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ORIGINAL RESEARCH

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Magnitude, associated risk factors, and trend comparisons of identified tuberculosis types among prisons in Ethiopia: A systematic review and meta-analysis

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Abstract

Background and Aims: Tuberculosis (TB) remained a major public health threat, particularly in developing countries with vulnerable groups, particularly prison inmates. A systematic review and meta-analysis of individual studies with varying prevalence rates were performed to identify risk factors associated with the recent magnitude of TB among prisoners.

Methods: A systematic search of research articles on the magnitude and risk factors of TB among prisoners in Ethiopia was conducted in registers, databases, and other sources. Cochran's *Q*, inverse variance (I^2), sensitivity analysis, funnel plot, Begg's, and Egger's regression tests were used to check heterogeneity and publication bias. A random-effects model was used to calculate the pooled burden of TB among prisoners.

Results: The total national prevalence of TB among prisoners was 9.84% (95% confidence interval [CI]: 7.16–12.52). According to the subgroup analysis, the highest prevalence was observed in patients infected by latent TB (51.20%), the Southern nations, nationalities and people's region (SNNPR) (29.63%), studies conducted in ≤200 (17.50%) sample sizes, and from 2017 to 2022 (11.49%) study periods. TB infection among prisoners was significantly associated with a history of contact with TB patients (adjusted odds ratio [AOR] = 2.75; 95% CI: 0.98–4.52), coughing for ≥2 weeks (AOR = 0.08; 95% CI: −0.16–0.33), being incarcerated in overcrowded cells with poor ventilation (AOR = 0.39; 95% CI: −0.01–0.78), and increasing with the duration of imprisonment (AOR = 1.29; 95% CI: −0.39–2.97].

Conclusion: Expectably high TB magnitude is found among prison inmates in Ethiopia. Duration of incarceration, coughing, ventilation of the cell, and contact with TB patients were all predictors of TB among prisoners. The management of TB requires early diagnosis, adequate medication, and the implementation of preventative and control measures suitable for prison inmates.

KEYWORDS

Ethiopia, meta-analysis, prisoners, prisons, risk factors, systematic review, tuberculosis

1 | INTRODUCTION

Mycobacterium tuberculosis complex bacteria are the primary cause of the airborne chronic infectious disease known as tuberculosis (TB). Although it primarily affects the lungs (pulmonary TB [PTB]), extrapulmonary TB can also affect other regions of the body.[1] As obligate aerobes, the tubercle bacilli thrive in places of the body with abundant oxygen. People with PTB exhale the bacilli while coughing, sneezing, and talking, which causes aerosols to spread from one person to another.[1] Worldwide, TB continues to be a serious public health issue and the leading cause of illness and mortality. At the moment, 1.7 billion people (or 26%) on the planet are thought to have *M. tuberculosis* (MTB) infections.[2] In 2019, Martinez et al.[3] reported that approximately 125,105 of the 11 million incarcerated individuals developed TB globally, with an incidence rate of 1148 cases per 100,000 person-years, with 2242 of those cases occurring in the African region.

Tuberculosis is a significant public health issue in Ethiopia. The nation continues to be one of the 22 countries with a high TB burden due to the significant number of undetected and contagious TB cases in the public. In Ethiopia, TB is one of the top 10 causes of hospitalization and fatalities among adults. Additionally, 191,000 new TB cases are anticipated to have occurred in Ethiopia in 2015. This ranking places Ethiopia fourth in Africa and tenth in the world. Ethiopia is one of the 27 nations with the highest burden of multidrug-resistant TB as well.[4–6]

The frequency of TB among inmates has been estimated to be up to 100 times greater than in the general population.[7] The higher frequency of TB in prisons may be attributed to a variety of variables. According to a study done on prisoners (anyone who is being held in a prison while a crime is being investigated, anyone who is awaiting trial, and anyone who has been given a term of imprisonment) in eastern Ethiopia, little is known about what causes TB among prisoners. Only 1.6% of the prisoners were aware of the causes of TB. According to other studies carried out in Ethiopian prisons,[8–18] the risks of contracting TB were linked to undernutrition, illiteracy, smoking, prolonged incarceration, overcrowding, and inadequate ventilation, reproductive age, urban residence before incarceration, HIV-coinfection, contact history with TB patients, and prior TB infection.

Regarding control, one of the cornerstones of the global End TB Plan[19] is the systematic screening of contacts and high-risk groups, but prison health services are frequently neglected and underfunded, which gives inmates opportunities to receive, concentrate, and spread TB both inside the prison population and to the general public. Despite the national TB preventive and control programs of Ethiopia integrating TB care in prisons, there is no systematic screening of inmates for possible infectiousness upon admission to stop transmission, disability, and death.[20] Single-cell RNA-sequencing,[21] lifestyle and traditional Chinese medicine,[22] and health in all policies and health in all laws[23] are recommended as very helpful in the diagnosis, treatment, and control of PTB.

The prevalence rates in Ethiopian prisons varied, ranging from 0.16[24] to 51.20%,[17] and often microscopy was a key diagnostic tool. However, through rigorous screening and the use of sophisticated laboratory tests, the prevalence may actually be higher than what has been reported. One of the factors contributing to the poor implementation of TB preventive and control programs in prisons may be the absence of nationally summarized data. Out of 10 studies,[25] 1 nationwide prevalence study was conducted in Ethiopian prisons without addressing the risk variables, leaving only individual studies with variable prevalence rates. To create health service plans that are best suited for prison settings, accurate illness estimates and risk factors are crucial. Therefore, a systematic review and meta-analysis were conducted to address this issue by determining the combined magnitude of TB and its risk factors.

2 | MATERIALS AND METHODS

2.1 | Country profile

Ethiopia is a 1,000,000 square kilometers (386,102 square miles) country in the Horn of Africa. Ethiopia is bounded by Eritrea to the north, Djibouti to the northeast, Somalia to the east, Kenya to the south, and South Sudan and Sudan to the west. Ethiopia's population was 113,881,451 in 2020, which is equivalent to 1.47%, according to Worldometer's analysis of the latest available United Nations data. In addition, the aforementioned analysis predicts that by 2020, 24,463,423 people, or 21.3% of the total population, will reside in urban areas.[26,27]

2.2 | Formulation of research questions and problems

This systematic review and meta-analysis were guided by the question, "What are the prevalence and risk factors of TB among prisoners in Ethiopia?" The problem was formulating during searching and assessing the global impact of TB on the current world in varying countries. Because of their various effects on different populations, the study focuses on the prevalence of TB in prisoners. This question further interests us in examining whether TB magnitude could be severe in prisoners or similar to other patients. The study evaluated the distinct risk variables for TB among prisoners rather than other population groups.

Several research articles on TB prevalence and its risk factors were systematically searched and collected in different databases. Many published articles were available separately, and a detailed review was essential to incorporate all of the results to reach a conclusion and prevent any information conflicts, ambiguities, or misconceptions.

2.3 | Systematic review registration protocol

The protocol for this study has been registered on the International Prospective Register of Systematic Reviews (PROSPERO), the University of York Center for Reviews and Dissemination and can be found at (https://www.crd.york.ac.uk/prospero/#myProspero) with an identification number CRD42023441173.

2.4 | Search strategy

A systematic search of research articles was conducted in registers and databases (PubMed/Medline, Scopus, ScienceDirect, Cochrane Library, Web of Science, EMBASE, Google Scholar, ResearchGate, and Directory of Open Access Journals [DOAJ]) and other sources (Websites, organizations, and Citation Searching). The research articles were searched using the following MeSH key terms and phrases taken from the title, abstract, and keywords in combination or separately using Boolean operators ("OR" or "AND"): "prevalence"/"magnitude"/"proportion," "tuberculosis," "mycobacterium," "mycobacterium tuberculosis," "pulmonary tuberculosis," "PTB," "associated factors"/"predictors"/"risk factors," "prisons"/"prisoners"/"inmates"/"Prison inmates," and "Ethiopia." The search strategy was carried out from January to March 2023.

