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Prevalence of tuberculosis among healthcare workers in India: a systematic review and meta-analysis

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Abstract

Tuberculosis (TB) poses a significant occupational hazard for healthcare workers (HCWs) in India, a country bearing a substantial portion of the global TB burden. This systematic review and meta-analysis aim to determine the prevalence of TB among HCWs in India. Analyzing ten studies up to 2024, we found a pooled prevalence of 2391.6 cases per 100,000 individuals, underscoring the critical occupational risk. Factors contributing to this high prevalence include inadequate ventilation, insufficient personal protective equipment, and frequent exposure to multidrug-resistant TB strains. Our findings emphasize the urgent need for stringent infection control measures, routine TB screening, and comprehensive educational programs. Policy recommendations include developing national TB screening guidelines and improving healthcare infrastructure. Protecting HCWs is crucial to achieving India's goal of TB elimination by 2025.

Key words: healthcare workers, tuberculosis, active TB.

Introduction

Tuberculosis (TB) remains one of the most critical public health challenges globally, particularly in countries with high endemic rates such as India, which alone accounts for approximately one-fourth of the global TB burden [1]. This infectious disease, caused by Mycobacterium tuberculosis, is predominantly spread through airborne particles, making it a significant occupational hazard, especially in healthcare settings. The incidence of TB among healthcare workers (HCWs) is alarmingly high, reflecting broader systemic vulnerabilities within healthcare infrastructures [2].

HCWs are at a heightened risk due to increased frequency of exposure to the pathogen, often compounded by the presence of multidrug-resistant (MDR) and extensively drug-resistant (XDR) TB strains. These strains not only complicate treatment but also highlight the critical need for stringent infection control measures in healthcare facilities [3]. Studies have indicated that TB incidence rates in HCWs are three times higher than those observed in the general population. This increased incidence is particularly pronounced in settings with inadequate ventilation, poor administrative controls, and insufficient personal protective equipment (PPE) [4].

Despite the acknowledged risks, comprehensive epidemiological data on TB among HCWs in India is sparse and often inconsistent. The variability in findings across studies can be attributed to differences in study design, local TB prevalence rates, and the specific healthcare settings examined. Most current literature focuses on localized data or specific subgroups of HCWs,

thus limiting the generalizability of the results [5]. Furthermore, there is a notable gap in systematic efforts to synthesize these findings to form actionable insights and robust policy frameworks that can be applied at a national or regional level. The objective of current systematic review is to find the prevalence of Tuberculosis among HCWs in India. This effort is aligned with the World Health Organization (WHO)'s End TB Strategy, which envisions significant reductions in TB incidence and mortality by the year 2035 along with India's ambitious achievement to move towards TB Elimination by 2025 [6].

Methods

Search strategy

Our systematic literature search was executed across multiple electronic databases including PubMed, Scopus, and Embase, complemented by the first ten pages of Google Scholar results, to ensure comprehensive coverage of available literature on tuberculosis among healthcare workers. The search incorporated both MeSH and free-text terms with the keywords "tuberculosis" and "health care workers," using Boolean operators AND and OR to refine the search queries. We focused on articles published from the inception of each database to March 31, 2024, and limited our review to works published in English to maintain consistency in data analysis. Additionally, the reference lists of all included studies were scrutinized to capture further relevant studies potentially missed in the initial database search. This meticulous and broad-scoped search strategy was designed to gather the most extensive and pertinent data set for our review on tuberculosis risks and controls among healthcare workers in India.

Inclusion and exclusion criteria

In this systematic review, we exclusively included cross-sectional studies. The study population comprised healthcare workers in India, specifically targeting those who are routinely exposed to infectious agents. This included Doctors, Medical Students, Medical Residents, Nurses, Laboratory Technicians, and other Health Workers. The primary outcomes of interest were cases of diagnosed tuberculosis, both pulmonary and extrapulmonary types, among the healthcare workers. Inclusion was limited to participants who were either currently receiving anti-tuberculosis treatment (ATT) or had received treatment during their employment period. The diagnosis had to be confirmed via Sputum Acid-Fast Bacillus (AFB) smear, NAAT or culture tests. We specifically excluded cases identified solely through latent TB infections, presumptive symptoms, or X-ray findings without microbiological confirmation.

Data extraction

Screening of studies

Title and abstract screening was meticulously carried out by two independent authors (RN and NP). They assessed the studies retrieved from the systematic search according to the predefined eligibility criteria. Articles identified at this stage were advanced for full-text screening. Disagreements concerning the inclusion of any study for full-text review were resolved through discussion to reach consensus among the co-authors. In instances where a conflict persisted, a third co-author (AD), was consulted to make a decisive evaluation on the inclusion of the study.

