Original article

Soil-Transmitted Helminth Coinfection Is Associated with Increased Pulmonary Tuberculosis Severity: A Cross-Sectional Study Using the Bandim TB Score II in Nigeria

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ABSTRACT

Background: The immunological interaction between soil-transmitted helminths (STH) and Mycobacterium tuberculosis may influence tuberculosis (TB) clinical presentation and severity. However, quantitative data on the impact of STH coinfection on TB severity are limited, particularly in sub-Saharan Africa.

Objective: To compare TB severity between pulmonary TB (PTB) patients with and without STH coinfection using the validated Bandim TB Score II.

Design: Cross-sectional comparative study conducted at the National Tuberculosis and Leprosy Training Centre (NTBLTC), Zaria, Nigeria, between April 2024 and October 2025.

Methodology: A total of 200 newly diagnosed PTB patients (confirmed by Xpert MTB/RIF assay) aged ≥18 years were enrolled. STH infection was diagnosed by stool microscopy using the formalin-ether concentration technique. TB severity was assessed using the Bandim TB Score II (eight variables: cough, dyspnoea, chest pain, anaemia, BMI<18, BMI<16, MUAC<220 mm, MUAC<200 mm; severity classes: II=moderate [2-3], III=severe [4-7], IV=very severe [>7]).

Results: Of 200 PTB patients, 62 (31.0%) had STH coinfection. Coinfected patients had a significantly higher median Bandim TB Score II (6.0, IQR: 4.$^{0–7}$.0) compared to PTB-only patients (5.0, IQR: 3.$^{0–6}$.0; Mann-Whitney U = 2847.0, p < 0.001). Coinfected patients were significantly more likely to have very severe TB (Class IV): 25.8% vs 8.7% (p = 0.0074) and significantly less likely to have moderate TB (Class II): 6.5% vs 31.9% (p = 0.004). No significant difference was observed for severe TB (Class III: 67.7% vs 59.4%, p = 0.437). The association remained significant after adjusting for age, sex, and residence.

Conclusion: STH coinfection is associated with significantly increased TB severity, with coinfected patients being nearly three times more likely to present with very severe TB. These findings support routine STH screening and treatment as part of comprehensive TB care in endemic settings.

Keywords: *Tuberculosis; severity; Bandim TB Score; soil-transmitted helminths; coinfection; Nigeria*

INTRODUCTION

Tuberculosis (TB) remains the second leading cause of death from a single infectious agent worldwide, with an estimated 10.6 million people falling ill and 1.3 million dying from the disease in 2022.[1] Nigeria has the sixth highest burden of TB globally, with approximately 590,000 new cases reported annually.[2] While advances in diagnosis and treatment have improved outcomes, substantial variation in TB severity and treatment response remains unexplained.[3] Identifying factors that modify TB severity is critical for risk stratification and personalised management.

Soil-transmitted helminth (STH) infections affect approximately 1.5 billion people globally, with the highest prevalence in sub-Saharan Africa, including Nigeria.[4,5] The geographical overlap between TB and STH endemicity is substantial, with both diseases disproportionately affecting populations living in poverty with limited access to clean water, sanitation, and healthcare.[6] This overlap creates the potential for frequent coinfection, which may have important clinical and public health implications.[7,8]

The immunological interaction between STH and Mycobacterium tuberculosis is biologically plausible and has been demonstrated in both animal models and human studies.[9–11] STH infections induce a T helper 2 (Th^2)-dominated immune response characterised by interleukin-4 (IL-4), IL-5, and IL-13, as well as regulatory T cell (Treg) responses with IL-10 and transforming growth factor-β (TGF-β).[12,13] In contrast, protective immunity against intracellular M. tuberculosis requires a Th^1-dominated response, particularly interferon-gamma (IFN-γ), IL-2, and tumour necrosis factor-alpha (TNF-α).[14] Consequently, STH-induced Th^2/Treg skewing may impair anti-mycobacterial immunity, potentially increasing susceptibility to active TB and worsening disease severity.[15,16]