2.5 | Inclusion and exclusion criteria for included studies

Inclusion criteria

- Country and setting: Ethiopian prisons from one region or mixed regions
- Study design: Cross-sectional, case-control, randomized trial
- Reported the sample size, TB cases, or prevalence
- Reported the risk factors of TB
- Unpublished studies, grey publications, peer-reviewed, and published in English
- Undertook experimental or retrospective works
- Reported types of laboratory tests and specimens used for works
- Reported type of TB identified
- Reported quality control/assurance measures

Exclusion criteria

- Studies conducted outside Ethiopia
- Reports on other pathogens and TB prevalence in other patient groups or not linked to TB prevalence in prisoners of Ethiopia
- Reported the knowledge, attitude, and practice of prisoners toward TB disease.
- Studies published in other languages
- Investigated drug resistance patterns only
- Incomplete data and inaccessible full-text articles after three emails from the corresponding author
- Previously reviewed papers, low-quality articles, duplicate publications, or extensions of analysis from original studies

2.6 | Outcome of interest

The main outcome of this study was the recent magnitude of TB in Ethiopian prisons. The study's secondary outcomes, on the other hand, focused on factors associated with TB among prisoners.

2.7 | Data extraction

The preferred reporting items for systematic reviews and meta-analyses, or PRISMA-2020 for systematic reviews, as advised by Page et al.[28] were utilized to develop the data abstraction process that was used to construct data from each of the included publications. The required data was extracted by the two authors (Am. G. and Ab. G.) using a standardized data extraction protocol in a Microsoft Excel 2021 spreadsheet. The data extraction protocol consists of the author and year of publication (study), region, study setting, study design, inclusion criteria, specimen type, diagnostic method, type of TB identified, sample size, number of positive cases, prevalence of TB, and quality score. The period from April 1 to June 30, 2022, was used for study selection, quality evaluation, and data extraction.

2.8 | Quality assessment of individual studies

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) method was used to evaluate the overall quality of the evidence.[29] The quality of each study was declared using the three major assessment tools (methodological quality, comparability, and outcome and statistical analysis of the study). Two points were given to each criterion. Publications with a total score of 5–6 points were considered to be high, 4 points to be moderate, and 0–3 points to be low-quality publications. Two reviewers (Am. G. and Ab. G.) separately chose the articles and assessed their quality. After agreement was obtained and disagreements between the reviewers were resolved through conversation, the articles were added.

2.9 | Sensitivity analysis, heterogeneity, and publication bias

The Cochran's Q statistic was used to identify heterogeneity between the included studies, while the inverse variance (I^2) was used to investigate heterogeneity across the included studies. These measures assess the presence of statistical heterogeneity.[30] In addition, the study conducted subgroup analyses and sensitivity analyses, utilizing Duval and Tweedie's Trim and Fill analysis in the random effect model, to investigate any potential sources of significant heterogeneities.[31] Subjectively, the funnel plot[32] and, more objectively, Begg's and Egger's regression tests were used to check for publication bias.[33]

2.10 | Statistical analysis

A random-effects model was used to estimate the size of the pooled effects. To sort out the causes of heterogeneity, subgroup analysis

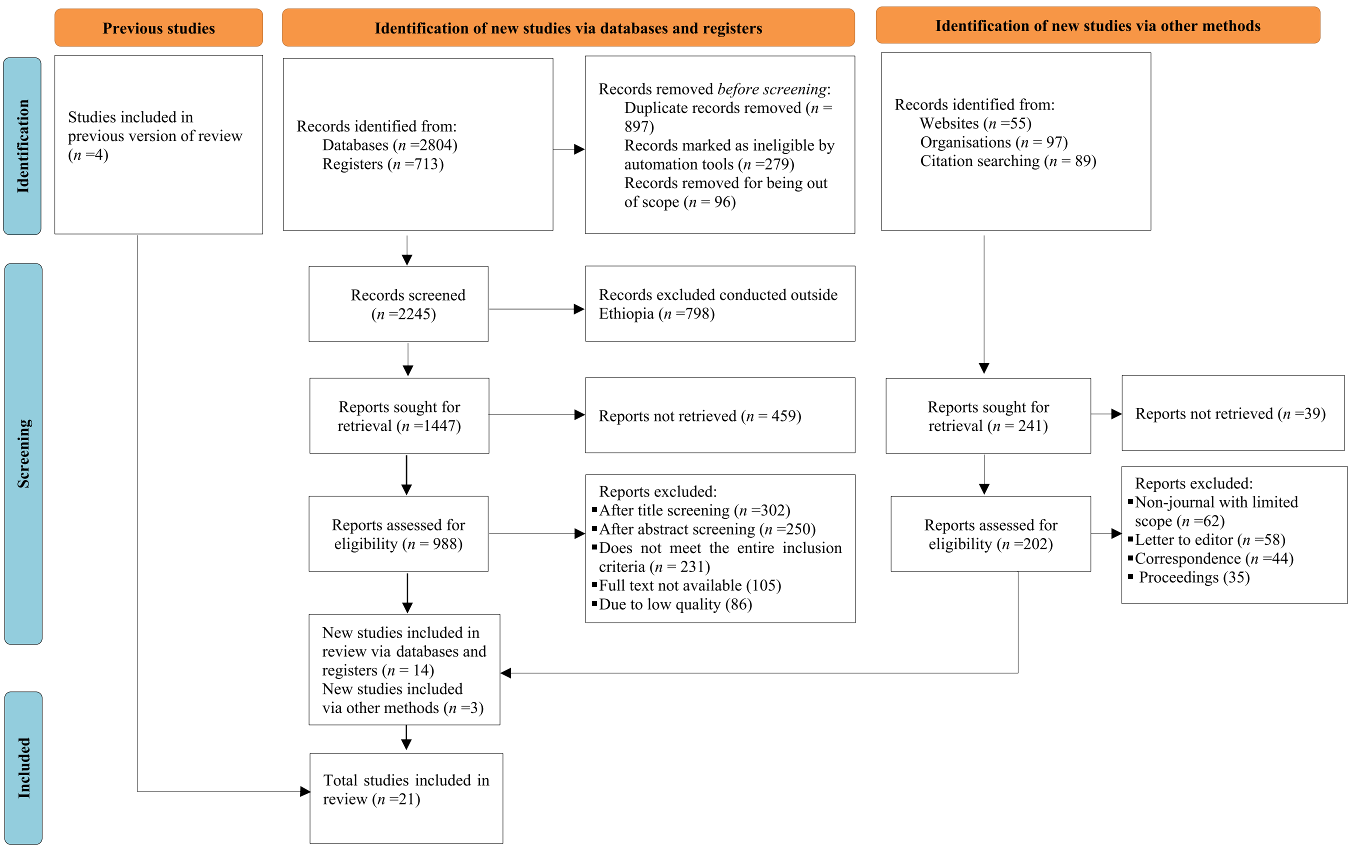

FIGURE 1 PRISMA-2020 flow diagram of eligible studies.

was conducted based on sample size, region of the study, identified TB type and year of publication. The Cochran's *Q* statistic with I^2 and funnel plot symmetry were used to assess the existence of statistical heterogeneity,[30] while publication bias was measured by using Begg's and Egger's test at the 5% significance level; a 0.05 *p*-value denotes the presence of publication bias.[33] For I^2, heterogeneity is categorized as high when it exceeds 75%, substantial when it is between 50% and 75%, moderate when it is between 25% and 50%, and low when it is below 25%.[30] For a funnel plot, a symmetric dot with an inverted funnel shape denotes that there is no publishing bias, and each dot represents a single study.[32] A log odds ratio was used to determine the association between TB and risk factors. Meta-analysis was performed using Stata software version 14, where $p < 0.05$ was considered statistically significant at two-sided tests.