Full-text screening and data extraction

Following the initial screening, the authors (RN and NP), reviewed the full-text articles deemed potentially eligible to confirm suitability and extract pertinent data. Any disagreements at this stage were again addressed through discussion among the authors, with third author (AD) resolving any unresolved issues. The data extracted from each qualified study were systematically organized into a Microsoft Excel spreadsheet for subsequent analysis. Extracted information included the author's initials, geographic location of the study, year of publication, study design, and specific outcomes relevant to our review, such as the number of TB cases (pulmonary and extrapulmonary) and the total sample size of healthcare workers. This comprehensive process of literature search, study screening, and data extraction was aligned with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA-2020) guidelines to ensure methodological rigor and transparency in reporting.

Quality assessment of the studies

The assessment of risk of bias in the included studies was meticulously conducted by two independent authors, AD and RN, utilizing the Joanna Briggs Institute (JBI) critical appraisal tool for prevalence studies.

Statistical analysis

The prevalence of tuberculosis among healthcare workers was calculated by dividing the number of individuals with positive smear or culture results by the total number of participants included in each study. This prevalence is reported per 100,000 individuals. We utilized a random effects model, based on the DerSimonian and Laird method, to calculate the pooled prevalence and 95% confidence intervals (CIs). Heterogeneity among studies was quantified using the Chi-square-based Q statistic and the I^2 test, with significance assessed at two-sided P values. Subgroup analyses were conducted based on different types of healthcare workers

(e.g., doctors, nurses, laboratory technicians), quality of study and types of TB (pulmonary vs. extrapulmonary). Sensitivity analyses were performed to assess the influence of individual studies on the overall meta-analysis outcome, providing insights into the stability and reliability of the synthesized data. Publication bias was evaluated using a funnel plot, and the presence of small study effects was statistically tested with Egger's test. In cases where publication bias was detected, we applied the trim and fill method to estimate the effect of this bias and adjust for it. Statistical significance was set at $P < 0.05$. We conducted the meta-analysis using STATA® software (version 18, STATA Corp.).

Results

In this systematic review addressing tuberculosis prevalence among healthcare workers, our search across five databases yielded 398 records, which, after the removal of 188 duplicates, left 210 for title and abstract screening. Of these, 29 full-text articles were assessed for eligibility, leading to the exclusion of 19 based on inappropriate methodology (10), unsuitable outcomes (3), and incompatible study design (6). The rigorous selection process culminated in 10 studies meeting all inclusion criteria for the final analysis. The complete selection process, from the initial database search to the final study inclusion, is visually summarized in the PRISMA flow chart provided (Figure 1).

Table 1 provides a summary of the prevalence estimates of TB among HCWs in India, as reported in various studies [7-16] conducted between 2004 and 2023. The diagnosed TB cases in these studies range from 5 to 125, with total sample sizes varying from 130 to 60,363 health care workers. The highest prevalence was observed in the 2023 study by Ahmad et al [16], while the lowest prevalence was reported in the 2004 study by Gopinatha et al. [7] Geographically, four studies were conducted in southern India, four in northern India, and two in Maharashtra. Most studies focused on doctors, with two studies including nurses and three studies involving laboratory technicians.

The quality of the studies [7-16] included in our meta-analysis, assessed using the Joanna Briggs Institute (JBI) tool, varied, with five studies rated as 'Good', four studies were judged as 'Moderate', and only one study was deemed 'Poor' (Table 2).

A meta-analysis (Figure 2) was performed to assess the prevalence of tuberculosis among healthcare workers across the studies included. Collectively, these studies encompassed a sample size of 81,288 individuals, out of which 330 were identified as positive cases of tuberculosis. Utilizing the random effects model, the pooled prevalence was calculated to be 2391.62 cases per 100,000 individuals with a 95% confidence interval (CI) of 1415.58 to 3601.34. The heterogeneity among the studies was substantial, as evidenced by an I^2 value of 97.58%, indicating that the variability in study outcomes was significant. This was further

supported by a Cochrane Q statistic with a p-value less than 0.01, confirming the presence of heterogeneity.

