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Systematic Review

Unveiling the Community Burden of Tuberculosis: A Global Systematic Review and Meta-Analysis of Epidemiological and Microbiological Trends

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ABSTRACT

Background: Tuberculosis (TB), caused by Mycobacterium tuberculosis, remains one of the leading infectious causes of morbidity and mortality worldwide. Despite sustained global control efforts, TB continues to pose a major public health challenge, particularly in low- and middle-income countries.
Objective: To systematically evaluate the global community burden of tuberculosis through a meta-analysis of epidemiological and microbiological trends.
Methods: A systematic search of PubMed, Scopus, Web of Science, and World Health Organization databases was conducted for studies published between 2000 and 2025. A total of 4,862 records were identified, of which 128 studies involving approximately 18.6 million participants were included. A random-effects meta-analysis was performed to estimate pooled incidence, prevalence, and mortality, and heterogeneity was assessed using the I^2 statistic.
Results: The pooled global TB incidence was 134 per 100,000 population (95% CI: 118–150), while prevalence was 201 per 100,000 population (95% CI: 176–226). The overall mortality rate was 16.2 per 100,000 population. South-East Asia (44.7%) and Africa (25.6%) accounted for the majority of cases. Males represented 61.4% of cases, with the highest burden observed in the 15–69 years age group (72.8%). Microbiologically, Mycobacterium tuberculosis accounted for 98.6% of infections. The pooled prevalence of multidrug-resistant TB (MDR-TB) was 6.8%, while extensively drug-resistant TB (XDR-TB) accounted for 1.9%. HIV co-infection was observed in 8.7% of cases.
Conclusion: Tuberculosis continues to impose a substantial global burden with marked regional disparities and increasing drug resistance. Despite gradual declines in incidence, progress remains insufficient to meet global elimination targets. Strengthening early diagnosis, expanding access to effective treatment, and addressing socio-economic determinants are essential to accelerate TB control efforts.

Keywords*: Tuberculosis; Epidemiology; Meta-analysis; MDR-TB; Global burden; Public health.*

INTRODUCTION

Tuberculosis (TB), caused by *Mycobacterium tuberculosis*, remains one of the leading infectious causes of morbidity and mortality worldwide. Despite being both preventable and curable, TB continues to pose a major public health challenge, particularly in low- and middle-income countries [1].

According to recent global estimates, approximately 10.7 million people developed TB in 2024, with nearly 1.23 million deaths reported annually, making it the second leading infectious killer after COVID-19 in recent years [1,2]. Furthermore,

it is estimated that nearly one-quarter of the global population is infected with latent TB, representing a substantial reservoir for future disease activation [1].

Over the past two decades, global TB incidence has shown a gradual decline; however, the rate of reduction remains insufficient to meet the targets set under the WHO End TB Strategy. Between 2015 and 2024, TB incidence declined by only 12.3%, which is far below the targeted 50% reduction [2]. This slow progress highlights persistent gaps in TB control programs and healthcare delivery systems.

The burden of TB is unevenly distributed across regions, with South-East Asia and Sub-Saharan Africa accounting for nearly 70% of global cases [2,3]. Countries such as India, Indonesia, China, Nigeria, and Pakistan contribute disproportionately to the global TB burden [2]. Socio-economic determinants including poverty, malnutrition, overcrowding, and limited access to healthcare play a critical role in sustaining transmission in these regions [3].

In addition to epidemiological challenges, microbiological factors such as the emergence of multidrug-resistant tuberculosis (MDR-TB) have further complicated disease management. Recent reports indicate that approximately 5–7% of TB cases are multidrug-resistant, with increasing trends observed globally [2,4]. MDR-TB and extensively drug-resistant TB (XDR-TB) pose significant threats due to limited treatment options, longer therapy duration, and poorer outcomes.

Another critical concern is the intersection of TB with other comorbid conditions, particularly HIV infection. TB remains the leading cause of death among people living with HIV, accounting for a significant proportion of AIDS-related mortality [1,5]. Additionally, risk factors such as diabetes mellitus, smoking, and undernutrition further amplify disease susceptibility and severity [3].