3 | RESULTS

3.1 | PRISMA flow chart description

In total, 3762 articles on the magnitude of TB and its associated risk factors were recovered throughout the world. one thousand two hundred and seventy-two records were removed before screening (duplicate records removed [$n = 897$], records marked as ineligible by automation tools [$n = 279$], and out-of-scope records [$n = 96$]). Of the remaining 2490 articles, 798 studies conducted outside Ethiopia were further excluded. Of the remaining 1692 articles in registers, databases, and other methods, 498 were not retrieved. Of the 1194 articles, 1173 were further excluded after observation and review as per the inclusion and exclusion criteria used. Only 21 reports were included in the final analysis (Figure 1).

3.2 | Characteristics of the eligible studies

The characteristics of 21 eligible studies are presented in Table 1. These studies were published between 2011 and 2022, and the current study included six regions and one mix ed group of prison inmates in the country. In this study, a total of 24,020 prison inmates were included to study the pooled prevalence of TB and its associated risk factors. Regarding study design, 20 were cross-sectional, and 1 was a random trial. Sputum, fine needle aspiration cytology, and blood were the specimens used for the diagnosis of TB. Interferon-gamma release assay, enzyme-linked immunosorbent assay, cytology, spectrophotometer, Ziehl–Neelsen microscopy,

TABLE 1 General characteristics of studies included in systematic review and meta-analysis.

References	Region	Study setting	Study design	Inclusion criteria	Specimen type	Diagnosis method	Type of TB identified	Sample size	Cases	Prevalence (95% CI)	Quality score
Abebe et al.[8]	Mixed	Eastern Ethiopian prisons (Dire Dawa, Jijiga and Harar)	Cross-sectional	▪ Cough for ≥2 weeks and consent to participate in the study	Sputum	ZN microscopy, Culture	PTB	371	33	8.9 (3.50–13.9)	5
Moges et al.[34]	Amhara	North Gondar Zone Prison	Cross-sectional	▪ Patients having cough of at least 1 week duration	Sputum, FNAC	LED microscopy, cytology	SPPTB	250	26	10.4 (6.89–14.51)	4
Zerdo et al.[9]	SNNPR	Gamo Goffa Zone Prison	Cross-sectional	▪ Inmates who had cough more than or equal to 2 weeks	Sputum	Direct smear microscopy, Culture	PTB	124	24	19.4 (12.8–27.4)	6
Biadglegne et al.[35]	Amhara	Woldia, Bahir Dar, Fenoteselam, Dessie, Deberebirhan, Debiretabor, Debremarkos and Gondar Prison	Cross-sectional	▪ Prison inmates who were willing to participate ▪ Has ≥1 week duration of cough	Sputum	ZN microscopy, GeneXpert, Culture	SNPTB	200	16	8.0 (5.2–11.5)	4
Ali et al.[36]	Mixed (Oromia, SNNPR and Harari)	Jimma, Nekemte, Ambo, Wolkite, Shashemene, Asella, Bonga, Mizan, Yabelo, Dilla, Sodo, Asebeteferi/Chiro, Harar prison.	Cross-sectional	▪ Cough of 2 weeks duration ▪ Sputum production ▪ Chest pain ▪ Recent loss of appetite ▪ Loss of weight in last 3 months ▪ Had history of anti TB treatment in the past 5 years ▪ Inmates living with HIV	Sputum	ZN microscopy, Culture	PTB	765	71	9.2 (7.2–11.4)	5
Addis et al.[37]	Amhara	Gondar Prison	Cross-sectional	▪ Prisoners with cough duration of more than 2 weeks	Sputum	ZN microscopy	SPPTB	384	33	8.59 (5.98–11.62)	5
Winsa and Mohammed[38]	Oromia	Bedele Woreda Prison	Cross-sectional	▪ All suspected prisoners who had cough for 2 weeks	Sputum	ZN microscopy	PTB	196	43	21.9 (14.3–33.7)	4
Adane et al.[39]	Tigray	Adigrat, Adwa, Alamata, Axum, Humera, Maychew, Mekelle, Shire and Wukro	Cross-sectional	▪ Providing written informed consent ▪ Being an age of ≥18 years ▪ Not being treated for TB at the time of the screening. ▪ Having had clinical symptoms of pulmonary TB (cough of ≥2 weeks and sputum production with at least one of the other symptoms such as night sweating for at least 2 weeks, fever for at least 2 weeks, chest pain for at least 2 weeks, and /or unintentional weight loss)	Sputum	ZN microscopy, Culture	PTB	809	32	4.0 (2.65–5.35)	6

(Continues)

TABLE 1 (Continued)

References	Region	Study setting	Study design	Inclusion criteria	Specimen type	Diagnosis method	Type of TB identified	Sample size	Cases	Prevalence (95% CI)	Quality score
Gebrecherkos et al.[10]	Amhara	North Gondar Zone	Cross-sectional	▪ Prison inmates who were willing to participate ▪ Had 2 weeks and above duration of cough	Sputum	LED microscopy, GeneXpert	SPPTB	282	15	5.3 (2.2–9.7)	5
Fuge and Ayanto[11]	SNNPR	Hadiya Zone Prison	Cross-sectional	▪ Prisoners who were mentally fit, willing to participate ▪ Above or equal to 15 years old ▪ Has ≥1 week duration of cough	Sputum	ZN microscopy	SPPTB	164	3	1.83 (0.23–4.59)	4
Bayu et al.[12]	SNNPR	Wolaita Zone	Cross-sectional	▪ A history of cough of ≥2 weeks	Sputum	ZN microscopy	PTB	302	15	4.97 (1.1–8.7)	5
Giza-chew Beza et al.[13]	Amhara	East Gojjam Zone (Motta, Bichena, and Debre Markos)	Cross-sectional	▪ Who had cough for more than 2 weeks	Sputum	GeneXpert	PTB	265	9	3.4 (0.9–7.9)	4
Merid et al.[40]	Sidama	Hawassa Prison	Cross-sectional	▪ Those with cough of ≥2 weeks	Sputum	ZN microscopy, GeneXpert	PTB	372	31	8.0 (5.2–11.5)	5
Berihun et al.[41]	Amhara	Debrebirhan Prison	Retrospective cross-sectional	▪ All inmates of the prison who were on antituberculosis during the study period	—	—	PTB	162	73	45.1 (32.3–57.4)	4
Abayineh[14]	Addis Ababa	Kality High Security and Kilinto Prison Centers	Cross-sectional	▪ All consented voluntary inmates with >18 years of age and 2 weeks caught at the study sites during the study period.	Sputum	ZN microscopy, GeneXpert	PTB	218	11	5.04 (1.4–11.7)	5
Agajie et al.[15]	BGR	Assosa, Kamashi and Metekel	Cross-sectional	▪ Prisoners greater than or equal to 18 years old ▪ Willing to participate ▪ Who had ≥2 weeks duration of cough and could produce sputum	Sputum	GeneXpert	PTB	3395	8	0.24 (0.098–1.4)	4
Tsegaye Sahle et al.[24]	Addis Ababa	Kality Federal Prison	Cross-sectional	▪ Men or women age 18 years or older ▪ Either newly entering the prison or a current resident of the prison ▪ Able and willing to provide informed consent.	Sputum	ZN Microscopy, CXR, GeneXpert, Culture	BC-PTB	13803	22	0.16 (0.1–1.5	6
Dibissa et al.[16]	Oromia	Western Oromia Region (Gimbi, West Wollega; Nekemte, East Wollega, Dambi Dollo, and Kelem Wollega)	Cross-sectional	▪ Prisoners with cough of 2 weeks or more	Sputum	ZN Microscopy, Culture, and GeneXpert	PTB	270	42	15.6 (11.5–20)	6

TABLE 1 (Continued)