In our meta-analysis exploring TB prevalence among healthcare workers, we conducted subgroup analyses (Figures 3 and 4) that revealed key insights into the heterogeneity across the pooled data. Professional categories—doctors, laboratory technicians, and nurses—were analyzed, showing that doctors had a TB prevalence of 2006.18 per 100,000 from 2,382 individuals, laboratory technicians had a notably higher prevalence of 6468.31 per 100,000 from a much smaller sample of 230, and nurses had a prevalence of 2726.83 per 100,000 from 353 individuals; heterogeneity levels were 70.76%, 95.73%, and 83.41% respectively. Further stratifying the studies by methodological quality ('good', 'moderate', and 'poor'), we found 'good' quality studies reported a prevalence of 6135.77 per 100,000 with a heterogeneity of 93.06%, while 'moderate' quality studies showed a prevalence of 765.23 per 100,000 and an I^2 of 91.41%; the single 'poor' quality study prevented heterogeneity assessment. These findings, revealing variations in TB prevalence among different healthcare worker groups and across study qualities, highlight the multifaceted nature of TB risk in healthcare settings and underscore the impact of study design on outcome variability.

Sensitivity analysis

In our meta-analysis, we conducted a sensitivity analysis (Figure 5) to ascertain the stability of the pooled prevalence of tuberculosis among healthcare workers. Employing the Freeman-Tukey double arcsine transformation, we recalculated the effect size with each study sequentially omitted, which ensured variances remained stable and appropriately weighted. The analysis indicated no single study disproportionately influenced the pooled results (Figure 5), with all recalculated prevalence rates exhibiting significant p-values ($p < 0.001$).

Publication bias

In evaluating publication bias within our meta-analysis on tuberculosis prevalence among healthcare workers, we implemented a funnel plot for visual inspection and the Egger's regression test for statistical confirmation, with results indicating a slight potential for small-study effects ($p = 0.0063$). To further ensure the robustness of our findings, we conducted a trim-and-fill analysis, which did not identify any missing studies, suggesting an absence of publication bias (Figure 6).

Discussion

This systematic review aimed to summarize the available evidence on TB among healthcare HCWs in India. Our meta-analysis reveals a significantly higher prevalence of TB among HCWs in India, with a pooled prevalence of 2,391.6 cases per 100,000 individuals. This finding underscores the occupational hazards faced by HCWs and the urgent need for enhanced TB control measures in healthcare settings. The review included ten studies conducted in India up to the year 2024.

The prevalence of TB among HCWs in our study aligns with findings from previous research, highlighting the persistent occupational risk in healthcare settings. For example, Gopinath et al. documented an incidence of TB among HCWs similar to the general population, with focal outbreaks indicating nosocomial transmission. Nurses and medical students had incidences two to four times higher than the general population in certain [7]. Similarly, Basavaraj et al. reported a TB incidence rate of 3,279 cases per 100,000 person-years among medical trainees at a public hospital in Pune, India, emphasizing the high risk due to frequent patient contact and the presence of drug-resistant TB strains [12]. Sharma et al. found that internal medicine residents were particularly vulnerable due to intensive exposure to infectious aerosols, poor ventilation, and inadequate use of PPE [14]. These consistent findings underscore the need for comprehensive TB control strategies, including stringent infection control measures, regular screening, and continuous education on TB prevention for HCWs.

Frequent and close contact with TB patients is a primary risk factor, especially for those working in high-risk departments such as general medicine and radiology [7]. Medical trainees, particularly interns and residents, face heightened risk due to prolonged exposure during their rotations. The presence of multidrug-resistant TB (MDR-TB) further exacerbates this risk, as evidenced by the higher incidence of drug-resistant TB cases among medical trainees [12]. Additional factors include inadequate use of personal protective equipment (PPE), such as N95 masks, and suboptimal implementation of infection control measures [15]. Occupational stress, poor nutrition, and adverse drug reactions during TB treatment also contribute to the increased vulnerability of HCWs, underscoring the need for comprehensive preventive strategies [8,11].

Subgroup analyses by professional categories showed distinct differences in TB prevalence: doctors had a prevalence of 2,006.18 per 100,000 (heterogeneity 70.76%), laboratory technicians had the highest prevalence at 6,468.31 per 100,000 (heterogeneity 95.73%), and nurses had a prevalence of 2,726.83 per 100,000 (heterogeneity 83.41%). Further stratification by study quality revealed that 'Good' quality studies reported a prevalence of 6,135.77 per 100,000 (heterogeneity 93.06%), while 'Moderate' quality studies showed a prevalence of

765.23 per 100,000 (heterogeneity 91.41%). The single 'Poor' quality study could not be assessed for heterogeneity.

