (WHO) recommends that the chest radiograph (CXR) is a valuable diagnostic tool in TB diagnosis, especially in low-income settings. It has high sensitivity in the diagnosis of pulmonary TB, whereas the specificity is low.^{38,39} This method has a sensitivity of between 87% and 98%, according to the World Health Organization (WHO), and is invaluable in PTB screening. CXR may detect cavitary lesions, consolidation, mass-like opacities, pleural effusion and calcifications or nodular changes in the lung.^{40,42} In their work, they found that DenseNet201 obtained a penetration rate of 98.6% with lung images and 96.47% with whole X-rays. Performance of Truenat® MTB, a chip-based nucleic acid amplification test for the diagnosis of PTB. It has a detection limit of 100 CFU/mL, moderate sensitivity (73.3%) and high specificity (97.9%), and results within less than one hour.^{43,44}

This study was limited to a single-centre population and conducted only in a tribal area, with no representation from slum or metropolitan populations where TB patterns differ. In this region, most participants were engaged in agriculture, while non-agricultural work was limited to small-scale office jobs, potentially underestimating TB risk in urban occupations. Additionally, the cross-sectional design and variability in sputum quality and radiological interpretation may have affected diagnostic accuracy.

Conclusion

Most of the pulmonary TB cases were represented by agricultural workers, followed by housewives, and the TB prevalence was higher among working-aged males and females in 21–40 years, which may be attributed

to social-economic issues and occupation-related issues. Both heavy smoking and drinking were significantly associated with TB risk as harmful behavioral factors. The clinical phenotypic expression was tightly linked to mycobacterial load, with high loads being associated with multi-symptomatic acute disease and low bacterial burdens leading to mild non-specific symptoms. The most common radiological abnormality was reticulonodular opacities, followed by cavitory lesions, suggesting diverse pulmonary involvement. Fungal co-infections were frequent with TB and rare with HIV/AIDS, emphasizing co-morbidities as critical indicators of disease complexity. The TrueNat showed better diagnostic value as compared with CXR, indicating the benefit of molecular tools to diagnose TB. Which may benefit the conventional tuberculosis elimination program as a gold diagnostic tool for rapid and undelayed diagnosis of PTB in order to ensure prompt and complete treatment of the cases.

Conflict of Interest: None

Source of Funding: I Sincerely Thank The Department Of Microbiology Staff At Vedantaa Institute Of Medical Sciences And Vedantaa Hospital And Research Centre, Dahanu, For Their Guidance And Support. Their Assistance And Provision Of Laboratory Facilities Were Invaluable For The Completion Of This Study. This Study Was Supported By The District Tuberculosis Office-Palghar, Under The Rntcp Centre, As Part Of The Tb Elimination Program 2025. Their Truenat Facility And Reagent Kits Support Were Invaluable In Conducting This Research.