References	Region	Study setting	Study design	Inclusion criteria	Specimen type	Diagnosis method	Type of TB identified	Sample size	Cases	Prevalence (95% CI)	Quality score
Adane et al.[42]	Mixed (Amhara and Tigray)	Mekelle, Shire, Adawa, Abi Addi, Humera, Adigrat, Maichew, Alamata, Wukro, Axum, Dessie, Woldia, Fenote Selam, Debre Markos, Debre Tabor and Bahir Dar	Cluster-randomized trial	▪ Patient is up to 15 years ▪ Has presumptive drug-resistant tuberculosis or extrapulmonary tuberculosis, or their HIV status is positive or unknown	Sputum	ZN Microscopy, CXR, GeneXpert, Culture	MTB	1124	34	3.0 (1–14)	4
Chekesa et al.[17]	Oromia	East Wollega Zone	Cross-sectional	▪ No previous treatment for TB ▪ Did not have signs and symptoms of TB at the study outset ▪ Above 18-year age ▪ Not pregnant in case of females	Blood	IGRA, ELISA, Spectro-photometer	LTBI	352	180	51.2 (46.45–57)	6
Duressa et al.[18]	BGR	Assosa, Kamashi and G/Beles	Cross-sectional	▪ Inmates with any cough of 2 weeks or more (or any duration if known HIV positive with or without sputum production), fever, chest pain, with current or previous TB treatment, unexplained weight loss for last 3 months, known contact with TB patient and loss of appetite were included	Sputum	GeneXpert	PTB	212	5	2.3 (0.5–5.4)	5

Abbreviations: BC-PTB, bacteriologically confirmed pulmonary tuberculosis; BGR, Benishangul-Gumuz region; CXR, chest x-ray; ELISA, enzyme-linked immunosorbent assay; FNAC, fine needle aspiration cytology; HIV, human immunodeficiency virus; IGRA, interferon-gamma release assay; LED, light-emitting diode; LTBI, latent tuberculosis infection; MTB, mycobacterium tuberculosis; PTB, pulmonary tuberculosis; SNNPR, Southern nations, nationalities and people's region; SNPTB, smear-negative pulmonary tuberculosis; SPPTB, smear-positive pulmonary tuberculosis; TB, tuberculosis; ZN, Ziehl–Neelsen.

light-emitting diode microscopy, direct smear microscopy, chest x-ray (CXR), GeneXpert, and Culture were the different diagnostic methods used to confirm TB among prisoners. 51.20% and 0.16% were the highest and lowest prevalences of TB, respectively. The sample size of prisoners among eligible studies ranged between 124 and 13,803 (Table 1).

3.3 | Magnitude of TB

The total national prevalence of TB among prisoners was 9.84 (95% confidence interval [CI]: 7.16–12.52) (Figure 2).

3.4 | Subgroup analysis

The highest pooled prevalence of TB among prisoners was reported from the Oromia region at 29.63% (95% CI: 4.63–54.64), followed by Amhara at 10.28% (95% CI: 5.60–14.95), mixed region at 8.05% (95% CI: 5.00–11.11), Southern nations, nationalities and people's region (SNNPR) at 7.63% (95% CI: 2.35–12.95), Tigray at 4.00% (95% CI: 2.65–5.35), and Addis Ababa at 1.91% (95% CI: −2.68–6.49), whereas a low prevalence of TB among prisoners was observed in the Benishangul-Gumuz region (BGR) at 0.92 (95% CI: −0.98, 2.81) (Table 2 and Figure 3). The pooled prevalence of TB among studies with sample sizes >200 (8.42%, 95% CI: 5.51–11.33) was lower than that of studies with sample sizes ≤200 (17.50%, 95% CI: 8.13–26.88) (Table 2 and Figure 4). The prevalence estimate of TB was higher between 2017 and 2022, with a pooled prevalence estimate of 11.49% (95% CI: 7.21–15.78), than the study period from 2011 to 2016 at 8.02% (95% CI: 5.62–10.41) (Table 2 and Figure 5). The highest pooled prevalence estimate of identified TB type among prisoners was recorded in latent tuberculosis infection (LTBI), with a pooled prevalence estimate of 51.20% (95% CI: 45.92–56.84), followed by PTB, smear-negative PTB, smear-positive PTB, and MTB, with a pooled prevalence estimate of 9.08% (95% CI: 5.98–12.19), 8.00% (95% CI: 5.20–11.50), 6.40% (95% CI: 2.30–10.50), and 3.00% (95% CI: −3.50–9.50), respectively. Whereas a low prevalence of TB type among prisoners was observed in the bacteriologically confirmed PTB at 0.16% (95% CI: −0.54–0.86) (Table 2 and Figure 6).

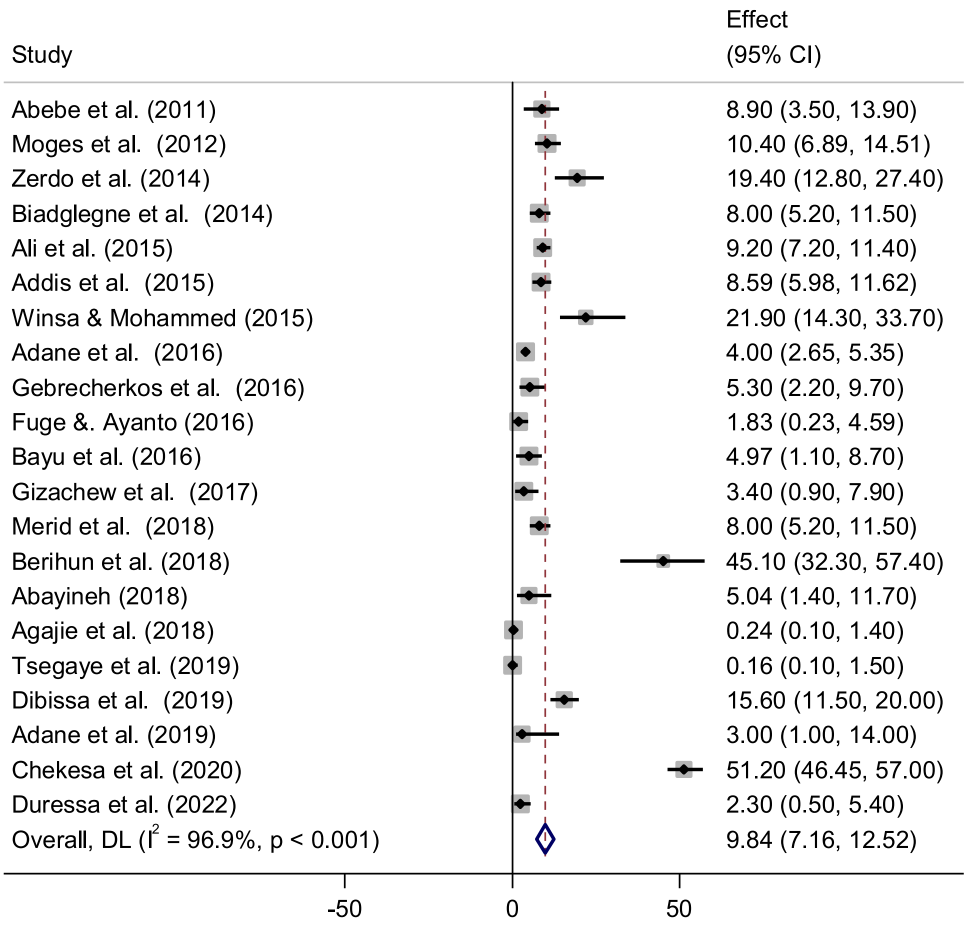

FIGURE 2 Forest plot of the magnitude of tuberculosis among prisoners in Ethiopia.

TABLE 2 Subgroup analysis of the magnitude of TB among prisoners.