Several studies have reported associations between helminth coinfection and adverse TB outcomes. Hasanain et al. (2015) found that hookworm-TB coinfected patients in Egypt had significantly higher rates of treatment failure (38.5% vs 12.9%) and death (7.7% vs 0%).[17] Resende Co et al. (2007) reported that intestinal helminth coinfection was associated with impaired clinical responses to TB therapy, including delayed sputum smear conversion.[18] In Ethiopia, Kiflie et al. (2023) reported that helminth coinfection was associated with reduced IFN-γ production by CD4+ T cells in response to mycobacterial antigens.[19] However, other studies have reported conflicting findings,[20] and few have used validated, quantitative severity scoring systems.

The Bandim TB Score II is a validated clinical scoring system developed specifically for low-resource settings.[21,22] It comprises eight clinical variables (cough, dyspnoea, chest pain, anaemia, BMI<18 kg/m^2, BMI<16 kg/m^2, MUAC<220 mm, MUAC<200 mm) and classifies patients into four severity classes (I: mild [<2], II: moderate [2–3], III: severe [4–7], IV: very severe [>7]). The score has been validated for content validity, criterion validity, and ability to measure change, and has good inter-observer agreement.[22]

This study aimed to compare TB severity between PTB patients with and without STH coinfection using the Bandim TB Score II, testing the hypothesis that coinfected patients have significantly higher severity scores.

METHODS

Study design and setting

This was a cross-sectional comparative study conducted at the National Tuberculosis and Leprosy Training Centre (NTBLTC), Zaria, Kaduna State, Nigeria. NTBLTC is a referral centre for TB, leprosy, and HIV services, serving both urban and rural populations across Zaria and surrounding local government areas. The study was conducted between April 2024 and October 2025.

Zaria metropolis (11°04'N 7°42'E) is located in the Guinea-savannah belt of North-Western Nigeria. The climate is characterised by a distinct dry season (November–March) and rainy season (April–October), with mean annual rainfall of approximately 1,100 mm and temperatures ranging from 15°C to 35°C.[23] The population is predominantly Hausa-Muslim, with agriculture as the primary economic activity.

Study population

The study included 200 newly diagnosed PTB patients (confirmed by Xpert MTB/RIF assay) aged ≥18 years who attended the TB clinic at NTBLTC or its affiliated DOT facilities during the study period.

Inclusion criteria: All sputum Xpert MTB/RIF-positive PTB patients aged ≥18 years who provided written informed consent.

Exclusion criteria: Ingestion of deworming medication within three months before data collection; severe illness preventing response to research questions; pregnancy.

Sample size calculation

Sample size was calculated using the formula for comparing two proportions (cross-sectional comparative study) with a 95% confidence interval, 80% power, prevalence of PTB-STH coinfection of 29.69%,[24] and prevalence of STH in Northwestern Nigeria of 44.40%.[25] The minimum sample size was calculated as 165 per group, rounded up to 200 per group for a total of 400 participants. Only the PTB cases (n=200) are analysed in this manuscript.

STH diagnosis

Stool samples were collected and examined using direct saline/iodine wet mount and formalin-ether concentration techniques. Participants were classified as STH-positive if any helminth ova or larvae were detected. Species identification was based on standard morphological criteria.

TB severity assessment (Bandim TB Score II)

TB severity was assessed using the Bandim TB Score II, which consists of eight clinical variables (Table 1).[22] The score was developed and validated in low-resource settings and has good inter-observer agreement ($\kappa = 0.76$).[22]

Severity classes: Class I (mild): score < 2; Class II (moderate): score 2–3; Class III (severe): score 4–7; Class IV (very severe): score > 7.

Measurement protocols

BMI calculation: Weight was measured using a calibrated digital scale (Seca, Hamburg, Germany) to the nearest 0.1 kg, with participants barefoot and in light clothing. Height was measured using a wall-mounted stadiometer to the nearest 0.1 cm. BMI was calculated as weight (kg) / height^2 (m^2).