References

1. Mok WM, Malar J, Soltan V, Smyth C, Ul Eman K, Subakti A, Lobo R, Mukuhwa T, Tobaiwa D, Lunga M, Denysenko V. Assessing tuberculosis stigma: a pooled multi-country descriptive analysis of 17 high-burden countries using a standardised tool. *Frontiers in Public Health*. 2026 May 7;14:1799432.[Google Scholar]
2. Glaziou P, Sismanidis C, Floyd K, Raviglione M. Global epidemiology of tuberculosis. *Cold Spring Harbor perspectives in medicine*. 2015 Feb;5(2):a017798. [Google Scholar]
3. Singh UB, Rade K, Rao R, Kumar N, Mattoo SK, Nair S, Zumla A, Sahu S. Lessons and updates from India's National Tuberculosis Elimination Program—bold decisions and innovative ways of fast-tracking progress toward ending tuberculosis. *IJD regions*. 2025 Mar 1;14:100599.[Google Scholar]
4. Burugina Nagaraja S, Thekkur P, Satyanarayana S, Tharyan P, Sagili KD, Tonsing J, Rao R, Sachdeva KS. Active case finding for tuberculosis in India: A syntheses of activities and outcomes reported by the national tuberculosis elimination programme. *Tropical Medicine and Infectious Disease*. 2021 Nov 30;6(4):206.[Google Scholar]
5. Garg T, Chaisson LH, Naufal F, Shapiro AE, Golub JE. A systematic review and meta-analysis of active case finding for tuberculosis in India. *The Lancet Regional Health-Southeast Asia*. 2022 Dec 1;7.[Google Scholar]
6. Jyothsna E, Balaram K, Challa RS, Dixit H, Shekhar S, Gaur A, Tiwari R. Evaluation of Fabrication Techniques and Material Properties in Fabrication of Complete Dentures: An Original Research. *Journal of Contemporary Clinical Practice*. 2024 Aug 21;10:454-8. [Google Scholar]
7. Zachariou M, Arandjelović O, Sloan DJ. Automated methods for tuberculosis detection/diagnosis: A literature review. *BioMedInformatics*. 2023 Sep 1;3(3):724-51.[Google Scholar]
8. Cattamanchi A, Dowdy DW, Davis JL, Worodria W, Yoo S, Joloba M, Matovu J, Hopewell PC, Huang L. Sensitivity of direct versus concentrated sputum smear microscopy in HIV-infected patients suspected of having pulmonary tuberculosis. *BMC infectious diseases*. 2009 May 6;9(1):53.[Google Scholar]
9. Ghosh M, Lahiri M, Dalal A, Parida KK, Kalia NP. Advancements in tuberculosis diagnostics: An update. *Microbial Pathogenesis*. 2025 Oct 1;207:107843. [Google Scholar]
10. Tawfick MM, Badawy MS, Taleb MH, Menofy NG. Tuberculosis Diagnosis and Detection of Drug Resistance: A Comprehensive Updated Review. *Journal of Pure & Applied Microbiology*. 2023 Dec 1;17(4):1978. [Google Scholar]
11. Engel N, Ochodo EA, Karanja PW, Schmidt BM, Janssen R, Steingart KR, Oliver S. Rapid molecular tests for tuberculosis and tuberculosis drug resistance: a qualitative evidence synthesis of recipient and provider views. *Cochrane Database of Systematic Reviews*. 2022(4).[Google Scholar]
12. Byrne RL, Wingfield T, Adams ER, Banu S, Bimba JS, Codlin A, Atienzar AC, Garg T, John S, Gurgel RQ, Sander M. Finding the missed millions: innovations to bring tuberculosis diagnosis closer to key populations. *BMC Global and Public Health*. 2024 May 17;2(1):33.[Google Scholar]
13. Malhotra A, Elísio D, Machiana A, Lwilla A, Hella J, Young N, Khosa C, Cossa M, Nguenha D, Mgaya R, Balate D. Decentralized TB diagnostic testing with Truenat MTB Plus and MTB-RIF Dx vs. hub-and-spoke GeneXpert MTB/RIF Ultra in Mozambique and Tanzania: a cost and cost-effectiveness analysis. *PLOS global public health*. 2025 May 30;5(5):e0004724.[Google Scholar]
14. Scott GY, Aborode AT, Adesola RO, Benson K, Omulepu

