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Research Article

Nutritional Status and Tuberculosis among Children under Five in Indonesia: A Systematic Review and Meta-Analysis

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A B S T R A C T

Background: According to the 2023 Indonesian Health Survey (SKI–Survei Kesehatan Indonesia), the national prevalence of stunting is 21.5%. In contrast, the prevalence of tuberculosis (TB) among infants has been reported to reach up to 38% in certain regions. Stunted children are particularly vulnerable to TB infection due to their compromised immune function.

Methods: The study used five popular and credible electronic database sources, such as Crossref, Google Scholar, ScienceDirect, Scopus, and Semantic Scholar, to ensure broad and accurate coverage of information. The studies or scientific articles searched were limited to the last ten years, from 2015 to 2025. Included studies were observational, conducted in Indonesia, involved infants, and investigated the relationship between nutritional status (underweight, stunting, wasting) and TB.

Results: Eight studies were selected because they met the inclusion criteria. All studies had observational designs, namely cross-sectional (observations at one time) and case-control (comparing groups with and without tuberculosis). The sample sizes of the studies varied widely, from small with only 60 participants to very large with up to 27,830 participants. In general, the majority of studies found that poor nutrition or stunting was positively associated with tuberculosis, meaning that people with nutritional problems were more likely to develop TB. The meta-analysis showed a pooled odds ratio (OR) of 4.10 (95% confidence interval: 2.17-7.74), with a high degree of heterogeneity among the studies (I^2 = 84.4%).

Conclusion: Malnutrition, particularly stunting, substantially elevates the risk of tuberculosis among infants in Indonesia. Therefore, effective TB prevention strategies must incorporate comprehensive nutritional interventions as a core component.

Keywords: Body Mass Index, Children under five, Tuberculosis, Meta-analysis, Stunting

Introduction

Tuberculosis (TB) is a chronic infectious disease, meaning that it develops slowly over a long period of time. The main cause is the bacterium Mycobacterium tuberculosis, which most commonly affects the lungs as the main respiratory organ. However, TB is not limited to the lungs; the infection can also spread to other organs, especially in individuals with weakened immune systems (Daniela F. et al., 2023). Tuberculosis is spread through the respiratory tract, usually when a person coughs, sneezes or talks, allowing the bacteria to be inhaled by others. The disease is particularly dangerous for vulnerable population groups, especially children under the age of five, as their immune systems are not yet fully developed to fight infection.[2,3] Furthermore, stunted children tend to have a weak immune system, making them more susceptible to infections, including TB. Data shows that stunted toddlers have a 2.36 times higher risk of contracting TB than children without stunting,[4] and they face mortality rates that are two to nine times higher compared to their well-nourished counterparts.[5]

Tuberculosis remains a major public health challenge, especially in low- and middle-income countries, including Indonesia. Despite various control programmes and global efforts, such as increased early detection, routine treatment, and public health campaigns, morbidity and mortality rates due to TB remain high.[6] In Indonesia alone, data shows that the number of TB cases continues to increase every year. In 2022, the number of reported cases reached 724,309, then increased to 821,200 cases in 2023, and in 2024 increased again to 856,420 cases.[7] More worryingly, about 9.7 per cent of all TB cases occurred in children under the age of five. This age group is considered very vulnerable because their immune systems are not yet optimally developed.[7]

Tuberculosis affecting children under the age of five remains a serious problem in developing countries, including Indonesia. This is inseparable from the high rate of stunting, which is a condition of growth failure in children due to chronic malnutrition. Stunting causes children to have a weaker immune system, making them more susceptible to infectious diseases such as TB. According to the 2024 "Survey on the Status of Nutrition in Indonesia (SSGI)", the prevalence or incidence rate of stunting in Indonesia nationally is 19.8%, which means almost 1 in 5 children are stunted.[8] Although this represents a decline, several regions still report prevalence rates exceeding 30%. A study conducted in Bandung found that 59.76% of 169 children under five were diagnosed with pulmonary TB.[9] Tuberculosis further deteriorates nutritional status by increasing metabolic demands, suppressing appetite, and impairing nutrient absorption, thereby establishing a bidirectional relationship between TB and malnutrition.[10–13] Moreover, paediatric tuberculosis not only leads to acute illness but also has long-term adverse effects on respiratory function and physical development.[14–16] Previous studies have shown that after undergoing TB treatment and being cured, some children still face health problems related to the respiratory system. The percentage of children experiencing these residual respiratory complaints varies widely, ranging from 1% to almost half (49%).[17]