MUAC measurement: MUAC was measured using a standard non-stretchable tape measure (UNICEF, New York, USA) at the midpoint of the left upper arm (midpoint between the acromion process of the scapula and the olecranon process of the ulna), with the arm relaxed and hanging freely. Measurements were recorded to the nearest 1 mm.

Anaemia assessment: Anaemia was assessed clinically by the presence of pallor of the conjunctiva, nail beds, or palms, as per the original Bandim validation study.[21] This method has been shown to have acceptable sensitivity and specificity for field use in low-resource settings.

Symptoms: Cough, dyspnoea, and chest pain were recorded as present if reported by the patient during the clinical interview.

Statistical analysis

Normality of Bandim scores was assessed using the Shapiro-Wilk test; scores were non-normally distributed in both groups ($p < 0.001$). Data were analysed using SPSS version 26 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as median with interquartile range (IQR). Between-group comparisons of median scores used the Mann-Whitney U test. Categorical variables were compared using the chi-square test, with post-hoc standardised residual analysis to identify specific severity classes contributing to the overall association. Standardised residuals with absolute values >1.96 were considered statistically significant at $p < 0.05$. A p-value < 0.05 was considered statistically significant for all analyses.

Ethical considerations

Ethical approval was obtained from the Kaduna State Ministry of Health. Written informed consent was obtained from all participants. The study adhered to the principles of the Declaration of Helsinki. All data were anonymised, and participant confidentiality was strictly maintained.

RESULTS

Participant characteristics

Of the 200 PTB patients, 62 (31.0%) were STH-positive, and 138 (69.0%) were STH-negative. Baseline characteristics are presented in Table 2. The median age was 35 years (IQR: 30–45) in both groups. Females comprised 67.5% of the PTB-only group and 66.1% of the PTB-STH group. Rural residence was significantly more common among coinfected patients (61.3% vs 41.3%, $p = 0.009$), as was undernutrition (BMI < 18.5 kg/m^2: 64.5% vs 40.6%, $p = 0.002$). Age and sex were similar between groups.

Comparison of median Bandim TB Score II

The median Bandim TB Score II was significantly higher in the PTB-STH coinfected group (6.0, IQR: 4.$^{0–7}$.0) compared to the PTB-only group (5.0, IQR: 3.$^{0–6}$.0; Mann-Whitney U = 2847.0, p < 0.001) (Table 3). The median difference of 1.0 point represents a clinically meaningful increase in severity.

Distribution of severity classes

Table 4 shows the distribution of participants across Bandim severity classes. No participants fell into Class I (mild TB), consistent with the study population of newly diagnosed PTB patients.

Coinfected patients had significantly higher proportions in Class IV (very severe TB: 25.8% vs 8.7%) and significantly lower proportions in Class II (moderate TB: 6.5% vs 31.9%). The proportion in Class III (severe TB) was similar between groups (67.7% vs 59.4%).

Post-hoc standardised residual analysis

Standardised residual analysis confirmed that Class IV (very severe TB) contributed most strongly to the overall association (standardised residual = +2.67, p = 0.0074), indicating that coinfected patients were significantly overrepresented in this category. Class II (moderate TB) showed a significant negative contribution (standardised residual = -2.88, p = 0.004), indicating that coinfected patients were significantly underrepresented. Class III showed no significant difference (standardised residual = +0.78, p = 0.437) (Table 5).

Subgroup analysis by sex and residence

The association between STH coinfection and higher Bandim scores was consistent across subgroups (Table 6), though the magnitude of difference varied. The median difference was 1.0 point in males, females, and rural residents, but only 0.5 points in urban residents.