To mitigate the high prevalence of TB among HCWs, several interventions are essential. Firstly, strict adherence to infection control measures, including the consistent use of appropriate PPE, is crucial [7]. Regular and routine TB screening for all HCWs, particularly those in high-exposure roles, can facilitate early detection and treatment, thereby reducing transmission [12]. Educational programs that raise awareness about TB risks and the importance of protective measures are vital [14]. Enhancing ventilation systems in healthcare settings to reduce airborne transmission and ensuring the isolation of TB patients are also critical steps [15]. Additionally, providing support for HCWs through access to adequate nutrition, mental health services, and management of work-related stress can help maintain overall health and reduce susceptibility to TB [8,11]. The Ministry of Health and Family Welfare in India, along with the WHO, has identified HCWs as a key population at greater risk of acquiring TB. They advocate for routine TB screening as part of health screening and medical fitness protocols and emphasize preventing nosocomial TB through active surveillance and systematic screening for early detection among HCWs.

At the policy level, several actions can be taken to reduce TB prevalence among HCWs. Developing and implementing national guidelines for routine TB screening and surveillance is critical [12]. These guidelines should focus on high-risk groups such as medical trainees and those working in high-exposure departments. Mandatory infection control training programs should be established to ensure all HCWs are well-versed in TB prevention practices [14]. Investment in healthcare infrastructure, such as improved ventilation systems and dedicated isolation rooms, is necessary to create safer work environments [15]. Policies should also support HCWs by providing free access to TB treatment, regular health check-ups, and mental health services [11]. Lastly, nationwide awareness and education campaigns can help reduce stigma associated with TB and encourage early diagnosis and treatment, ultimately leading to better health outcomes for HCWs and the broader community [7].

Our study's primary strength lies in its comprehensive and systematic review of TB prevalence among HCWs in India, covering literature up to 2024. This provides a current and relevant assessment of the TB burden among HCWs. Robust statistical methods, including subgroup and sensitivity analyses, enhance the reliability of our findings. However, the study has several limitations. High heterogeneity (I^2 = 97.58%) indicates significant variability in study outcomes, affecting generalizability. The exclusion of grey literature may have led to the omission of relevant data. Retrospective studies may suffer from recall bias, and underreporting of TB cases due to stigma could underestimate the true prevalence. While our analysis indicated no significant publication bias, the potential for small-study effects remains.

Future research should focus on conducting longitudinal studies to track TB incidence and intervention effectiveness among HCWs over time. Research on high-risk subgroups, such as laboratory technicians, is needed to identify specific risk factors and protective measures. Evaluating the impact of policy changes and conducting economic evaluations can help optimize resource allocation and justify investments in TB prevention.

Conclusions

This systematic review and meta-analysis reveal a significantly higher prevalence of TB among HCWs in India, with 2,391.6 cases per 100,000 individuals. To mitigate this risk, strict infection control, regular screening, continuous education, and improved healthcare infrastructure are essential. Policy recommendations focus on national TB screening guidelines, mandatory training, and investment in healthcare facilities. As we aim to end the TB epidemic by 2025, protecting our HCWs is essential. By prioritizing their health and safety, we can ensure a healthier future for all. Let us commit to "Saving the Saviours" who dedicate their lives to saving others.