Effective tuberculosis control among children under five necessitates an integrated approach that addresses both nutritional and environmental risk factors. Key determinants of childhood TB include malnutrition, close contact with infectious TB cases, household overcrowding, inadequate sanitation, and low maternal educational attainment.[18–20] Micronutrients, which include essential vitamins and minerals such as vitamin A, vitamin D, iron and zinc, play a crucial role in maintaining and strengthening the immune system. When the body is deficient in these nutrients, the body's ability to fight off infections decreases due to impaired immune cell function.[21,22] Inadequate dietary intake, along with comorbid conditions such as diarrhoea and respiratory infections, further exacerbates children's vulnerability to tuberculosis. Various global initiatives led by world health organisations such as WHO have set out a strategy to completely eradicate tuberculosis. One of the main focuses in this strategy is to provide preventive treatment to children who are in close contact or live with family members infected with TB. However, implementation has been limited; in 2023, only 42% of eligible children received preventive therapy.[23] In Indonesia, tuberculosis control programmes targeting children have been integrated with national stunting reduction initiatives; however, the implementation of this integration remains suboptimal.[24,25]

Previous studies have explored how nutritional status affects the risk of tuberculosis in children under five. However, in Indonesia, one of the countries with the highest number of TB cases in the world, no studies have combined and thoroughly analysed all these studies in the form of a systematic review or meta-analysis. This study fills this gap by collecting and analysing data from various related studies in Indonesia to get a clearer picture of the relationship between nutrition and TB in children under five. With results that are expected to be valid and reliable, this study can provide a strong basis for policymakers to design more effective health programmes, especially in efforts to reduce TB and stunting rates, which are two health problems that affect the welfare of children and the future of the nation.

Methods

The method used in this research is a systematic literature review, which aims to collect and analyse relevant literature or studies in a structured and thorough manner. To ensure that the implementation and reporting of this review

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are in accordance with international standards, the research followed the PRISMA 2020 guidelines. PRISMA is a continuously updated framework to help researchers report the process and results of systematic reviews in a clear, transparent and complete manner.[26] The use of this guide ensures that all important steps in the review, such as study selection, quality assessment, and data analysis, are well-documented and accountable. Thus, the results of the review become more credible and reliable as a basis for decision-making or policy development.

Eligibility criteria

To develop eligibility criteria for studies to be included in the systematic review and meta-analysis, the researchers used the PICOS approach, which includes aspects of "Population, Intervention or Exposure, Comparison, Outcome, and Study design". This framework helps to clearly define the key elements that each study must meet to be relevant for analysis together. For this review, the eligibility criteria were (1) studies conducted in Indonesia; (2) studies involving children under five years of age as the target population; (3) studies examining the association between nutritional status (e.g., underweight, stunting, or wasting) and tuberculosis; (4) studies reporting effect sizes or providing sufficient data to calculate them; and (5) observational study designs. Studies were disqualified if they: (a) did not have publications in English or Indonesian; (b) involved populations older than 25 years; (c) were reviews, editorials, commentaries, or case reports; or (d) did not provide clear data on nutritional status and tuberculosis outcomes.

Search Strategy

To obtain a complete and relevant set of literature, researchers conducted searches in several trusted electronic databases that are frequently used in medical and scientific research, such as Crossref, Google Scholar, ScienceDirect, Scopus, and Semantic Scholar. The focus of the search was on studies published in English during the 2015 to 2025 timeframe to ensure the data collected was sufficiently up-to-date. The medical subject heading (MeSH) and free text terms used were as follows: ("stunting"[Title/Abstract] OR "chronic malnutrition"[Title/Abstract]) AND ("tuberculosis" OR "TB"[Title/Abstract]) AND ("children under five"[Title/Abstract] OR "under-five children"[Title/Abstract] OR "under 5 years" OR "preschool children" OR "toddlers") AND (Indonesia). In addition to electronic searches, researchers also conducted manual searches by checking the reference lists of relevant articles and reviews to find additional sources that may have been overlooked. This approach ensured that the literature collected was comprehensive and representative.