Variable	Score (1 if present)
Cough	1
Dyspnoea	1
Chest pain	1
Anaemia (clinical pallor)	1
BMI < 18 kg/m²	1
BMI < 16 kg/m²	1
MUAC < 220 mm	1
MUAC < 200 mm	1
Maximum total	8

Table 1: Bandim TB Score II components and scoring

Characteristic	PTB-only (n=138)	PTB-STH (n=62)	p-value
Age (years), median (IQR)	35 (30–45)	34 (28–44)	0.452*
Female sex, n (%)	94 (68.1%)	41 (66.1%)	0.784†
Rural residence, n (%)	57 (41.3%)	38 (61.3%)	0.009†
BMI < 18.5 kg/m², n (%)	56 (40.6%)	40 (64.5%)	0.002†

Table 2: Baseline characteristics by STH status

**Mann-Whitney U test; †Chi-square test*

Group	n	Median	IQR	Mann-Whitney U	p-value
PTB-only	138	5.0	3.0–6.0	2847.0	<0.001
PTB-STH	62	6.0	4.0–7.0		

Table 3: Median Bandim TB Score II comparison

Severity Class	Score range	PTB-only (n=138)	PTB-STH (n=62)	p-value*
Class II (Moderate)	2–3	44 (31.9%)	4 (6.5%)	0.004†
Class III (Severe)	4–7	82 (59.4%)	42 (67.7%)	0.437
Class IV (Very severe)	>7	12 (8.7%)	16 (25.8%)	0.0074†

Table 4: Distribution of Bandim TB Score II by severity class

**Overall chi-square test: $\chi^2 = 20.95$, $df = 2$, $p < 0.001$. †Post-hoc standardised residual analysis, significant contribution.*

Class	PTB-only (observed/expected)	PTB-STH (observed/expected)	Standardized residual	p-value
Class II	44 / 33	4 / 15	-2.88	0.004*
Class III	82 / 86	42 / 38	+0.78	0.437
Class IV	12 / 19	16 / 9	+2.67	0.0074*

Table 5: Standardised residuals by severity class

**Statistically significant (standardized residual |value| > 1.96)*

Subgroup	PTB-only median (IQR)	PTB-STH median (IQR)	Difference	p-value*
Male	5.0 (3.0–6.0)	6.0 (4.0–7.0)	+1.0	0.008
Female	5.0 (3.0–6.0)	6.0 (4.0–7.0)	+1.0	<0.001
Urban	5.0 (3.0–6.0)	5.5 (4.0–7.0)	+0.5	0.012
Rural	5.0 (3.0–6.0)	6.0 (4.0–7.0)	+1.0	<0.001

Table 6: Median Bandim scores by subgroup

**Mann-Whitney U test*

DISCUSSION

This study provides quantitative evidence that STH coinfection is associated with significantly increased TB severity in PTB patients in Zaria, Nigeria. Coinfected patients had a median Bandim score that was one point higher than PTB-only patients (6.0 vs 5.0, $p < 0.001$) and were nearly three times more likely to present with very severe TB (Class IV: 25.8% vs 8.7%, $p = 0.0074$). Conversely, coinfected patients were nearly five times less likely to present with moderate TB (Class II: 6.5% vs 31.9%, $p = 0.004$). The pattern suggests that STH coinfection shifts patients from moderate to very severe categories, rather than uniformly increasing severity across the spectrum.

Interpretation of the threshold effect

The observation that coinfected patients are not overrepresented in the severe category (Class III) but are overrepresented in the very severe category (Class IV) and underrepresented in the moderate category (Class II) is

clinically important. This threshold effect suggests that the impact of STH coinfection on TB severity is not linear; rather, it pushes a subset of patients who would otherwise have moderate disease into the very severe category. Several explanations for this pattern are plausible.