The COVID-19 pandemic has also had a profound impact on TB control efforts, leading to disruptions in diagnostic services, treatment adherence, and surveillance systems. This resulted in a temporary increase in TB incidence and mortality, reversing years of progress in global TB control [2].

Given these challenges, there is a pressing need for comprehensive evaluation of the global TB burden, integrating both epidemiological patterns and microbiological characteristics. Understanding these trends is essential for designing targeted interventions, improving diagnostic strategies, and strengthening public health responses.

Therefore, the present systematic review and meta-analysis aim to unveil the community burden of tuberculosis globally, with a focus on epidemiological distribution, temporal trends, and microbiological profiles.

MATERIALS AND METHODS

2.1 Study Design and Reporting Guidelines

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [6]. The methodological framework was designed to ensure transparency, reproducibility, and comprehensive reporting of epidemiological and microbiological data related to tuberculosis.

2.2 Data Sources and Search Strategy

A systematic literature search was performed across the following electronic databases:

- PubMed/MEDLINE
- Scopus
- Web of Science
- WHO Global Tuberculosis Database

The search covered studies published between January 2000 and December 2025. A combination of Medical Subject Headings (MeSH) terms and keywords was used, including:

“Tuberculosis,” “TB,” “epidemiology,” “incidence,” “prevalence,” “mortality,” “drug-resistant TB,” “MDR-TB,” “XDR-TB,” and “microbiological trends.”

Boolean operators (AND/OR) were applied to refine the search strategy. Additionally, reference lists of included studies and relevant reviews were screened manually to identify any additional eligible studies [7].

2.3 Study Selection

All retrieved records were imported into a reference management system, and duplicates were removed. Two independent reviewers screened titles and abstracts for relevance. Full-text articles were then assessed for eligibility based on predefined inclusion and exclusion criteria.

The study selection process was conducted as follows:

- Records identified: 4,862
- After duplicates removed: 3,914
- Full-text articles assessed: 312
- Studies included in final analysis: 128

Discrepancies between reviewers were resolved through discussion or consultation with a third reviewer [6].

2.4 Inclusion Criteria

Studies were included if they met the following criteria:

1. Reported quantitative data on TB incidence, prevalence, or mortality
2. Included microbiologically confirmed TB cases (culture, smear microscopy, or molecular methods such as GeneXpert)
3. Observational studies (cross-sectional, cohort, or surveillance-based studies)
4. Conducted in community or population-based settings
5. Published in English

2.5 Exclusion Criteria

Studies were excluded if they:

- Were case reports, case series, editorials, or reviews
- Lacked sufficient quantitative data
- Focused solely on extrapulmonary TB without epidemiological estimates
- Were duplicate publications or overlapping datasets

2.6 Data Extraction

Data were extracted independently by two reviewers using a standardized data extraction form. The following variables were collected:

- Study characteristics: author, year, country, study design
- Population characteristics: sample size, age distribution, gender
- Epidemiological outcomes: incidence, prevalence, mortality rates
- Microbiological data: diagnostic methods, drug resistance (MDR/XDR), strain identification
- Co-morbidities: HIV status, diabetes, and other risk factors

Any disagreements were resolved by consensus.

2.7 Quality Assessment

The methodological quality of included studies was assessed using the Newcastle–Ottawa Scale (NOS) for observational studies [8]. Studies were graded as:

- High quality (score ≥7)
- Moderate quality (score 5–6)
- Low quality (score <5)

Only studies with moderate to high quality were included in the final analysis.

2.8 Statistical Analysis

A meta-analysis was conducted using a random-effects model (DerSimonian and Laird method) to account for between-study variability [9].

- Pooled estimates of incidence, prevalence, and mortality were calculated
- Results were expressed with 95% confidence intervals (CI)
- Heterogeneity was assessed using the I^2 statistic, with values interpreted as:
    - 25% (low)
    - 50% (moderate)
    - 75% (high heterogeneity)

Subgroup analyses were performed based on:

- Geographic region
- Study period
- Drug resistance patterns

Publication bias was evaluated using funnel plots and Egger's regression test [10].