Study selection

After conducting a literature search from various sources, all results found were collected and organised using Mendeley, a software that helps manage research references efficiently. The first step was to remove duplicate data to avoid repetition of analysis. Then, two researchers independently conducted a screening process by carefully reading the title, abstract and full content of the article to determine if the study met the pre-defined inclusion criteria. After determining eligible studies, the researchers extracted important quantitative data and other relevant information from the studies. If there are differences of opinion between the two researchers when screening studies or extracting data, they discuss to seek agreement. If the discussion doesn't lead to agreement, a third reviewer is brought in to give their opinion and help reach a final decision. This process aims to maintain the objectivity and quality of data selection so that the research results are valid and accountable.

Data extraction

Data collection was carried out independently by two researchers to ensure accuracy and reduce bias. The information collected included the name of the first author and the year of publication as an identity and the time of implementation of the study, then the location of the study, which is usually in the form of a district or city, as well as the type of research design used. The age group of participants was also recorded to ensure compatibility with the target population. In addition, the sample size indicating the number of participants in the study was also taken. Data related to nutritional status assessment tools or methods used to measure the nutritional condition of participants were also collected, as well as prevalence data in the form of numerators and denominators describing the frequency of occurrence in the study population. All of this information is neatly organised and stored in Microsoft Excel format to facilitate further data management and analysis.

Risk of Bias (Quality Assessment).

A customised Critical Appraisal Checklist, specifically developed for quantitative observational studies, was utilised by two independent reviewers to assess the risk of bias. Each article was assessed using 12 evaluation criteria, including the clarity of the research objective, sample recruitment methods, accuracy of exposure and outcome measurements, control of confounding variables, reporting of results as adjusted odds ratios (aOR), and the practical relevance and implications of the findings. Scoring was conducted on a three-point scale: 0 (no), 1 (unclear), and 2 (yes), with a maximum possible score of 24. Discrepancies in scoring among reviewers were resolved through discussion to reach consensus; when disagreements persisted, a third researcher helped make the final decision.

Statistical Analysis

During the data collection process, four reviewers worked independently to ensure the accuracy and consistency of

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the data collected, using Microsoft Excel as a tool. The data collected focused on the important variables of under-five children's nutritional status, including undernutrition or stunting, and the incidence of tuberculosis among this group. To comprehensively analyse the data, the meta-analysis was conducted using the latest version of RStudio software from Posit Software. One important aspect of meta-analysis is evaluating heterogeneity, which is the extent to which results from different studies differ from each other. This assessment was done using the I^2 statistic, which measures the proportion of variation between studies that is due to real differences rather than mere chance. In addition, Cochrane's Q test was used to determine whether the detected heterogeneity was statistically significant. An I^2 value of 25% indicates low heterogeneity, 50% indicates moderate, and 75% or more indicates a high level of heterogeneity. If the heterogeneity was relatively large (more than 50%) or the statistical test results showed significance (p-value less than 0.05), then a random-effects model was selected for the meta-analysis, as this model accommodates variation between studies. However, if heterogeneity was low and insignificant, a fixed effects model was used, which assumes that all studies estimate the same effect.

To maintain consistency and enhance comparability across studies, this meta-analysis utilised bivariate analysis results, as nutritional status variables were not included in the multivariate models in several of the included studies. We presented the data as odds ratios (OR) or prevalence ratios (PR) with their 95% confidence intervals. Statistical significance was set at $p < 0.05$. Findings were visualised using forest plots. For the stratified meta-analysis, we categorised data by study setting, source population, and study design. A funnel plot analysis was conducted to assess publication bias; the resulting plots showed symmetrical distributions, indicating no significant evidence of publication bias.