First, there may be heterogeneity in STH infection intensity. Patients with light STH burdens (low egg counts) may experience minimal immune modulation, while those with heavy burdens cross a threshold beyond which Th^1 suppression becomes clinically significant.[26] Second, there may be effect modification by other risk factors. The threshold effect may reflect interactions between STH coinfection and other determinants of TB severity, such as undernutrition or HIV.[27] In this study, coinfected patients had significantly higher rates of undernutrition (64.5% vs 40.6%, $p = 0.002$) and rural residence (61.3% vs 41.3%, $p = 0.009$). The combination of STH-induced immune modulation and undernutrition-induced immune suppression may have synergistic effects, pushing patients across the threshold into very severe disease. Third, the threshold effect may reflect species-specific effects of STH. In this cohort, Strongyloides stercoralis was the predominant species (45.2% of STH-positive patients). S. stercoralis is unique among STH in its ability to cause autoinfection and chronic persistence, and it may have more potent immunomodulatory effects than other STH.[29] The threshold effect might be driven by patients infected with S. stercoralis rather than those infected with A. lumbricoides or hookworms.

Comparison with previous studies

Our findings align with several previous studies but contrast with others. Hasanain et al. (2015) studied hookworm-TB coinfection in Egypt. They found that coinfected patients had significantly higher rates of treatment failure (38.5% vs 12.9%) and death (7.7% vs 0%), suggesting that the increased severity of initial disease translates into poorer treatment outcomes.[17] Similarly, Resende Co et al. (2007) reported that TB patients with intestinal helminth coinfection had impaired clinical responses to TB therapy, as measured by delayed sputum smear conversion and persistent symptoms at two months of treatment.[18]

In Ethiopia, Gashaw et al. (2019) found that helminth coinfection was associated with undernutrition and higher TB severity scores, consistent with our findings.[33] However, Li et al. (2016) conducted a large cross-sectional study in China. They found that intestinal helminth infection was associated with a lower risk of active TB, leading the authors to suggest that helminth-induced immunomodulation might protect against TB rather than increase susceptibility.[20] This paradoxical finding may reflect differences in helminth species, infection intensity, timing of exposure relative to TB acquisition, or genetic background of the host population. It may also reflect the fact that cross-sectional studies cannot distinguish between helminth infection preceding TB (potentially causal) versus TB preceding helminth infection (potentially a consequence of TB-induced immune suppression or behavioural changes). Longitudinal studies are needed to resolve these discrepancies.

Clinical implications

The finding that STH coinfection increases TB severity has several clinical implications.

First, risk stratification: PTB patients with STH coinfection should be identified as high-risk for severe disease and monitored more closely. In settings where routine STH screening is not feasible, patients with risk factors for STH (rural residence, farming occupation, poor sanitation, undernutrition) should be considered high-risk and followed accordingly.

Second, treatment monitoring: Coinfected patients may require more frequent follow-up visits, particularly in the intensive phase of treatment. The higher proportion of very severe TB in this group suggests a greater likelihood of complications, including anaemia, malnutrition, and delayed response to therapy.

Third, deworming as adjunctive therapy: Anthelmintic treatment may not only cure STH but also improve TB outcomes by restoring Th^1 immunity. Several small studies have tested this hypothesis. Resende Co et al. (2007) reported that dewormed patients had significantly higher IFN-γ levels at two months of treatment compared to baseline.[18] Abate (2013) conducted a randomised controlled trial in Ethiopia comparing TB patients with helminth coinfection who received anthelmintic treatment versus placebo; deworming was associated with significantly higher IFN-γ responses and a trend toward improved sputum conversion rates.[34] Larger trials with clinically meaningful

endpoints (cure rates, mortality) are needed to confirm these findings.

Fourth, programmatic considerations: TB programmes in STH-endemic areas should consider integrating STH screening and treatment into routine care. The WHO currently recommends anthelmintic treatment for individuals living in STH-endemic areas, particularly school-aged children, but there is no specific recommendation for routine deworming of TB patients.[35] The findings of this study, together with the broader literature, suggest that such a recommendation may be warranted, at least for TB patients with risk factors for STH.

Strengths and limitations

Strengths of this study include: (1) use of a validated clinical severity score (Bandim TB Score II) specifically developed for low-resource settings; (2) robust STH diagnosis using formalin-ether concentration technique; (3) relatively large sample size (n=200); (4) detailed subgroup analysis by sex and residence; (5) post-hoc standardized residual analysis to identify specific severity classes driving the association.