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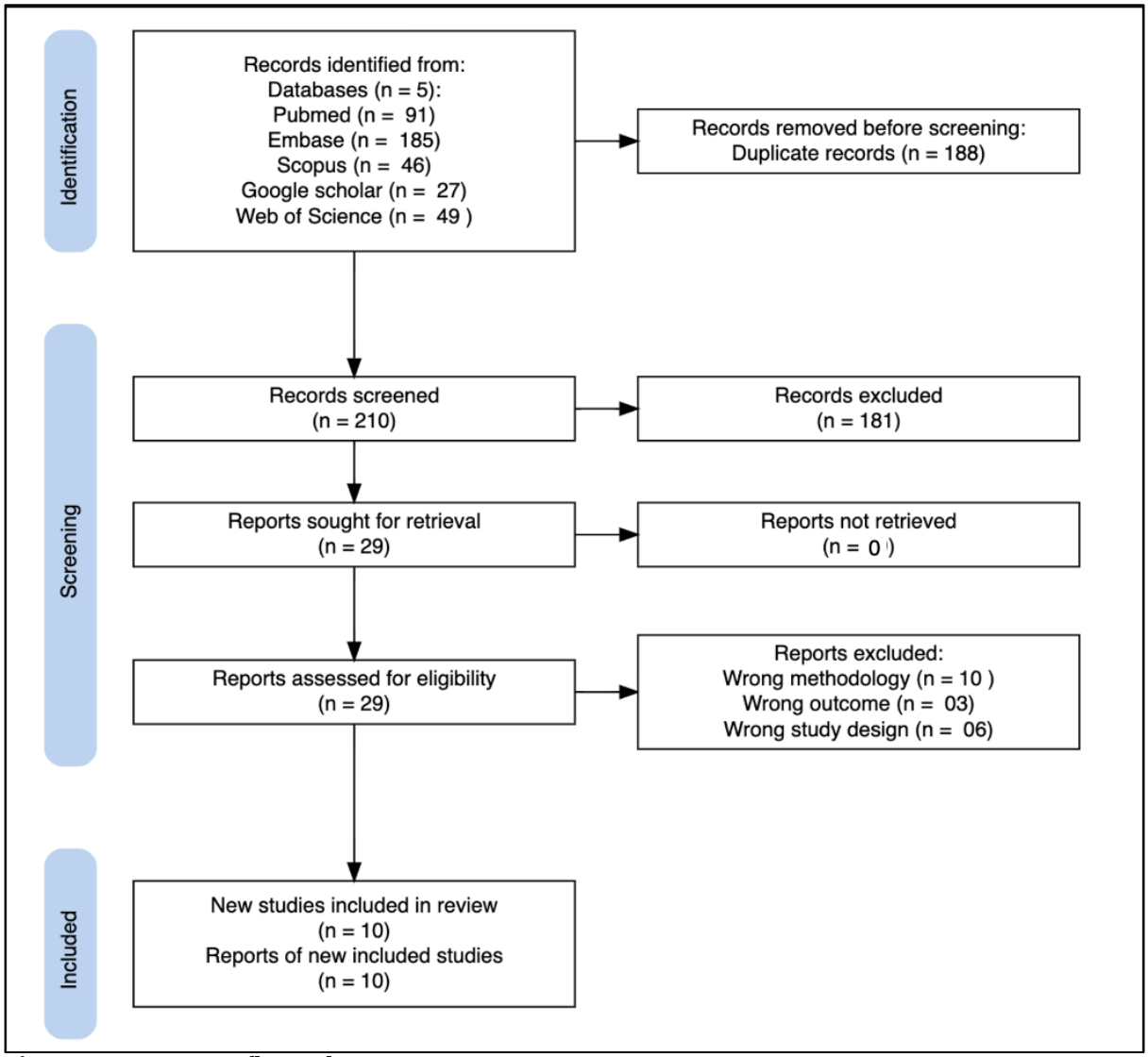

Figure 1. PRISMA flow chart-

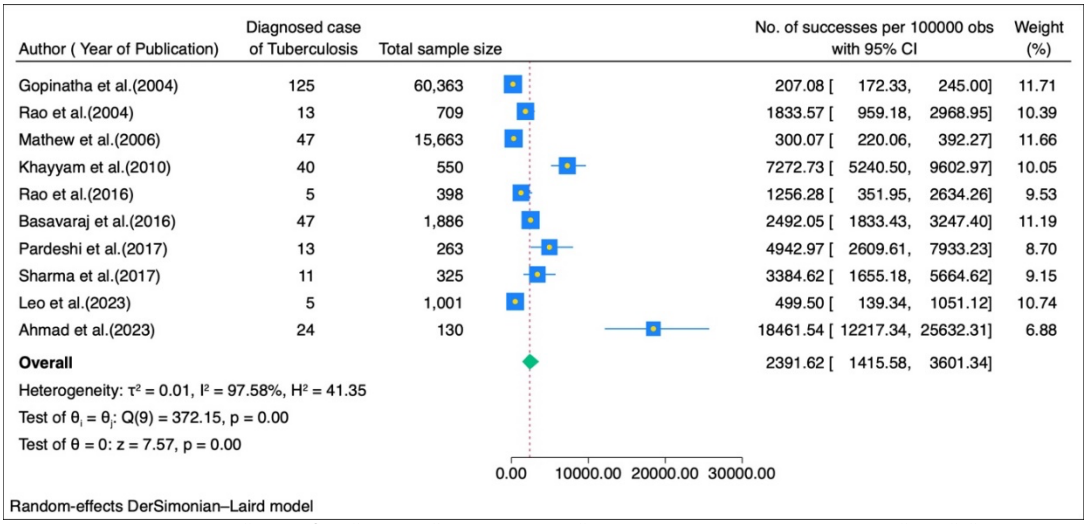

Figure 2. Forest plot of tuberculosis prevalence estimates among healthcare workers in India.