Variables	Characteristics	Included studies	Sample size	Prevalence (95% CI)	I^2, *p*-value
Sample size	≤200	5	846	17.50 (8.13–26.88)	94.7, $p < 0.001$
	>200	16	23,174	8.42 (5.51–11.33)	97.3, $p < 0.001$
Region	Mixed	3	2260	8. 05 (5.00–11.11)	37.0, $p = 0.204$
	Amhara	6	1543	10.28 (5.60–14.95)	88.6, $p < 0.001$
	SNNPR	4	962	7.63 (2.35–12.95)	88.7, $p < 0.001$
	Oromia	3	818	29.63 (4.63–54.64)	98.2, $p < 0.001$
	Tigray	1	809	4.00 (2.65–5.35)	–
	Addis Ababa	2	14,021	1.91 (−2.68–6.49)	70.5, $p = 0.066$
	BGR	2	3607	0.92 (−0.98–2.81)	60.6, $p = 0.111$
Identified TB type	PTB	13	7461	9.08 (5.98–12.19)	94.7, $p < 0.001$
	SPPTB	4	1080	6.40 (2.30–10.50)	86.3, $p < 0.001$
	SNPTB	1	200	8.00 (5.20–11.50)	–
	BC-PTB	1	13,803	0.16 (−0.54–0.86)	–
	MTB	1	1124	3.00 (−3.50–9.50)	–
	LTB	1	352	51.20 (45.92–56.84)	–
Publication year	2011–2016	11	3847	8.02 (5.62–10.41)	84.9, $p < 0.001$
	2017–2022	10	20,173	11.49 (7.21–15.78)	98.1, $p < 0.001$
	Overall	21	24,020	9.84 (7.16–12.52)	96.9, $p < 0.001$

Abbreviations: BC-PTB, bacteriologically confirmed pulmonary tuberculosis; BGR, Benishangul-Gumuz region; LTBI, latent tuberculosis infection; MTB, mycobacterium tuberculosis; PTB, pulmonary tuberculosis; SNNPR, Southern nations, nationalities and people's region; SNPTB, smear-negative pulmonary tuberculosis; SPPTB, smear-positive pulmonary tuberculosis.

3.5 | Heterogeneity and publication bias

Heterogeneity and publication bias were identified in the included studies. High levels of heterogeneity were present in the included studies ($I^2 = 96.9\%$, $p = 0.001$). The subjectively stated funnel plot (Figure 7) revealed an asymmetrical distribution. Using the findings of the tests by Egger and Begg, it was objectively determined that there was no substantial publication bias ($p > 0.05$).

3.6 | Sensitivity analysis

A sensitivity analysis was carried out by removing each study one at a time to clarify the impact of each study on the pooled effect size. However, during the sensitivity analysis, five studies (Adane et al.[39]; Fuge & Ayanto[11]; Agajie et al.[15]; Tsegaye Sahle et al.[24]; and Duressa et al.[18]) had relatively determinant effects on the overall magnitude of TB in Ethiopian prisoners, while a relatively higher source of heterogeneity came from the Chekesa et al.[17] study (Figure 8).

3.7 | Factors associated with TB among prisoners

In this meta-analysis, several potential risk factors associated with TB among prisoners in Ethiopia were reviewed. However, contact history with TB patients, coughing ≥2 weeks, poor ventilation of the cell, and length of imprisonment were factors significantly associated with TB magnitude (Figures 9–12).

4 | DISCUSSION

Tuberculosis poses a serious public health threat across the globe, particularly in prisons in developing countries like Ethiopia. The current study was designed to complement global efforts toward the control of TB by providing useful epidemiological data that will aid its control. The study provides information on TB, its magnitude at the national and regional levels, its distribution across regions, types, periods, and settings, and finally, its determinant factors. The findings will help in assessing the successes of TB control programs in Ethiopia, which usually target prisoners, children, pregnant women, and the general public. Moreover, it provides information that will

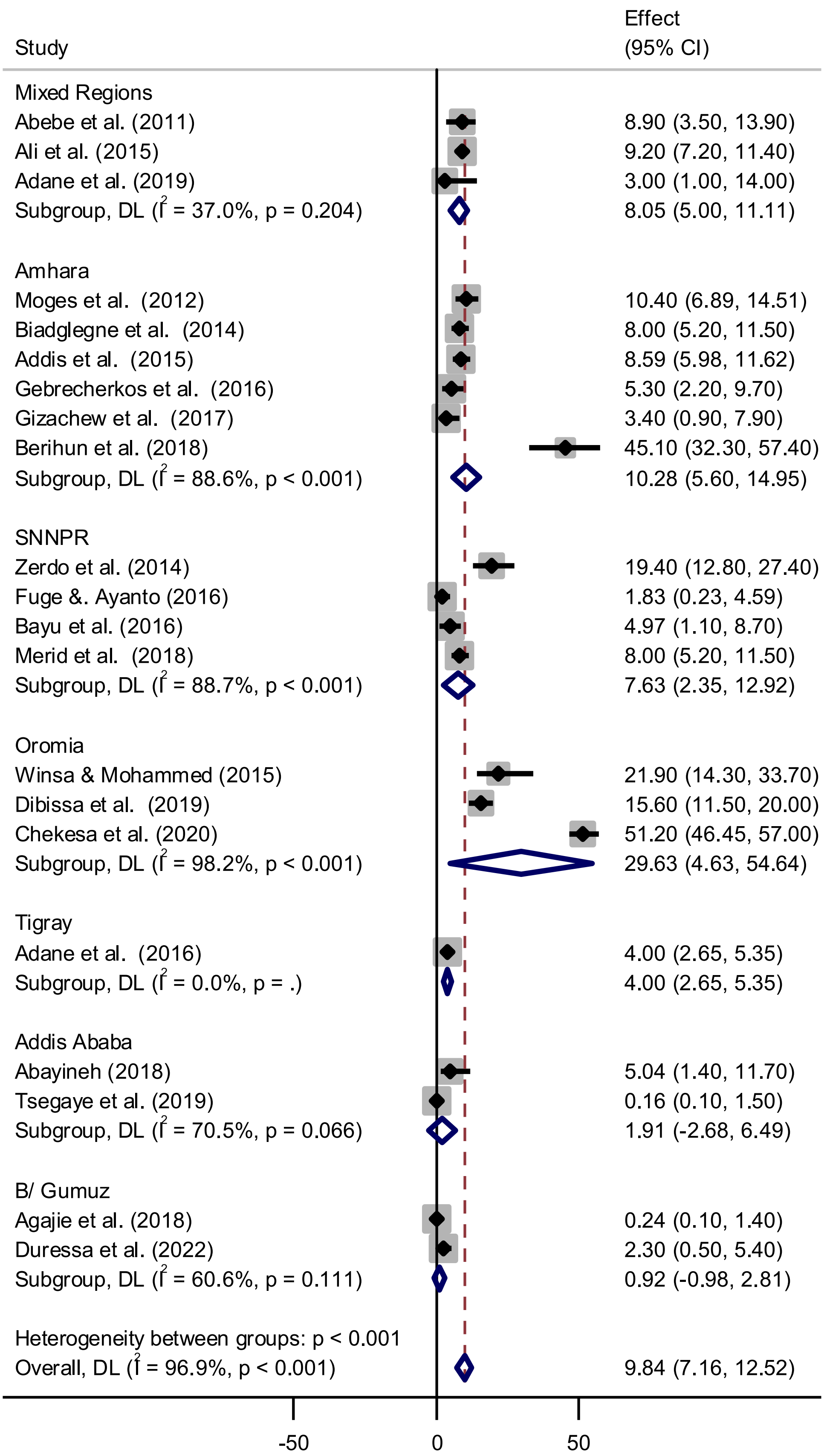

FIGURE 3 Subgroup analysis by region on the pooled prevalence of tuberculosis among prisoners in Ethiopia.