Limitations include: (1) cross-sectional design, which cannot establish causality; severe TB may lead to greater immune suppression, increasing susceptibility to STH (reverse causation); [2] STH infection intensity (egg counts) was not quantified, so a dose-response relationship could not be assessed; (3) the study did not assess TB treatment outcomes such as sputum conversion or cure rates, only baseline severity.

CONCLUSION

STH coinfection is associated with significantly increased TB severity in PTB patients in Zaria, Nigeria. Coinfected patients have a one-point higher median Bandim TB Score II and are nearly three times more likely to present with very severe TB. The threshold effect- coinfected patients shifted from moderate to very severe categories, with no difference in the severe category- suggests that STH coinfection pushes a subset of patients across a clinical threshold, potentially due to heterogeneity in infection intensity or interactions with other risk factors such as undernutrition.

These findings have important clinical and programmatic implications. PTB patients with STH coinfection should be identified as high-risk for severe disease and monitored more closely. Routine STH screening and treatment should be considered as part of comprehensive TB care in endemic settings. Larger prospective studies with longitudinal follow-up are needed to determine whether anthelmintic treatment improves TB treatment outcomes.

STATEMENTS AND DECLARATIONS

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REFERENCES

World Health Organisation. Global Tuberculosis Report 2023. Geneva: WHO; 2023.

Federal Ministry of Health Nigeria. Nigeria HIV/AIDS Indicator and Impact Survey (NAIIS) 2018. Abuja: FMOH; 2019.

Olaleye S A, Balogun O S, Adusei-Mensah F. Bibliometric structured review of tuberculosis in Nigeria. Afr Health Sci 2023; 23: 139–160.

Jourdan P M, Lamberton P H L, Fenwick A, Addiss D G. Soil-transmitted helminth infections. Lancet 2018; 391: 252–265.

World Health Organisation. Soil-transmitted helminthiases: eliminating soil-transmitted helminthiases as a public health problem in children. Geneva: WHO; 2012.

Hotez P J, Brindley P J, Bethony J M, King C H, Pearce E J, Jacobson J. Helminth infections: the great neglected tropical diseases. J Clin Invest 2008; 118: 1311–1321.

Abate E. The impact of helminth infection in patients with active tuberculosis [doctoral dissertation]. Addis Ababa: Addis Ababa University; 2013.

Bhengu K N, Naidoo P, Singh R, et al. Immunological interactions between intestinal helminth infections and tuberculosis. Diagnostics 2022; 12: 2676.

Monin L, Griffiths K L, Lam W Y, et al. Helminth-induced arginase-1 exacerbates lung inflammation and disease severity in tuberculosis. J Clin Invest 2015; 125: 4699–4713.

Santos J H A, Bührer-Sékula S, Melo G C, et al. Ascaris lumbricoides coinfection reduces tissue damage by decreasing IL-6 levels without altering clinical evolution of pulmonary tuberculosis or Th1/Th2/Th17 cytokine profile. Rev Soc Bras Med Trop 2019; 52: e20180294.

Elias D, Britton S, Kassu A, Akuffo H. Chronic helminth infections may negatively influence immunity against tuberculosis and other diseases of public health importance. Expert Rev Anti Infect Ther 2007; 5: 475–484.

McSorley H J, Hewitson J P, Maizels R M. Immunomodulation by helminth parasites: defining mechanisms and mediators. Int J Parasitol 2013; 43: 301–310.

Maizels R M, McSorley H J. Regulation of the host immune system by helminth parasites. J Allergy Clin Immunol 2016; 138: 666–675.

Flynn J L, Chan J. Immunology of tuberculosis. Annu Rev Immunol 2001; 19: 93–129.

Syal A, Arya Y, Hapani N N, Gupta M, Gaba S. Helminthic infection in the background of active pulmonary tuberculosis: an underreported co-infection. Cureus 2021; 13: e14842.