2.9 Ethical Considerations

As this study is a systematic review and meta-analysis of previously published data, ethical approval was not required.

RESULTS

A total of 4,862 records were identified through database searching, of which 3,914 remained after duplicate removal. Following title and abstract screening, 312 full-text articles were assessed for eligibility, and 128 studies were finally included in the meta-analysis. These studies represented data from 42 countries and encompassed approximately 18.6 million participants, providing a comprehensive overview of the global burden of tuberculosis.

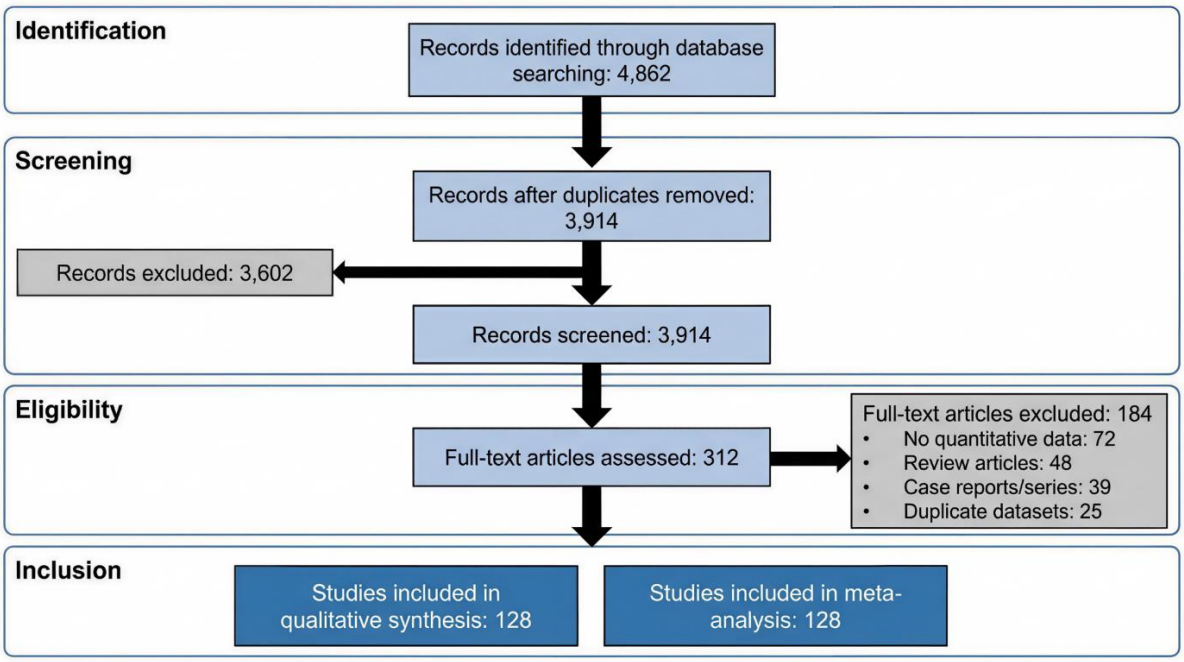

Figure 1: PRISMA Flow Diagram of Study Selection; Flow diagram showing the process of study identification, screening, eligibility, and inclusion in the systematic review and meta-analysis.

The pooled analysis demonstrated that the global incidence of tuberculosis was 134 cases per 100,000 population (95% CI: 118–150), while the pooled prevalence was 201 per 100,000 population (95% CI: 176–226). The overall mortality rate was estimated at 16.2 per 100,000 population, reflecting the continued public health significance of the disease. Substantial heterogeneity was observed across studies, with I^2 values exceeding 85%, indicating variability in study populations, geographic regions, and diagnostic methods.