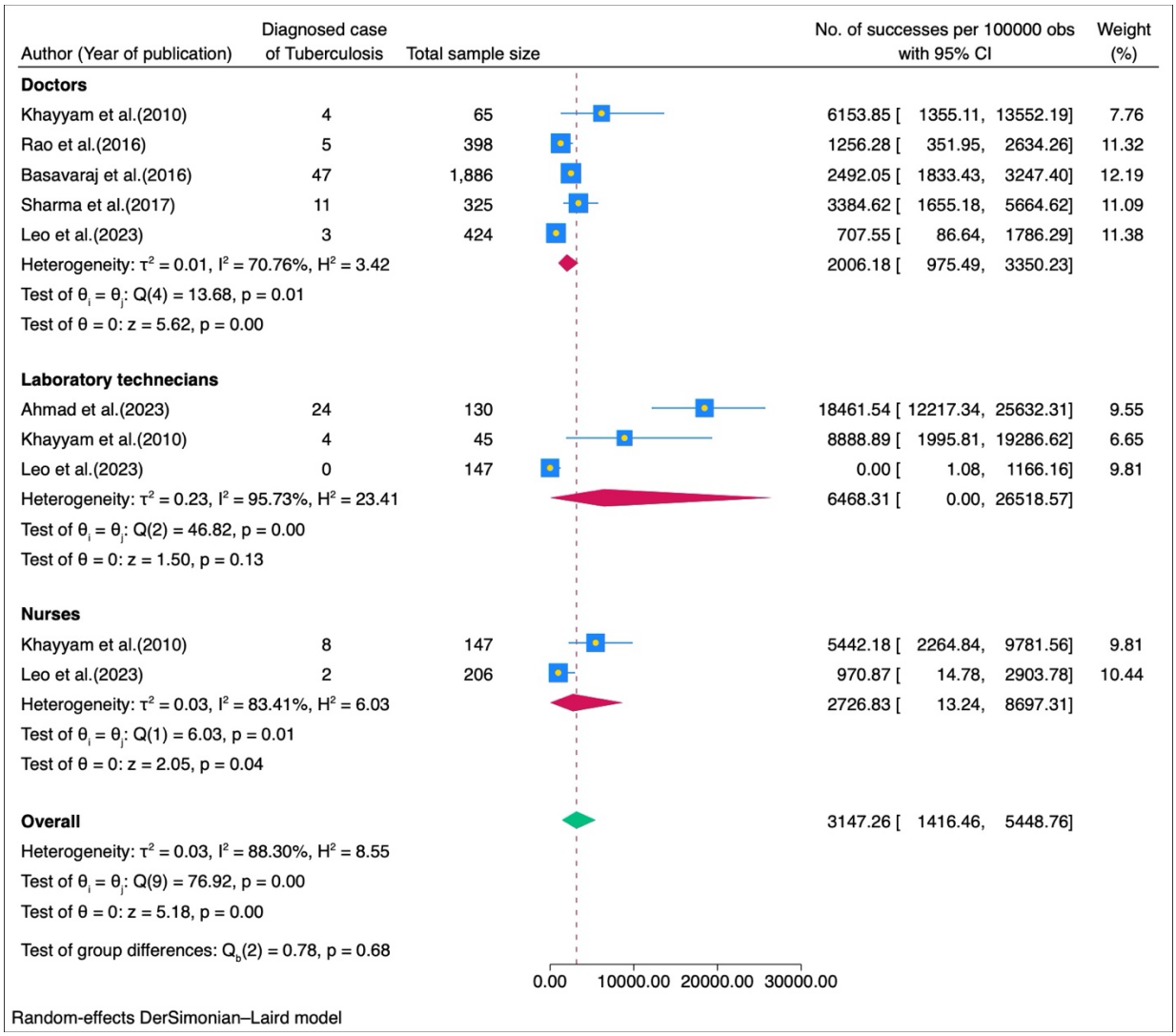

Figure 3. Subgroup analysis forest plot of tuberculosis prevalence among healthcare workers in India by occupation.