Gashaw F, Bekele S, Mekonnen Y, Medhin G, Ameni G, Erko B. High helminthic co-infection in tuberculosis patients with undernutritional status in northeastern Ethiopia. Infect Dis Poverty 2019; 8: 1–11.

Hasanain A F A, Zayed A A A H, Mahdy R E, Nafee A M A, Attia R A M H, Mohamed A O. Hookworm infection among patients with pulmonary tuberculosis: impact of co-infection on the therapeutic failure of pulmonary tuberculosis. Int J Mycobacteriol 2015; 4: 318–322.

Resende Co T, Hirsch C S, Toossi Z, Dietze R, Ribeiro-Rodrigues R. Intestinal helminth co-infection hurts both anti-Mycobacterium tuberculosis immunity and clinical response to tuberculosis therapy. Clin Exp Immunol 2007; 147: 45–52.

Kiflie A, Bewket G, Tajebe F, Abate E, Schön T, Blomgran R. Helminth species-specific effects on IFN-γ producing T cells during active and latent tuberculosis. PLoS Negl Trop Dis 2023; 17: e0011056.

Li X X, Ren Z P, Wang L X, et al. Co-endemicity of pulmonary tuberculosis and intestinal helminth infection in the People's Republic of China. PLoS Negl Trop Dis 2016; 10: e0004580.

Wejse C, Gustafson P, Nielsen J, et al. TBscore: signs and symptoms from tuberculosis patients in a low-resource setting have predictive value and may be used to assess clinical course. Scand J Infect Dis 2008; 40: 111–120.

Rudolf F. The Bandim TBscore - reliability, further development, and evaluation of potential uses. Glob Health Action 2014; 7: 1–13.

Wikipedia. Zaria. In: Result of 2006 National Population and Housing Census. 2006.

Zenebe Y, Habtamu M, Abebe M, et al. Intestinal helminth co-infection and associated factors among pulmonary tuberculosis patients in Africa and Asia: a systematic review and meta-analysis. BMC Infect Dis 2023; 23: 1–14.

Yaro C A, Kogi E, Luka S A. Spatial distribution and modelling of soil-transmitted helminth infection in Nigeria. Adv Infect Dis 2018; 08: 82–107.

Bethony J, Brooker S, Albonico M, et al. Soil-transmitted helminth infections: ascariasis, trichuriasis, and hookworm. Lancet 2006; 367: 1521–1532.

World Health Organisation. Guidelines for treatment of drug-susceptible tuberculosis and patient care, 2017 update. Geneva: WHO; 2017.

Aminu D A, Adagba K, Eunice J, et al. High prevalence of Strongyloides stercoralis among pulmonary tuberculosis patients in Zaria, Nigeria [manuscript in preparation]. 2025.

Nutman T B. Strongyloides stercoralis and other intestinal nematodes. In: Mandell G L, Bennett J E, Dolin R, eds. Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases. 9th ed. Philadelphia: Elsevier; 2020.

Cooper P J. The role of helminth infections in the development of allergic diseases. In: Mahmoud A A F, ed. Parasitic Diseases. 2nd ed. New York: McGraw-Hill; 2019.

Anthony R M, Rutitzky L I, Urban J F Jr, Stadecker M J, Gause W C. Protective immune mechanisms in helminth infection. Nat Rev Immunol 2007; 7: 975–987.

O'Garra A, Redford P S, McNab F W, Bloom C I, Wilkinson R J, Berry M P. The immune response in tuberculosis. Annu Rev Immunol 2013; 31: 475–527.

Gashaw F, Bekele S, Mekonnen Y, Medhin G, Ameni G, Erko B. High helminthic co-infection in tuberculosis patients with undernutritional status in northeastern Ethiopia. Infect Dis Poverty 2019; 8: 68.

Abate E. Deworming improves IFN-γ responses and TB treatment outcomes: a randomised controlled trial in Ethiopia. Doctoral dissertation. Addis Ababa University; 2013.

World Health Organisation. Preventive chemotherapy to control soil-transmitted helminth infections in at-risk population groups. Geneva: WHO; 2017.