Result

Selection Process

As shown in the PRISMA flow diagram, articles were identified by searching five electronic databases: Crossref (n = 1,000), Google Scholar (n = 1,039), ScienceDirect (n = 336), Scopus (n = 76), and Semantic Scholar (n = 5), yielding a total of 2,456 records. Prior to the screening process, 245 articles were removed—31 due to duplication and 214 excluded by an automated filtering tool—resulting in 2,211 articles that proceeded to the title and abstract screening stage. Of the total records identified, 2,101 articles were excluded after title and abstract screening due to irrelevance. After a full-text eligibility review of the remaining 110 articles, 102 were excluded for the reasons listed below: inappropriate study design (n = 45), irrelevant study population (n = 23), unrelated outcomes (n = 14), unsuitable intervention or exposure (n = 11), inadequate measurement of key variables (n = 6), and inaccessible full-text manuscripts (n = 3). After the selection process, eight articles were found to meet the inclusion criteria and were, therefore, integrated into this systematic review. The PRISMA flow diagram (Figure 1) visually represents this entire selection journey.

Characteristics of Studies

The eight studies analysed in this review included cross-sectional and case-control designs, which allowed for data collection from a variety of methodological approaches. These studies were conducted in a number of regions in Indonesia, including two studies in Surabaya, as well as one study each in Sukabumi, Makassar, Semarang, Bogor and Bandung. In addition, there was one nationwide study that used data from Riskesdas 2018, an important health survey in Indonesia. Sample sizes between studies varied widely, ranging from a study involving 60 participants by Wijayanti, (2020) to a study with the largest sample size of 27,830 participants by Widyastuti, (2021). These variations suggest differences in the scope and scale of the studies, which may affect the generalisability of the findings in the context of under-five child health and the association of nutritional status with tuberculosis in Indonesia. Most studies assessed nutritional status using Z-scores, while a few employed the weight-for-length ratio. The sources of study participants also differed, with data collected from hospitals, health centres, and community settings. Notably, in community-based studies, tuberculosis status was determined solely through respondent interviews, which may limit diagnostic accuracy. In contrast, studies conducted in healthcare settings such as hospitals and health centres employed more valid and standardised diagnostic approaches, including chest X-rays, tuberculin skin tests, radiological assessments, and clinical diagnoses by experienced physicians.

This study shows that children who are malnourished or stunted have a higher chance of developing tuberculosis compared to children with normal nutritional status. The number used to describe the strength of this relationship is the odds ratio (OR) or prevalence ratio (PR), which in this study ranged from 1.78 to 13.21. This means that the risk of TB in malnourished or stunted children can increase almost two-fold to more than thirteen-fold compared to children without nutritional problems.

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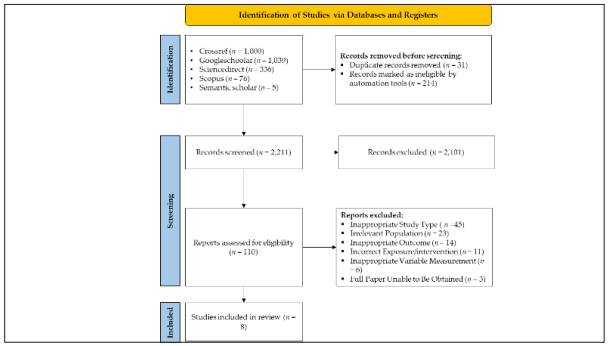

Figure 1.Prisma Flowchart

Table 1.Characteristic of Included Studies

Author (Year)	District/ city	Study Design	Year of Study	Sample Size	Undernutrition/ Stunting	TB	No TB	Main Result (OR/PR)	Nutritional Status Measurement	Source Participants
Setyoningrum, 2024	Surabaya	Cross-sectional	2010–2018	367	105	68/277	37/90	8.88	Z-score	Hospital
Farsida, 2023	Sukabumi	Case-control	2019	76	28	19/38	9/38	3.22	Body weight/ Body length	Hospital
Manillaturrochmah, 2022	Surabaya	Case-control	-	113	47	30/56	17/57	2.71	Body weight/ Body length	Hospital
Purnamasari, 2022	Bogor	Cross-sectional	2019	194	3	3/69	0/125	13.21	Z-score	Community
Widyastuti, 2021	Indonesia	Cross-sectional	2018	27830	74	23/5625	51/22205	1.78	Body weight/ Body length	Community
Haerana, 2021	Makassar	Cross-sectional	2018–2019	126	31	23/48	8/78	8.05	Z-score	Primary Health Center
Wijayanti, 2020	Semarang	Case-control	2013	60	16	15/30	1/30	2.75	Z-score	Primary Health Center
Jahiroh, 2017	Bandung	Case-control	2013	174	98	39/58	59/116	1.98	Z-score	Primary Health Center