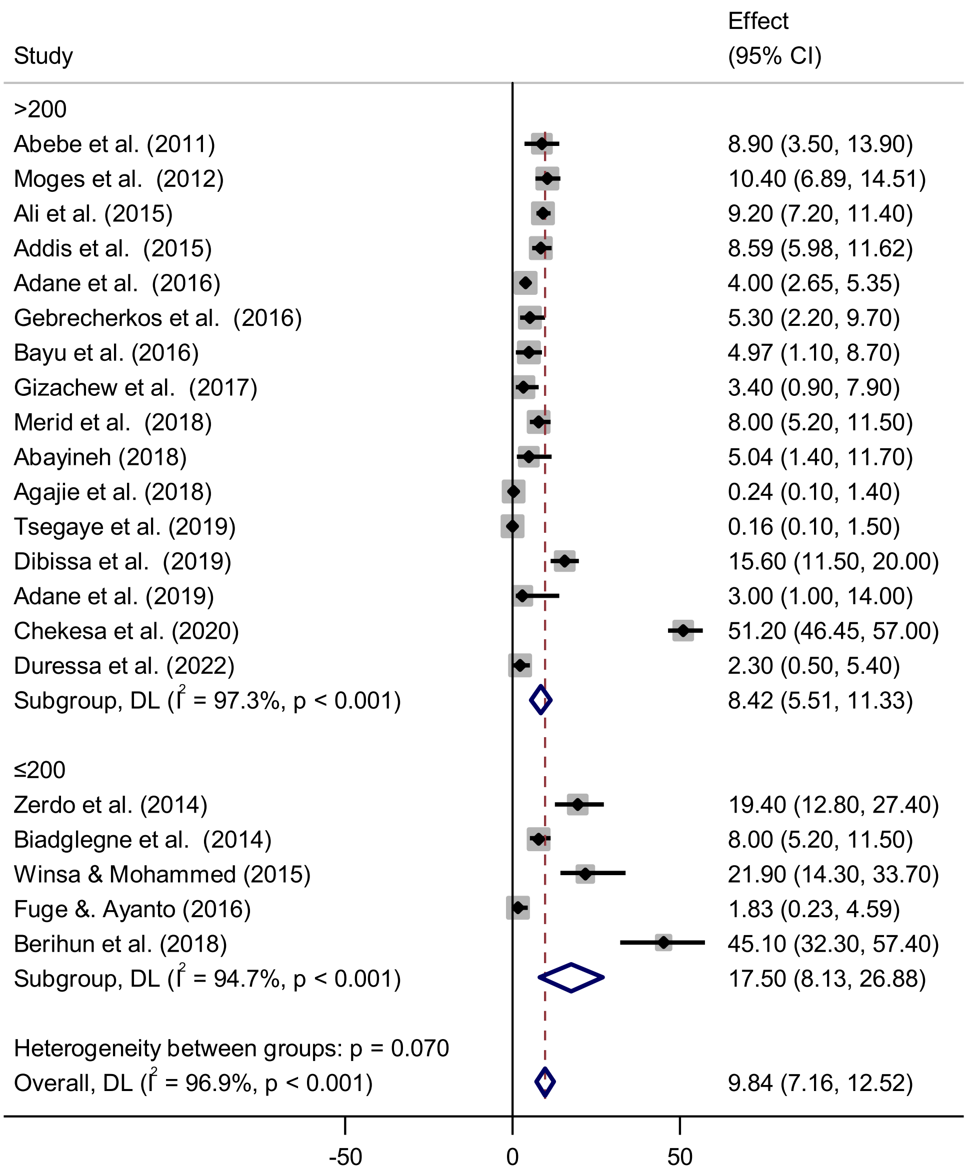

FIGURE 4 Subgroup analysis by sample size on the pooled prevalence of tuberculosis among prisoners in Ethiopia.

serve as a guide for targeted and cost-effective control, which is a subject of debate globally.[43]

The pooled magnitude of TB among prisoners was 9.84% (95% CI: 7.16–12.52; I^2 = 96.9%). This combined magnitude is comparable to findings from prisons in Paraguay,[44] Malaysia,[45] Sub-Saharan Africa (SSA),[46] Iran,[47] Ethiopia,[25] and South Africa,[48] where the prevalence rates are 7.1% in 2009, 7.7%, 7.74%, 7.9%, 8.33%, and 8.8%, respectively. However, the result of this meta-analysis was higher than the previous systematic review reports conducted from prison inmates in South Africa (2.1%),[49] Thailand (2.1%),[50] Peru (2.51%),[51] SSA (2%–3.6%), Brazil (4.5%),[52] Tajikistan (4.5%),[53] and Cameroon (5.23%).[54] Moreover, the magnitude was lower than studies conducted in previous reports among prison inmates in Brazil (12%),[55] Uganda (13.7%),[56] Paraguay (14.5%) in 2018,[44] and the Democratic Republic of the Congo (17.7%).[57] Geographical variation, overcrowding, method of diagnosis, and the number of prisoners in a cell with poor ventilation are some of the possible reasons that could account for the observed differences.

In this study, LTBI was the most prevalent identified TB type among prisoners with a pooled prevalence of 51.20% than other types. Comparatively similar studies were reported from southern Ethiopia (50.5%) by Teklu et al.[58] and outside Ethiopia such as Spain (54.6%).[59] However, the magnitude of LTBI in prisons were markedly higher than the prevalence reported in the United States (6.3%),[60] the United Kingdom (11.5%),[61] Brazil (25.2%),[62] and Canada (32.3%).[63] Moreover, the magnitude was lower than studies conducted in previous reports among prisoners in Colombia (67.6%),[64] and Malaysia (88.8%).[65] The variation in the study population from high-income countries, diagnostic methods, a prison environment in a nation with low TB incidence, more effective TB control programs inside and outside prisons, and

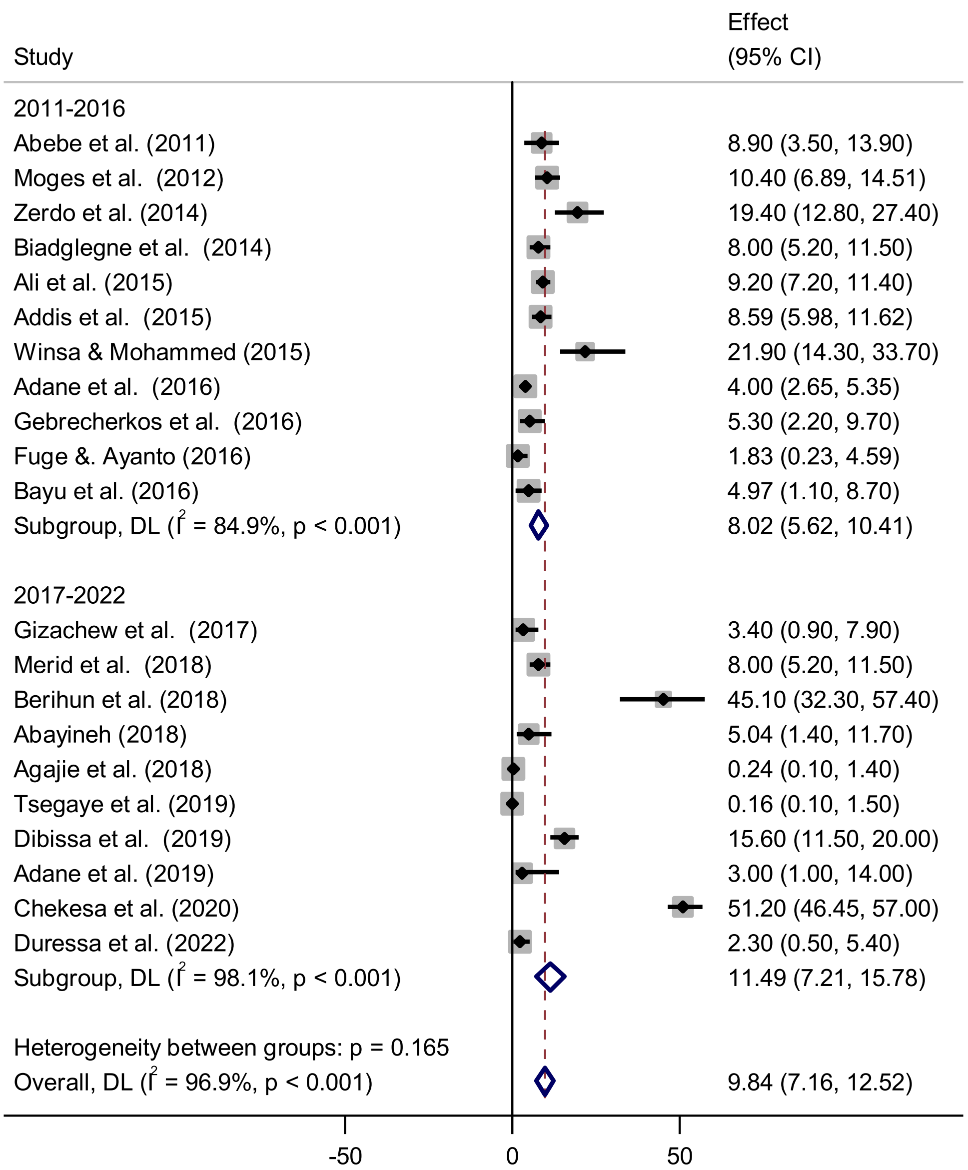

FIGURE 5 Subgroup analysis by publication year on the pooled prevalence of tuberculosis among prisoners in Ethiopia.

prison-based TB screening programs in these countries than in Ethiopia are likely explanations for that difference.