- I, Ajayi OO, Nibokun EO, Somuah DK, Nkhoma F, Omole GD, Omeoga CH. Diagnostic innovations for tuberculosis in sub-Saharan Africa. *Discover Public Health*. 2025 Apr 25;22(1):188.[Google Scholar]
15. Inbaraj LR, Daniel J, Narayanan MK, Srinivasalu VA, Bhaskar A, Scandrett K, Rajendran P, Kirubakaran R, Shewade HD, Malaisamy M. Truenat MTB assays for pulmonary tuberculosis and rifampicin resistance in adults and adolescents. *Cochrane Database of Systematic Reviews*. 2025(3).[Google Scholar]
16. Inbaraj LR, Srinivasalu VA, Narayanan MK, Bhaskar A, Daniel J, Scandrett K, Korobitsyn A, Ismail N, Takwoingi Y. Diagnostic accuracy of low-complexity, manual nucleic acid amplification tests for the detection of pulmonary and extrapulmonary tuberculosis in adults and adolescents: a systematic review and meta-analysis. *The Lancet Microbe*. 2025 Sep 19.[Google Scholar]
17. Kim J, Park BG, Lim DH, Jang WS, Nam J, Mihn DC, Lim CS. Development and evaluation of a multiplex loop-mediated isothermal amplification (LAMP) assay for differentiation of *Mycobacterium tuberculosis* and non-tuberculosis mycobacterium in clinical samples. *Plos one*. 2021 Jan 6;16(1):e0244753.[Google Scholar]
18. Kotei E, Thirunavukarasu R. A Comprehensive Review on Advancement in Deep Learning Techniques for Automatic Detection of Tuberculosis from Chest X-ray Images: E. Kotei, R. Thirunavukarasu. *Archives of computational methods in engineering*. 2024 Jan;31(1):455-74.[Google Scholar]
19. Park JH, Choe J, Bae M, Choi S, Jung KH, Kim MJ, Chong YP, Lee SO, Choi SH, Kim YS, Woo JH. Clinical characteristics and radiologic features of immunocompromised patients with pauci-bacillary pulmonary tuberculosis receiving delayed diagnosis and treatment. *In Open forum infectious diseases* 2019 Feb (Vol. 6, No. 2, p. ofz002). US: Oxford University Press.[Google Scholar]
20. Vayr F, Martin-Blondel G, Savall F, Soulat JM, Deffontaines G, Herin F. Occupational exposure to human *Mycobacterium bovis* infection: A systematic review. *PLoS neglected tropical diseases*. 2018 Jan 16;12(1):e0006208.[Google Scholar]
21. Mlangeni N, Malotle M, Made F, Ramodike J, Sikweyiya Y, Du Preez C, Thompson NS, Zungu M. Factors associated with TB screening among agricultural workers in Limpopo Province, South Africa. *Global Health Action*. 2023 Dec 31;16(1):2162227.[Google Scholar]
22. Tibebu M, Mekonnen W, Awoke T, Gebre-Selassie S, Yamuah L. A high prevalence of tuberculosis among dairy farm workers in Addis Ababa and its surroundings. *Journal of Mycobacterial Diseases*. 2014;4:e1000139. [Google Scholar]
23. Pratiwi RD, Pramono D. Socio-economic and environmental risk factors of tuberculosis in wonosobo, central Java, Indonesia.[Google Scholar]
24. Lönnroth K, Jaramillo E, Williams BG, Dye C, Raviglione M. Drivers of tuberculosis epidemics: the role of risk factors and social determinants. *Social science & medicine*. 2009 Jun 1;68(12):2240-6.[Google Scholar]
25. Ahn DI. Addressing poverty in TB control: options for national TB control programmes. *World Health Organization*; 2005 Dec 31.[Google Scholar]
26. Yiengprugsawan V, Lim LL, Carmichael GA, Seubsman SA, Sleigh AC. Tracking and decomposing health and disease inequality in Thailand. *Annals of Epidemiology*. 2009 Nov 1;19(11):800-7.[Google Scholar]
27. Mujtaba MA, Richardson M, Shahzad H, Javed MI, Raja GK, Shaiq PA, Haldar P, Saeed S. Demographic and Clinical Determinants of Tuberculosis and TB Recurrence: A Double-Edged Retrospective Study from Pakistan. *Journal of Tropical Medicine*. 2022;2022(1):4408306. [Google Scholar]
28. Kirenga BJ, Sengooba W, Muwonge C, Nakiyingi L, Kyaligonza S, Kasozi S, Mugabe F, Boeree M, Joloba M, Okwera A. Tuberculosis risk factors among tuberculosis patients in Kampala, Uganda: implications for tuberculosis control. *BMC public health*. 2015 Jan 21;15(1):13.[Google Scholar]
29. Ticlla MR, Hella J, Hiza H, Sasamalo M, Mhimbira F, Rutaiwa LK, Droz S, Schaller S, Reither K, Hilty M, Comas I. The sputum microbiome in pulmonary tuberculosis and its association with disease manifestations: a cross-sectional study. *Frontiers in microbiology*. 2021 Aug 20;12:633396.[Google Scholar]
30. Luies L, Du Preez I. The echo of pulmonary tuberculosis: mechanisms of clinical symptoms and other disease-induced systemic complications. *Clinical microbiology reviews*. 2020 Sep 16;33(4):10-128.[Google Scholar]
31. Park HY, Suh GY, Chung MP, Kim H, Kwon OJ, Chung MJ, Kim TS, Lee KS, Koh WJ. Comparison of clinical and radiographic characteristics between nodular bronchiectatic form of nontuberculous mycobacterial lung disease and diffuse panbronchiolitis. *Journal of Korean medical science*. 2009 Jun 1;24(3):427-32. [Google Scholar]
32. Chakradhar P, Veerasekharaiah M, Chakradhar D. A prospective study of aetiological profile of cavitary lesion on CXR of patients attending to department of pulmonology of tertiary care hospital. *J. Evid. Based Med. Healthc*. 2019; 6(5), 298-303.[Google Scholar]
33. Vuong MF, Hollingshead CM, Waymack JR. Aspergillosis. *In StatPearls [Internet]* 2023 Feb 22. StatPearls Publishing.[Google Scholar]
34. Jigan SI, Nagamoti JM, Hoti SL, Nagamoti MB, Kundekar PS, Carvalho A, Pillai HP. Association of Mycotic Lung