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Figure 2.Map of the distribution of articles included in the meta-analysis

Quality Appraisal of Studies

To ensure that the studies included in this review were of good methodological quality, a critical appraisal process was conducted on each study. This assessment used a customised checklist that included 12 evaluation criteria, such as clarity of research objectives, appropriateness of design, validity of data, and relevance of results. The checklist is an adaptation of the "Critical Appraisal Skills Program (CASP)" guidelines, a tool widely used internationally to assess the quality of quantitative research. Each study was assessed based on key methodological criteria, including the clarity of the research objective, sample recruitment strategies, accuracy of exposure and outcome measurements, consideration of potential confounders, reporting of results as adjusted odds ratios (aOR), and the relevance and practical implications of the findings. A scoring system was applied, assigning 0 (no), 1 (unclear), or 2 (yes) for each criterion, with a maximum possible score of 24 points per study.

The description of the questions in the study quality assessment consists of 12 criteria. The first criterion asked whether the study had a clear problem focus. The second criterion assessed whether the participant recruitment process was conducted in an acceptable manner. The third criterion evaluated whether the exposure to chronic kidney disease was accurately measured to reduce potential bias. The fourth criterion assesses the accuracy of the measurement of the outcome, i.e., death status, also to minimise bias. The fifth criterion looks at whether the researchers have identified all relevant confounding factors and considered them in the study design or analysis. The sixth criterion relates to the adequacy and duration of follow-up of the study subjects. The seventh criterion asks whether the results of the study are reported in the form of an adjusted odds ratio (aOR). The eighth criterion assesses the accuracy of the results. The ninth criterion assesses the reliability of the results. The tenth criterion considers whether the results can be applied in the context of the local community. The eleventh criterion assesses the consistency of the results with other existing research evidence. And the twelfth criterion assesses the implications of the research results for practice in the field. Each question was scored on a scale: 0 for "No", 1 for "Don't know", and 2 for "Yes".

Most of the studies we included showed strong methodological rigour, ranging from good to excellent, and three even scored at the top (≥22) in our quality assessment, namely Setyoningrum (2024), Jahiroh (2017), and Haerana (2021). These studies demonstrated robust methodological design, adequate control for confounding variables, and clear presentation of multivariate analysis results. In contrast, three other studies, Farsida (2023), Manillaturrochmah (2023), and Purnamasari (2022), had lower scores (≤17), mainly due to the absence of follow-up, not reporting aOR, and weaknesses in controlling confounders. Common methodological limitations across the included studies included the predominance of cross-sectional designs without longitudinal follow-up and inconsistencies in reporting adjusted outcome measures. Regardless, all articles met the inclusion criteria and were included in the meta-analysis.

Meta-Analysis

A pooled analysis of eight studies examining the association between nutritional status (malnutrition or stunting) and the incidence of tuberculosis in children under five in Indonesia found that undernourished children have about four times the risk of developing TB compared to well-nourished children. This was shown through an odds ratio (OR) of 4.10 with a 95% confidence interval of 2.17 to 7.74, which was obtained from a random effects model. Random-effects models are used because they take into account differences between studies, such as variations in methods, population, or location. However, to ensure consistency, we also conducted an analysis using a fixed effects model, which yielded similar results (OR = 4.10; 95% CI: 3.33-5.05), thus strengthening the validity of the main findings.

Although there was a high degree of heterogeneity (I^2 of 84.4% and $p < 0.0001$), indicating that the results from individual studies varied considerably, most studies still showed the same direction of association and were statistically significant. This means that despite the different

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contexts and characteristics between studies, they all tend to show that poor nutritional status is consistently associated with a higher risk of TB in children, making these findings important as a basis for nutrition and TB control interventions in vulnerable age groups.