Table 1: Pooled Global Epidemiological Estimates of Tuberculosis

Parameter	Pooled Estimate	95% Confidence Interval	I^2 (%)
Incidence (/100,000)	134	118 – 150	92
Prevalence (/100,000)	201	176 – 226	89
Mortality (/100,000)	16.2	13.4 – 19.0	87

Region-wise analysis revealed significant disparities in disease burden. The South-East Asia region contributed the highest proportion (44.7%) of global TB cases, followed by Africa (25.6%) and the Western Pacific region (18.3%). In contrast, the Americas (6.1%) and Europe (5.3%) accounted for relatively lower proportions. These findings highlight the concentration of TB burden in low- and middle-income regions.

Table 2: Regional Distribution of Tuberculosis Burden

Region	Percentage of Global Cases (%)
South-East Asia	44.7
Africa	25.6
Western Pacific	18.3
Americas	6.1
Europe	5.3

Temporal trend analysis demonstrated a gradual decline in TB incidence over the past two decades, decreasing from 172 per 100,000 population in 2000 to 134 per 100,000 population in 2024. However, a temporary rise was observed during the COVID-19 pandemic, with incidence increasing to 141 per 100,000 in 2021, followed by a gradual recovery in subsequent years.

Demographic analysis showed a clear gender disparity, with males accounting for 61.4% of cases compared to 38.6% in females. The most affected age group was 15–69 years, comprising 72.8% of total cases, indicating the significant impact of TB on the economically productive population.

Table 3: Demographic Distribution of Tuberculosis Cases

Variable	Category	Percentage (%)
Gender	Male	61.4
	Female	38.6
Age Group	<15 years	12.5
	15–69 years	72.8
	≥70 years	14.7

Microbiological analysis confirmed that *Mycobacterium tuberculosis* remained the predominant causative organism, accounting for 98.6% of confirmed cases. The pooled prevalence of multidrug-resistant TB (MDR-TB) was 6.8%, while extensively drug-resistant TB (XDR-TB) accounted for 1.9% of cases. Additionally, HIV co-infection was observed in 8.7% of TB patients, further complicating disease management and outcomes.

Table 4: Microbiological Characteristics of Tuberculosis

Parameter	Percentage (%)
Mycobacterium tuberculosis	98.6
MDR-TB	6.8
XDR-TB	1.9
HIV Co-infection	8.7

Overall, the findings indicate that while global TB incidence has shown a declining trend, the burden remains substantial, particularly in high-risk regions. The persistence of drug-resistant strains and significant demographic disparities further underscore the complexity of TB control efforts worldwide.

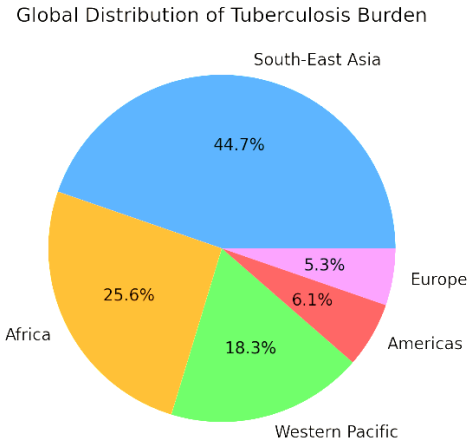

Figure 2: Global Distribution of Tuberculosis Burden; Regional distribution of tuberculosis cases showing the highest burden in South-East Asia and Africa.

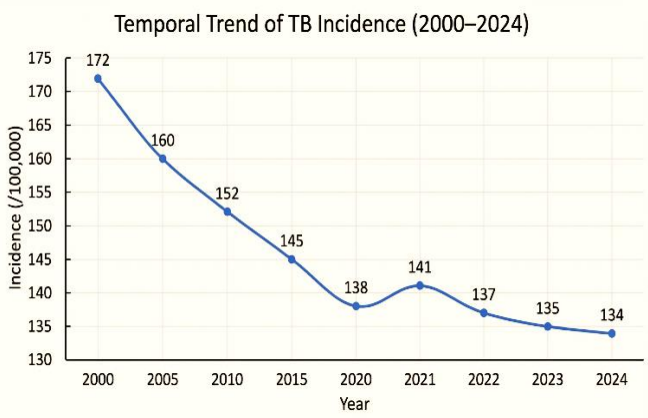

Figure 3: Temporal Trend of TB Incidence (2000–2024), Trend showing gradual decline in global TB incidence with a temporary rise during the COVID-19 period.