The odds of developing TB were 2.75 times higher among prisoners who had a history of contact with TB patients as compared to their counterparts. It agrees with the findings conducted in SSA[46] and India,[66] which reported 2.43 and 3.64 times more infected, respectively. This might be because they are more likely to be exposed to TB bacteria. Moreover, congregate environments, like prisons and detention centers, put residents there at a higher risk of contracting TB than the general population. As a result of the close contact between people in these environments and the potential for the TB pathogen to spread more readily.

The pooled results showed that prisoners coughing ≥2 weeks were 0.08 times more likely to be infected with TB than their counterparts. Similarly, two studies[67,68] that looked at the length of coughing indicated that patients who coughed for 2 weeks or more had a higher risk of contracting the illness than patients who coughed for less time or did not cough. This is due to the fact that a TB patient's infectiousness is directly correlated with the quantity of tubercle bacilli that they discharge into the air. Patients who exhale few or no tubercle bacilli are less contagious than patients who expel a large number of bacilli. The pathogenic TB bacteria are released into the air when a person with TB illness of the throat or lungs coughs, speaks, or sings. These TB bacteria could infect surrounding individuals through inhalation. When TB

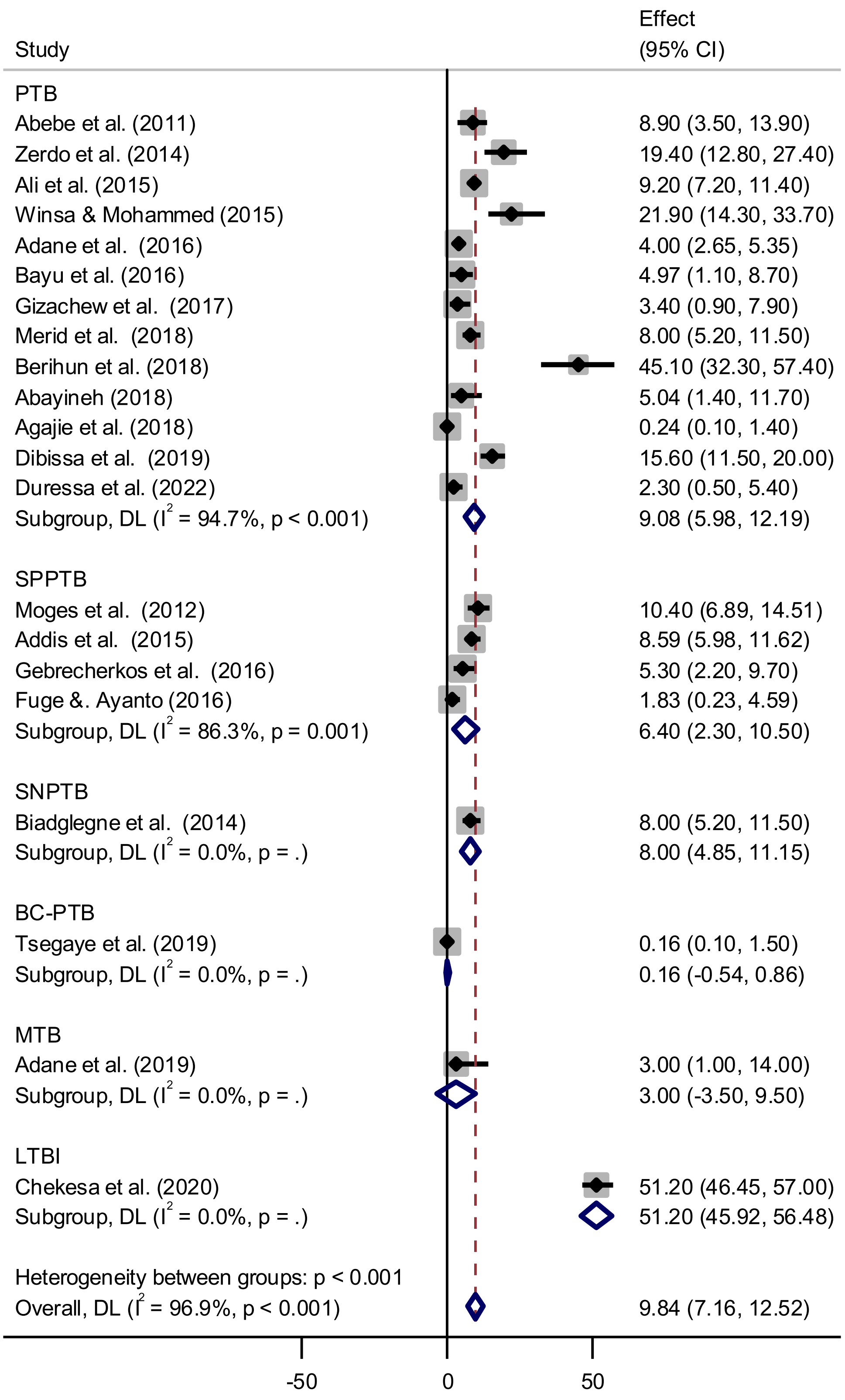

FIGURE 6 Subgroup analysis by identified tuberculosis (TB) type on the pooled prevalence of TB among prisoners in Ethiopia. BC-PTB, bacteriologically confirmed pulmonary tuberculosis; LTBI, latent tuberculosis infection; MTB, *Mycobacterium tuberculosis*; PTB, pulmonary tuberculosis; SNPTB, smear-negative pulmonary tuberculosis; SPPTB, smear-positive pulmonary tuberculosis.

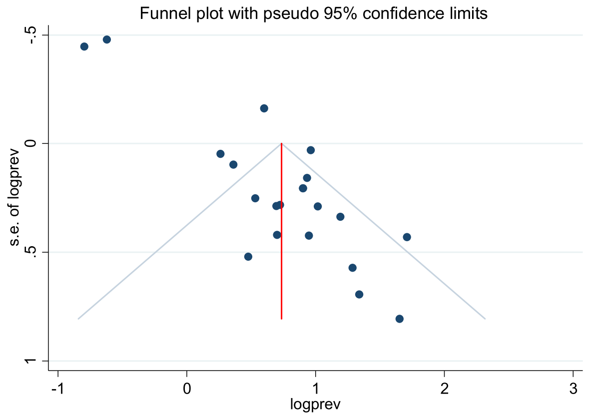

FIGURE 7 Funnel plot of the transformed prevalence estimates of tuberculosis among prisoners in Ethiopia.

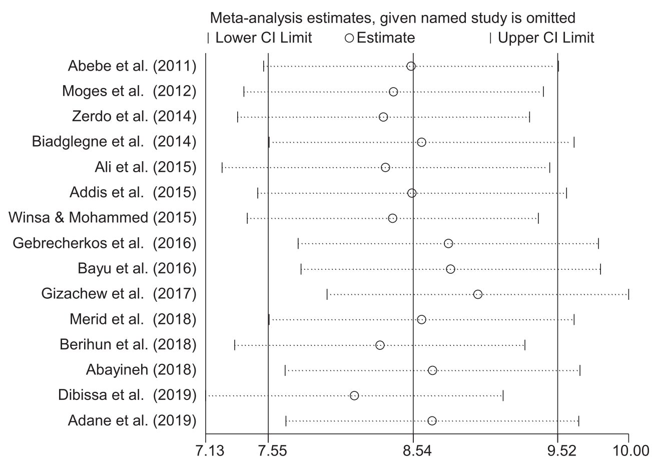

FIGURE 8 Sensitivity analysis result of the included studies that assessed the proportion of tuberculosis among prisoners in Ethiopia, 2011–2022.

pathogens are inhaled, they might congregate in the lungs and start to multiply.