In this analysis, there is asymmetry in the distribution of the data. Most studies reporting high log ORs (e.g., between 8.05 and 13.21) are clustered on the right side of the plot, while studies with smaller effects (1.78-2.75) are few and appear on the left side. This pattern suggests the possibility that studies with smaller or insignificant effects are under-published or difficult to find, known as publication bias. The result of this bias is that the meta-analysis results may be overly optimistic or overestimate the strength of the association between poor nutrition and tuberculosis. Although the studies analysed showed good methodological quality, the absence of studies with small or insignificant effects may decrease the validity and generalisability of the overall analysis. Therefore, these findings should still be interpreted with caution, while considering possible bias in scientific publications.

Table 2.Critical Appraisal Checklist for Qualitative Studies Using CASP

Primary Study	Criteria												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
Setyoningrum, 2024	2	2	2	2	2	1	2	2	2	2	2	2	23
Farsida, 2023	2	1	2	2	1	0	0	2	1	2	2	2	17
Manillaturrochmah, 2022	2	1	2	2	0	0	0	2	1	2	2	2	16
Purnamasari, 2022	2	2	1	2	1	0	0	1	1	2	2	2	16
Widyastuti, 2021	2	2	1	1	2	0	1	2	1	2	2	2	18
Haerana, 2021	2	2	2	2	2	1	1	2	2	2	2	2	22
Wijayanti, 2020	2	1	2	2	1	1	2	2	1	2	2	2	20
Jahiroh, 2017	2	2	2	2	2	1	2	2	2	2	2	2	23

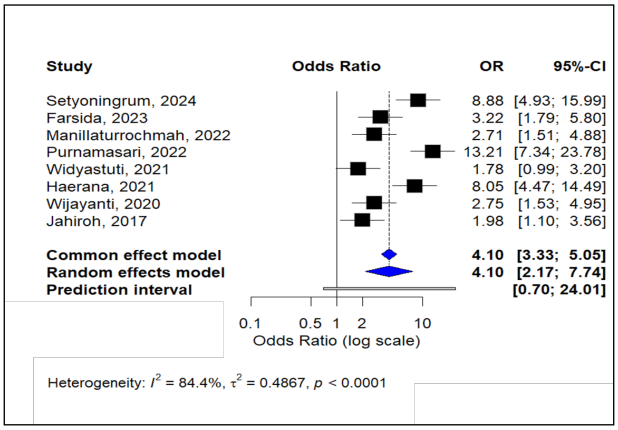

Figure 3.Forest Plot for Overall Studies

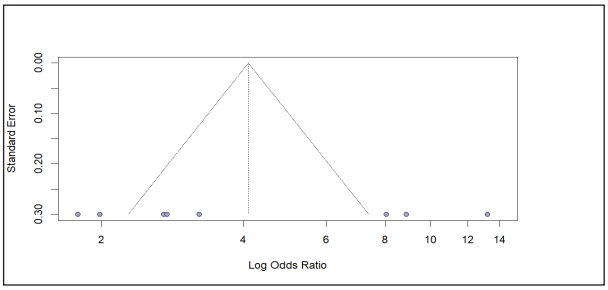

Figure 4.Funnel Plot for Overall Studies

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Discussion

This study presents a systematic synthesis of eight different studies examining the association between malnutrition (specifically stunting) and tuberculosis incidence in children under five in Indonesia. The studies analysed used cross-sectional and case-control designs, and random-effects models were used to account for between-study heterogeneity. The results showed that children with stunting or malnutrition had more than four times the risk of developing TB compared to well-nourished children, strengthening evidence that malnutrition increases vulnerability to serious infections such as TB.

A 2023 meta-analysis of over 48,000 participants reported a prevalence of malnutrition of 48% among TB patients, with higher rates in low-income groups, rural areas, and large households.[32] Malnourished TB patients are more likely to have serious complications, increased mortality, and slower sputum conversion, as well as a greater risk of drug resistance, highlighting the need for integrated nutritional and social interventions.