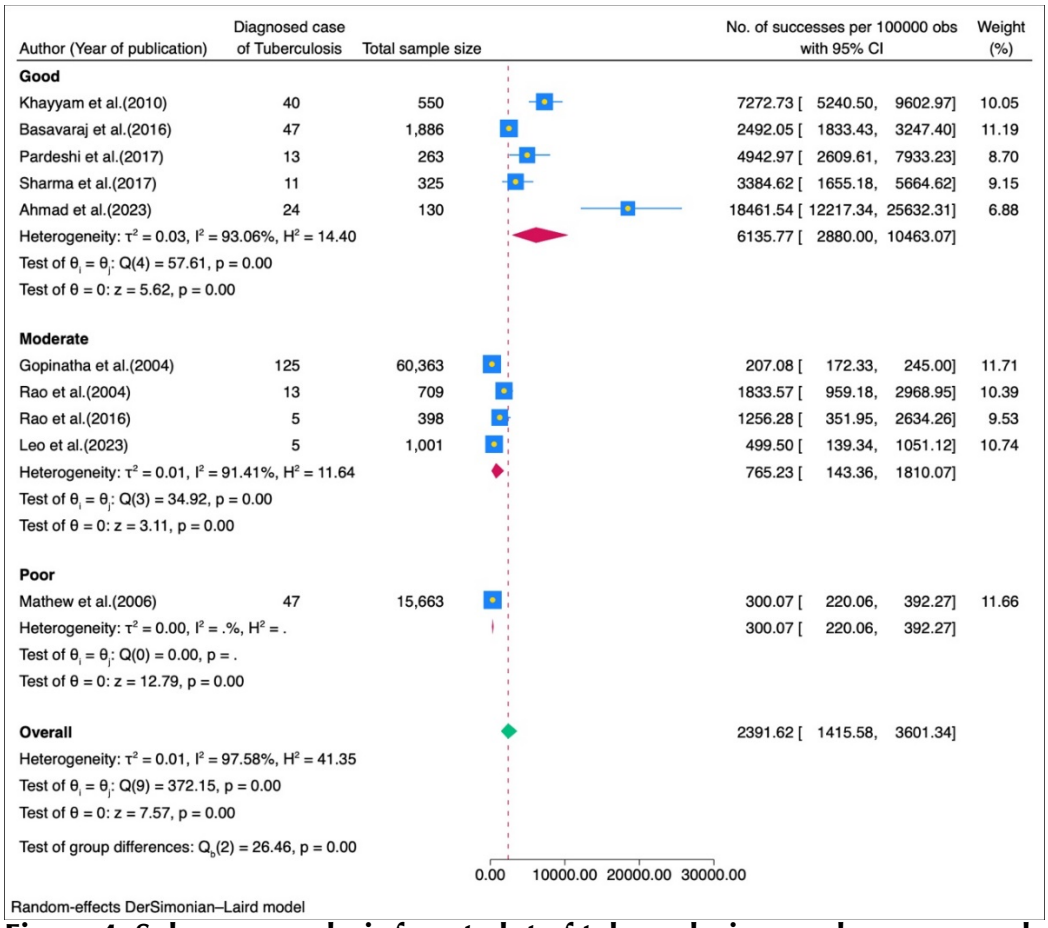

Figure 4. Subgroup analysis forest plot of tuberculosis prevalence among healthcare workers in india by study quality

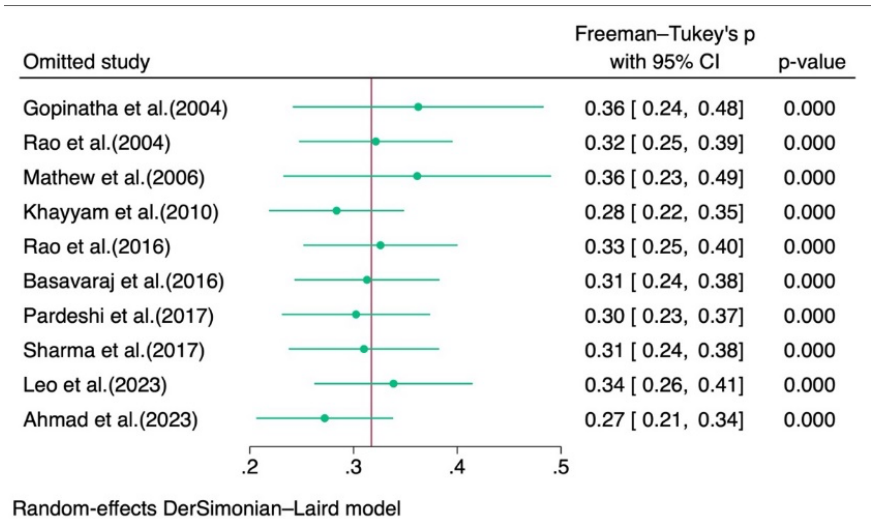

Figure 5. Sensitivity analysis plot of tuberculosis prevalence estimates among healthcare workers in India.