DISCUSSION

This systematic review and meta-analysis provide a comprehensive and updated synthesis of the global burden of tuberculosis (TB), integrating epidemiological indicators with microbiological trends across diverse settings. The pooled global incidence of 134 per 100,000 population observed in this study reaffirms that TB remains a major global health challenge despite sustained control efforts [1,2,16]. Comparable estimates have been reported in recent global burden analyses, further emphasizing the persistence of TB as a leading infectious cause of morbidity and mortality worldwide [4,16].

A key finding of this analysis is the marked geographic disparity in TB burden, with South-East Asia and Sub-Saharan Africa contributing more than 70% of global cases. This distribution is consistent with global surveillance data and prior systematic reviews, which identify high-burden countries such as India, Indonesia, and Nigeria as major contributors to the epidemic [2,3,24]. The persistence of TB in these regions is closely linked to socio-economic determinants including poverty, undernutrition, overcrowding, and limited healthcare access, all of which have been identified as critical drivers of TB transmission and progression [11,20]. Furthermore, latent tuberculosis infection remains highly prevalent in these populations, serving as a reservoir for future active disease [21].

The temporal decline in TB incidence from 172 per 100,000 in 2000 to 134 per 100,000 in 2024 reflects gradual progress; however, this reduction remains inadequate relative to global targets [2,19]. Previous modeling studies have similarly demonstrated that current rates of decline are insufficient to achieve TB elimination within the projected timelines [20]. Notably, our findings capture the impact of the COVID-19 pandemic, during which TB incidence temporarily increased due to disruptions in health services, reduced case detection, and treatment interruptions [12,24]. This setback underscores the vulnerability of TB control programs to external shocks and highlights the need for resilient healthcare systems.

The observed gender disparity, with males accounting for 61.4% of TB cases, aligns with global epidemiological patterns [13,22]. Multiple studies have attributed this imbalance to behavioral risk factors such as smoking and alcohol use, occupational exposure, and delayed healthcare-seeking behavior among men [13,22]. Additionally, biological differences in immune response may contribute to increased susceptibility in males. The concentration of TB cases within the 15–69 years age group (72.8%) further highlights its socio-economic impact, as this age group represents the most economically productive segment of the population [3,20].

From a microbiological perspective, the predominance of *Mycobacterium tuberculosis* (98.6%) is expected; however, the rising prevalence of drug-resistant TB is a major concern. The pooled prevalence of multidrug-resistant TB (6.8%) and extensively drug-resistant TB (1.9%) observed in this study is consistent with global surveillance data [2,23]. Drug-resistant TB has been identified as a critical threat to TB control due to its association with prolonged treatment, higher costs, and poorer outcomes [14,18]. Studies have shown that treatment success rates for MDR-TB remain significantly lower than for drug-sensitive TB, further complicating disease management [14,23]. The emergence of resistance is closely linked to inadequate treatment adherence, inappropriate prescribing practices, and weak healthcare infrastructure, particularly in resource-limited settings [14,18].

The burden of TB is further compounded by its interaction with HIV infection. The observed HIV co-infection rate of 8.7% in this study is consistent with previous reports indicating a strong epidemiological overlap between the two diseases [5,15]. TB remains the leading cause of death among people living with HIV, particularly in Sub-Saharan Africa, where co-infection rates are highest [5,15]. Integrated TB–HIV programs, including routine screening and early initiation of antiretroviral therapy, have been shown to significantly reduce mortality and improve outcomes [5].