In addition, data from Makassar City (July 2018–April 2019) showed a prevalence of TB infection of 38.1% in toddlers who had household contact with TB patients, with a prevalence of stunting of 24.6%. Stunted children have a higher risk of TB infection (aPR 2.36; 95% CI 1.60–3.44), and factors such as intensive contact and not receiving BCG also increase the risk.[44]

In line with this, a study in Pekalongan (2025) using a cross-sectional design on 100 toddlers showed that poor nutritional status, low economic conditions, a history of TB contact, and immunisation status were significantly associated with TB incidence. Factors such as low maternal education, less varied diet, and repeated infections also contribute to stunting.[45] In Semarang City, TB screening was conducted on 149 toddlers in 2023, with 74.5% of the toddlers being stunted and 21.5% testing positive for TB. Of those testing positive, 25.2% had clinical TB and 6.3% had latent TB. Follow-up included immediate treatment, nutritional support, growth monitoring, and comprehensive psychosocial support.[46]

On World TB Day 2024, the Indonesian Ministry of Health emphasised the importance of integrating TB interventions and stunting management through integrated health posts (Posyandu), where weight loss or poor appetite are early indicators of TB in children. This initiative is designed to detect and treat TB cases in toddlers who may not exhibit the typical cough symptom.[47] Furthermore, a 2023 multilevel study noted a triple burden of malnutrition in Indonesia, where maternal and child malnutrition can be indicated by stunting, micronutrient deficiencies, and obesity. Determining factors include parental education status, sanitation, prenatal interventions, and the community environment. These findings recommend integrated nutrition interventions from the household to the community level.[48] Based on recent trends, integrating TB control programmes with nutrition interventions (especially stunting) at the community level through integrated health posts (posyandu) is a key strategy. Family education, household contact detection, and child nutrition screening must be carried out simultaneously to enhance preventive and therapeutic effects. National policies such as the ongoing Free Nutritious Meal programme aimed at reducing stunting, complemented by TB detection, can break the vicious cycle of malnutrition and TB.

A cross-sectional study in Makassar (July 2018–April 2019) involving toddlers with household contact with TB cases showed a TB infection prevalence of 38.1%, while stunting prevalence reached 24.6%. Children with stunting had a higher risk of TB infection with an aPR of 2.36 (95% CI 1.60–3.44) compared to non-stunting children. Other factors such as male gender, not receiving BCG immunisation, and high contact intensity also increased the risk. This study provides strong evidence of the association between stunting and TB infection in the context of household contact of toddlers in Indonesia.[43]

Research shows that a small decrease in body mass index (BMI), a measure of nutritional status, can have a significant impact on the risk of contracting TB. Each unit decrease in BMI is associated with a 13.8% increase in the risk of contracting tuberculosis.[36,37] The situation is further exacerbated when TB patients are also malnourished, especially those infected with TB that is resistant to standard treatment (drug-resistant). In such cases, the risk of death is twice as high compared to TB patients with adequate nutritional status. This highlights the importance of improving nutrition in TB treatment and control, as nutritional status is not only a risk factor for infection but also significantly influences treatment success and patient survival.[33]

In the national context, the prevalence of stunting in toddlers in Indonesia continues to decline, from around 30% in 2018 to 21.5% in 2023. However, this decline has not yet reached the 2024 RPJMN target, namely ≤14%.[41] Dominant factors associated with stunting include child age > 24 months, low birth weight, low economic status, low maternal education, large families, living in remote areas and poor sanitation. This trend is relevant to strengthening the integration of nutritional interventions in childhood TB control programmes because the targets of malnutrition interventions are increasingly clear.[41,42]

Malnutrition significantly increases children's susceptibility to tuberculosis by compromising the innate and adaptive immune responses and impairing granuloma

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formation, which is essential for containing the spread of Mycobacterium tuberculosis. When a person lacks essential protein and micronutrients, their immune system is significantly compromised. One impact is the shrinkage of lymphoid organs such as the lymph nodes and spleen, which are central to the production and maturation of immune cells, particularly T cells. The number of T cells decreases, and their ability to fight infection is weakened. Furthermore, the body produces fewer important cytokines, such as interleukin-2 (IL-2) and interferon-gamma (IFN-γ), which are needed to activate and multiply T cells to attack the TB-causing bacteria, Mycobacterium tuberculosis. Nutritional deficiencies also inhibit the production of iNOS, an enzyme that plays a key role in the killing of bacteria by immune cells. Without these components, the body is less able to fight TB infection, making malnourished patients more susceptible and making it more difficult to recover from the disease. In children who are inherently more immunologically vulnerable, malnutrition creates a compounding effect that accelerates the progression and increases the severity of TB. This underscores the urgent need for targeted prevention and treatment strategies tailored to this high-risk population.[38–40]