Prisoners incarcerated in overcrowded cells with poor ventilation were 0.39 times more likely to have TB than those who were incarcerated in small cells with good ventilation. It is supported by other studies conducted elsewhere, which reported that both inadequate ventilation and crowded living conditions increase the risk of contracting TB.[69–71] Because there are not enough TB prevention and control initiatives in prisons and there is not enough access to health and referral services, the high TB incidence among chronic coughers may be explained by these factors. This may also be related to insufficient screening of prisoners upon entry into the facilities, poor ventilation, overcrowding, a lack of early case identification, and a lack of periodic TB screening for prisoners (concerns related to accessibility and the application of recommended screening strategies).

The current study found a strong statistical relationship between the magnitude of TB and the duration of imprisonment (adjusted odds ratio = 1.29 [95% CI: −0.39–2.97]), with the risk of TB increasing with the duration of imprisonment for those prisoners whose duration of incarceration is short. This result was consistent with previous studies conducted in SSA,[46] South Africa,[48] and India.[66] This might be because prisoners are not in a closed system, due to the number of people entering, departing, and reentering and the poor environmental situation, possibly increasing the transmission probability.

4.1 | Limitations of the study

The current study has certain limitations. Reports that were published in languages other than English were not included in this systematic review and meta-analysis. The different TB diagnostic methods used in the various studies also had an impact on the overall magnitude. Moreover, it was challenging to generalize the results due to a lack of information and data from a few regions. Furthermore, only studies conducted between 2011 and 2022 were included.

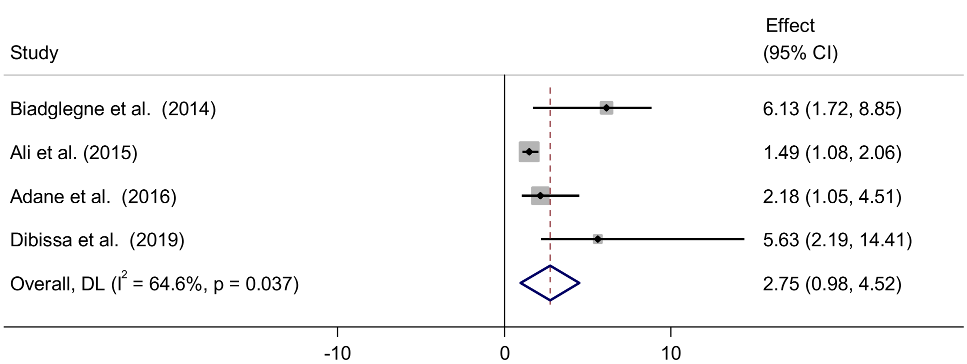

FIGURE 9 Association of contact history with tuberculosis patients with TB.

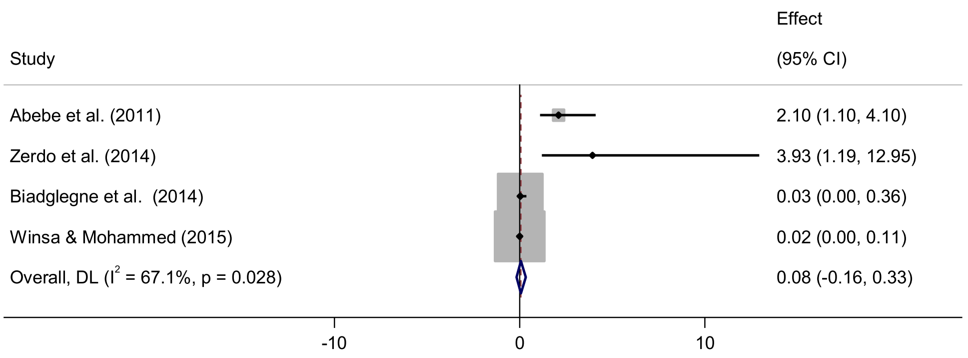

FIGURE 10 Association of coughing ≥2 weeks with tuberculosis.

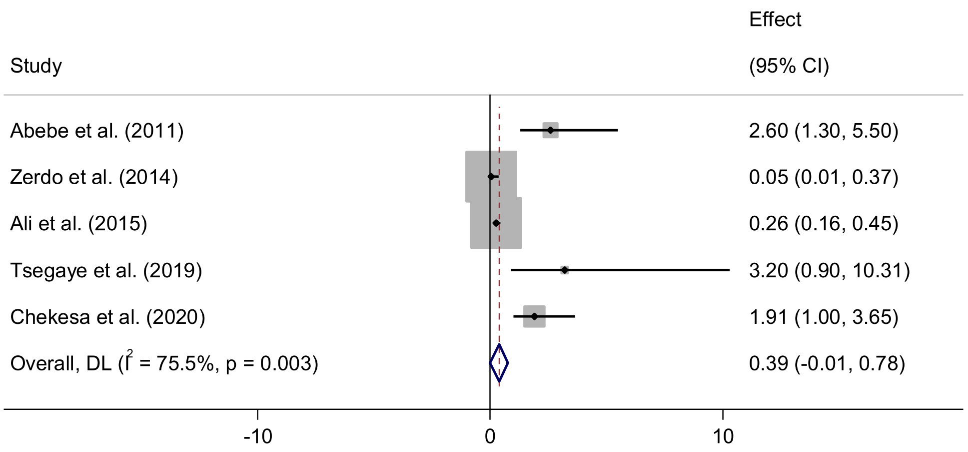

FIGURE 11 Association of poor ventilation of the cell with tuberculosis.

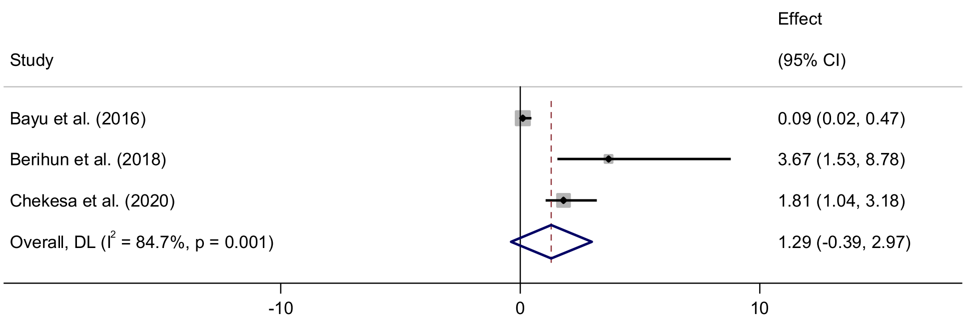

FIGURE 12 Association of length of imprisonment with tuberculosis.

5 | CONCLUSION

In the present study, LTBI was the most prevalent TB type among prisoners. In Ethiopia, the overall trend of TB prevalence among prisoners has been increasing, from 8.02% in 2011–2016 to 11.49% in 2017–2022. This increasing prevalence trend of TB may be the cause of the transmission of TB within prisons, between inmates, and between different populations. In Ethiopian prisons, prolonged incarceration, coughing, poor ventilation of the cell, and prior contact with TB patients are all risk factors for TB infection. To address this issue and successfully implement the control and end TB strategy in the prison population, methods for early screening, diagnosis of long imprisonment, appropriate ventilation of the call, and contact history should be established. For better diagnosis, treatment, and reduction of the TB burden among prisoners, CXR, Culture, and/or molecular diagnostics should be recommended.

AUTHOR CONTRIBUTIONS

Amere Genet: Methodology; resources; data curation; validation; visualization; project administration; supervision; writing—original draft. **Abayeneh Girma**: Conceptualization; data curation; software; formal analysis; investigation; validation; visualization; writing—review and editing. Both authors read and approved the final version of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

All the data in this review are included in the manuscript.

TRANSPARENCY STATEMENT

The lead author Abayeneh Girma affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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