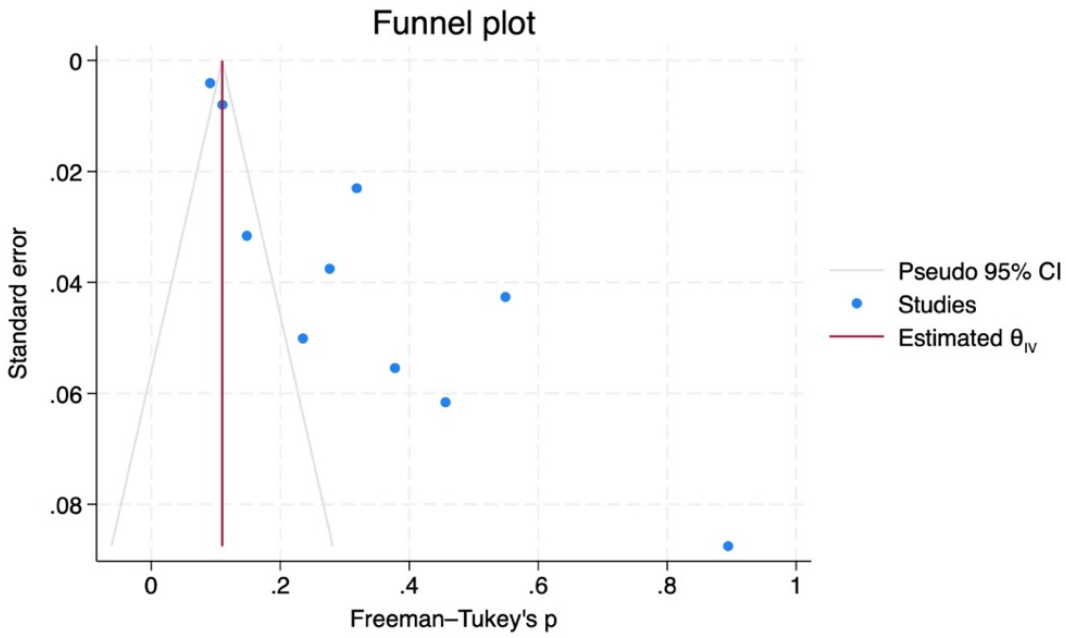

Figure 6. Funnel plot for assessing publication bias in studies on tuberculosis prevalence among healthcare workers in India

Table 1. Characteristics of studies included in the meta-analysis.

Author	Year of study	Population	Place of study	Sample size	Prevalence of Tuberculosis (TB)		Total cases of TB
					Pulmonary	Extra-pulmonary	
Gopinath et al. (7)	2004	Hospital staff & students	Tamil Nadu	60363	71	54	125
Rao et al. (8)	2004	Resident doctors	Chandigarh	709	-	-	13
Mathew et al. (9)	2006	Health care workers	Tamil Nadu	15663	22	25	47
Khayyam et al. (10)	2010	Health care workers	Delhi	5502	-	-	40
Rao et al. (11)	2016	PG Residents	Pondicherry	398	2	3	5
Basavaraj et al. (12)	2016	Medical trainees	Maharashtra	1886	-	-	47
Pardeshi et al. (13)	2017	PG Residents	Maharashtra	263	-	-	13
Sharma et al. (14)	2017	Medical Residents	Uttar Pradesh	325	6	5	11
Leo et al. (15)	2023	Health care workers	Pondicherry	1001	2	3	5
Ahmad et al. (16)	2023	MO, LT, TBHV	Uttarakhand & Uttar Pradesh	130	-	-	24

Table 2. Quality of the studies included.

	Was the sample frame appropriate to address the target population?	**Were study participants sampled in an appropriate way?**	**Was the sample size adequate?**	**Were the study subjects and the setting described in detail?**	**Was the data analysis conducted with sufficient coverage of the identified sample?**	**Were valid methods used for identification of the condition?**	**Was the condition measured in a standard, reliable way for all participants?**	**Was there appropriate statistical analysis?**	**Was the response rate adequate, and if not, was the low response rate managed appropriately?**	Total Score	Quality of study
Gopinath et al. (7)	Yes	Unclear	Yes	Unclear	Yes	Yes	Yes	Unclear	Unclear	5	Moderate
Rao et al. (8)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	Good
Mathew et al. (9)	Yes	Unclear	Unclear	Unclear	Unclear	Unclear	Yes	Yes	Unclear	3	Poor
Khayyam et al. (10)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	Good
Rao et al. (11)	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Unclear	Unclear	6	Moderate
Basavaraj et al. (12)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	Good
Pardeshi et al. (13)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	8	Good
Sharma et al. (14)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	Good
Leo et al. (15)	Yes	No	Yes	Unclear	Unclear	Yes	Yes	Yes	Unclear	5	Moderate
Ahmad et al. (16)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	8	Good