These findings have significant implications for public health policy and strategic planning in Indonesia. Tuberculosis prevention efforts must encompass more than just early detection and treatment but also targeted nutritional interventions, especially for high-risk groups such as young children. Integrating national stunting reduction initiatives with existing TB control programmes is crucial for improving overall health outcomes. This integration is especially crucial given the bidirectional relationship between stunting and TB, which can reinforce each other in a vicious cycle. Although a statistically significant association was found between nutritional status and tuberculosis incidence in children under five years of age, the I^2 value of 84.4% indicates a very high degree of variability between the results of each of the included studies. I^2 measures the extent to which variation between studies is not due to chance, and a value above 75% is considered to indicate high heterogeneity. This means that the studies differed in what they analysed. This variation can affect the consistency of the results and indicate that findings are not entirely uniform across contexts. This heterogeneity can stem from differences in study design (cross-sectional versus case-control), variations in sample size, the methodology used to assess nutritional status, and the varying geographic settings in which the studies were conducted.

Strengths And Limitations

This research has several strengths that deserve attention. Firstly, the literature search strategy was very comprehensive, as it used not just one or two databases but five major credible data sources. In addition, the wide time coverage from 2000 to 2025 made it possible to collect as many relevant and recent studies as possible, so the results of this review reflect the most current conditions and findings. Secondly, all the analysed studies are from Indonesia, which significantly increases the relevance of the findings in the local context. This is important because the unique social, economic, cultural and health system conditions in Indonesia may influence the relationship between malnutrition and tuberculosis. Third, the meta-analysis involved data from a large number of participants representing different regions and backgrounds, as well as from two different types of research designs (cross-sectional and case-control). This approach enriches the quality of the data and increases the validity of the findings, as it covers a wide range of research situations and methods. Overall, this provides a more comprehensive understanding of how malnutrition plays a role in increasing the risk of tuberculosis in children under five, supporting more targeted and evidence-based public health efforts.

However, there are some limitations that should be considered when interpreting the results. Firstly, the high heterogeneity value (I^2 = 84.4%) indicates that there are considerable differences between the studies analysed. This variation could arise from the different ways the studies were conducted, the different number of participants, and the use of non-uniform methods in measuring children's nutritional status. This makes the combined results less consistent. Secondly, the majority of the studies analysed used a cross-sectional design, which only observes data at one point in time without taking into account the time sequence of events. This design has limitations in determining the exact causal relationship between malnutrition and tuberculosis, so the results obtained are more associational than causal. Third, although researchers have checked for possible publication bias by using funnel plots, it cannot be confirmed that such bias does not exist at all. Publication bias means that studies with insignificant or negative results may not be widely published, making the available data less representative. Lastly, some of the primary studies included may have methodological flaws, such as not adjusting for confounding factors that could affect the results (e.g., socioeconomic or environmental factors). These shortcomings may cause the pooled estimates from the meta-analysis to be less accurate and their reliability to decrease.

Conclusion

The conclusion of this meta-analysis is that malnutrition, particularly stunting, plays a significant role in increasing the risk of tuberculosis among children under five in Indonesia. Children with poor nutritional status have a much higher chance of being infected with TB compared

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to nutritionally healthy children. Therefore, tuberculosis control programmes cannot rely solely on medical treatment or classic prevention efforts such as early detection and treatment but must also take the nutritional aspects of children seriously. A broader and holistic approach is needed, integrating nutritional improvement and addressing socio-economic issues that serve as hidden risk factors, such as poverty, limited access to health services, and an unfavourable environment. This is crucial for prevention efforts to be effective and have a long-term impact. In addition, to understand more clearly the causal relationship between malnutrition and tuberculosis and to measure the benefits of nutrition interventions, longitudinal studies are needed. Such studies can provide more robust data on how improved nutrition can reduce the risk of tuberculosis and help design more targeted and sustainable health strategies in the future.

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Conflict of Interest

The authors report no competing interests.

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