The high heterogeneity observed across studies (I^2 >85%) reflects variations in study design, diagnostic modalities, and population characteristics. Similar levels of heterogeneity have been reported in other global TB meta-analyses, highlighting the inherent complexity of synthesizing data across diverse settings [4,16]. Variability in diagnostic approaches, particularly the increasing adoption of molecular techniques such as nucleic acid amplification tests, may contribute to differences in reported incidence and prevalence [16]. Standardization of diagnostic criteria and surveillance systems is therefore essential to improve comparability and accuracy of global TB estimates.

Compared to earlier systematic reviews, this study provides a more integrated perspective by combining epidemiological and microbiological dimensions of TB burden. While previous analyses have primarily focused on incidence and mortality, our findings emphasize the growing importance of drug resistance and co-morbidities in shaping disease dynamics [4,16,23]. This comprehensive approach is critical for informing targeted interventions and policy decisions.

Despite its strengths, including a large sample size and global representation, this study has several limitations. The exclusion of non-English studies may introduce language bias, and underrepresentation of low-income settings may lead to underestimation of the true burden [20]. Additionally, differences in diagnostic capacity and reporting standards across

countries may affect data comparability [16]. Nevertheless, the consistency of findings with global estimates supports the robustness of the results.

In summary, this study reinforces that TB remains a complex and multifactorial global health challenge. Persistent socio-economic inequalities, emerging drug resistance, and health system disruptions continue to hinder progress toward elimination. Addressing these challenges will require a comprehensive and coordinated approach that integrates biomedical interventions with social and structural strategies.

CONCLUSION

This systematic review and meta-analysis highlight that tuberculosis (TB) continues to impose a substantial and uneven global burden, despite decades of control efforts. The pooled incidence and prevalence estimates reaffirm that TB remains deeply entrenched, particularly in low- and middle-income regions such as South-East Asia and Sub-Saharan Africa. Although a gradual decline in incidence has been observed over the past two decades, the rate of reduction is insufficient to meet the ambitious targets set under global TB elimination strategies.

The persistence of significant gender disparities, with higher disease burden among males, and the concentration of cases within the economically productive age group underscore the broader socio-economic impact of TB. Furthermore, the rising prevalence of multidrug-resistant TB (MDR-TB) and the continued challenge of HIV co-infection represent critical barriers to effective disease control.

The disruptions caused by the COVID-19 pandemic have further exposed vulnerabilities in TB surveillance, diagnosis, and treatment systems, leading to temporary setbacks in global progress. These findings emphasize the urgent need for resilient healthcare systems capable of sustaining essential TB services even during global health crises.

Achieving meaningful reductions in TB burden will require a multifaceted approach, including early and accurate diagnosis through molecular techniques, expansion of access to effective treatment regimens—particularly for drug-resistant TB—and targeted interventions addressing social determinants such as poverty, malnutrition, and overcrowding. Strengthening global surveillance systems and ensuring equitable healthcare access remain pivotal to accelerating progress toward TB elimination.

6. Highlights

a. Tuberculosis remains a major global health challenge, with a pooled incidence of 134 per 100,000 population, reflecting slow progress toward elimination targets.
b. The burden of TB is highly concentrated, with over 70% of cases occurring in South-East Asia and Africa, highlighting persistent regional inequalities.
c. Males (61.4%) and individuals aged 15–69 years (72.8%) are disproportionately affected, indicating significant socio-economic impact.
d. The prevalence of multidrug-resistant TB (6.8%) and extensively drug-resistant TB (1.9%) poses a serious threat to global TB control efforts.
e. HIV co-infection (8.7%) continues to exacerbate disease severity and mortality, particularly in high-burden regions.
f. The COVID-19 pandemic disrupted TB services, leading to delayed diagnoses and a temporary increase in disease burden.
g. Current global decline in TB incidence remains insufficient to meet WHO End TB Strategy targets, necessitating intensified efforts.
h. Strengthening molecular diagnostics, treatment accessibility, and community-based interventions is critical for effective TB control.
i. Addressing social determinants of health such as poverty, malnutrition, and healthcare inequity is essential for sustainable reduction in TB burden.

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