- Infections with Multidrug-resistant Tuberculosis and Immunocompromised Status of Patients. *Journal of Pure & Applied Microbiology*. 2026 Mar 1;20(1):817. [Google Scholar]
35. Solanki P, Jayant S, Singh KG, Tiwari K, Paul R, Singh K. Clinical correlation and analysis of fungal co-infections in pulmonary tuberculosis patients. [Google Scholar]
36. Al-Rifai RH, Pearson F, Critchley JA, Abu-Raddad LJ. Association between diabetes mellitus and active tuberculosis: A systematic review and meta-analysis. *PloS one*. 2017 Nov 21;12(11):e0187967. [Google Scholar]
37. Jeon CY, Murray MB. Diabetes mellitus increases the risk of active tuberculosis: a systematic review of 13 observational studies. *PLoS medicine*. 2008 Jul;5(7):e152. [Google Scholar]
38. Foe-Essomba JR, Kenmoe S, Tchatchouang S, Ebogo-Belobo JT, Mbagi DS, Kengne-Ndé C, Mahamat G, Kame-Ngasse GI, Noura EA, Mbongue Mikangue CA, Feudjio AF. Diabetes mellitus and tuberculosis, a systematic review and meta-analysis with sensitivity analysis for studies comparable for confounders. *PLoS One*. 2021 Dec 10;16(12):e0261246. [Google Scholar]
39. Nayyar A, Shrivastava R, Jain S. Transfer Learning for Automated Two-class Classification of Pulmonary Tuberculosis in Chest X-Ray Images. *Current Medicinal Chemistry*. 2026 Feb;33(6):1264-83. [Google Scholar]
40. Nachiappan AC, Rahbar K, Shi X, Guy ES, Mortani Barbosa Jr EJ, Shroff GS, Ocazionez D, Schlesinger AE, Katz SI, Hammer MM. Pulmonary tuberculosis: role of radiology in diagnosis and management. *Radiographics*. 2017 Jan;37(1):52-72. [Google Scholar]
41. Pinto LM, Pai M, Dheda K, Schwartzman K, Menzies D, Steingart KR. Scoring systems using chest radiographic features for the diagnosis of pulmonary tuberculosis in adults: a systematic review. *European Respiratory Journal*. 2013 Aug;42(2):480-94. [Google Scholar]
42. Van't Hoog A, Viney K, Biermann O, Yang B, Leeflang MM, Langendam MW. Symptom-and chest-radiography screening for active pulmonary tuberculosis in HIV-negative adults and adults with unknown HIV status. *Cochrane Database of Systematic Reviews*. 2022(3). [Google Scholar]
43. Feyisa DW, Ayano YM, Debelee TG, Schwenker F. Weak localization of radiographic manifestations in pulmonary tuberculosis from chest X-ray: a systematic review. *Sensors*. 2023 Jul 29;23(15):6781. [Google Scholar]
44. Nagai K, Horita N, Yamamoto M, Tsukahara T, Nagakura H, Tashiro K, Shibata Y, Watanabe H, Nakashima K, Ushio R, Ikeda M. Diagnostic test accuracy of loop-mediated isothermal amplification assay for *Mycobacterium tuberculosis*: systematic review and meta-analysis. *Scientific reports*. 2016 Dec 13;6(1):39090. [Google Scholar]