

Determinants of Tuberculosis Incidence Among Children Under Five in Karanganyar, Central Java, Indonesia

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Received: August 17, 2025; Accepted: December 30, 2025; Available online: January 16, 2026

ABSTRACT

Background: Tuberculosis (TB) remains a major infectious disease and a leading cause of mortality worldwide, with 10.8 million cases and 1.25 million deaths reported in 2023. Indonesia is classified as a high-burden TB country, with 78,566 cases reported among children under five years of age. Young children are particularly vulnerable due to their immature immune systems. In Karanganyar Regency, Central Java, Indonesia, 137 cases of TB among under-five children were recorded in 2023. This study aimed to analyze the risk factors associated with TB incidence among children under five in Karanganyar Regency.

Subjects and Method: This study employed an analytic observational design using a case-control approach. A total of 200 children under five were randomly selected, comprising 50 TB cases and 150 non-TB controls. Data were analyzed using simple logistic regression and path analysis to examine direct and indirect relationships among variables.

Results: The incidence of TB among children under five increased with a history of contact with TB patients ($b = 0.18$; 95% CI = 0.10–0.26; $p < 0.001$) and living in homes with high humidity ($b = 0.09$; 95% CI = 0.01–0.17; $p = 0.019$). Conversely, TB incidence decreased with good lighting ($b = -0.11$; 95% CI = -0.19 to -0.03; $p = 0.005$), presence of bedroom windows ($b = -0.41$; 95% CI = -0.51 to -0.31; $p < 0.001$), living room windows ($b = -0.31$; 95% CI = -0.41 to -0.22; $p < 0.001$), and residence in highland areas ($b = -0.13$; 95% CI = -0.21 to -0.06; $p < 0.001$). Nutritional status was negatively affected by TB ($b = -0.30$; 95% CI = -0.43 to -0.15; $p < 0.001$) and positively influenced by family income ($b = 0.17$; 95% CI = 0.03–0.31; $p = 0.016$), with income exerting both direct and indirect effects through TB. The path analysis model demonstrated good fit (Chi-square $p = 0.068$; RMSEA = 0.052; CFI = 0.981; TLI = 0.960).

Conclusion: The risk of TB among children under five increases with exposure to adult TB cases and living in humid housing conditions. Conversely, TB incidence decreases in children residing in well-lit homes with bedroom and living room windows and in highland areas. Nutritional status is influenced by both TB and family income, with income affecting TB directly and indirectly.

Keywords: childhood tuberculosis, nutritional status, Tuberculosis, contact history, housing environment

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Cite this as:

Hartini N, Murti B, Rahardjo SS, Sumardiyono, Dewi YLR (2025). Determinants of Tuberculosis Incidence Among Children Under Five in Karanganyar, Central Java, Indonesia. *J Epidemiol Public Health*. 11(1): 68-79. <https://doi.org/10.26911/jepublichealth.2026.11.01.06>.



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BACKGROUND

Tuberculosis (TB) is an infectious disease caused by *Mycobacterium tuberculosis*. According to the World Health Organization (WHO) Global Tuberculosis Report 2024, TB remains a leading cause of death worldwide, accounting for approximately 1.6 million deaths annually (WHO, 2024). TB is transmitted through airborne droplet nuclei (<5 microns) expelled when an individual with pulmonary TB coughs, sneezes, or speaks (Ministry of Health of the Republic of Indonesia [MoH RI, 2019]).

Globally, 8.2 million people were diagnosed with TB in 2023, marking the highest number of cases reported since WHO began global TB surveillance in 1995. This represents a significant increase from 5.8 million cases in 2020, 6.4 million in 2021, and 7.5 million new cases in 2022. The estimated number of undiagnosed TB cases also rose from 10.1 million in 2020 to 10.8 million in 2023. In 2023, TB caused an estimated 1.25 million deaths worldwide, including 161,000 deaths among people living with HIV (WHO, 2024).

TB can affect individuals of all ages and sexes, though the highest burden occurs among adult males aged over 15 years, with an estimated 6.0 million cases (55% of the total). Females over 15 years accounted for approximately 3.6 million cases (33%), and children and adolescents aged 0–14 years represented 1.3 million cases (12%) (WHO, 2024).

Southeast Asia contributed 39% (approximately 3.4 million) of new TB cases globally, with Indonesia accounting for a substantial portion. According to the MoH RI, TB cases in Indonesia increased from 443,235 in 2021 to 724,309 in 2022 and 821,200 in 2023. During the first half of 2024, 317,514 new pulmonary TB cases were reported (MoH RI, 2024).

Globally, 1.3 million TB cases in 2023 were reported among children under 15 years of age (WHO, 2024). According to the Centers for Disease Control and Prevention (CDC), TB is most prevalent among children under five years (Rahajoe, 2016). In Indonesia, 2023 data show 136,969 TB cases in children, with 78,566 cases among children under five and 58,403 cases in children aged 5–14 years. This represents an increase from 110,881 total pediatric TB cases in 2022, including 62,926 cases in children under five (MoH RI, 2024).

High TB incidence among young children is influenced by multiple factors. According to John Gordon's theory (1950), disease occurs due to interactions among the host, the agent, and the environment. Risk factors for TB in children under five are similar to those in adults. A study by Brajadenta et al. (2018) reported that children aged 0–5 years have a 35-fold higher risk of developing pulmonary TB compared to adults. Childhood TB also carries a higher risk of severe complications, such as TB meningitis (Seddon & Shingadia, 2014).

Childhood TB is closely linked to the family environment. Adequate housing, proper ventilation, and controlled humidity are critical, yet often depend on family economic capacity. Studies indicate that poor household ventilation and low socioeconomic status are associated with higher TB incidence among young children. Good ventilation promotes air circulation, reducing indoor humidity, which is essential in TB prevention.

Children under five are particularly vulnerable due to their immature immune systems. Data from MoH RI (2022) indicate that the highest TB cases among children occur in West Java (13,922 cases, 36%), Central Java (5,121 cases, 13%), and DKI Jakarta (2,984 cases, 7%). Central Java

ranks second nationally in TB burden, with 87,074 reported cases in 2023 (Central Java Health Office, 2023).

Regional characteristics affect TB risk factors differently. Karanganyar Regency in Central Java comprises both lowland and highland areas, which may influence TB occurrence in children under five. In 2023, Karanganyar had 57,056 children under five, with TB cases increasing over three consecutive years: from 5 cases in 2021 to 106 cases in 2022 (a 2,020% increase) and 137 cases in 2023 (a 29.9% increase).

Based on the above, this study aims to analyze the risk factors for TB in children under five in Karanganyar Regency, including the influence of nutritional status, family income, history of TB contact, household lighting, humidity, presence of bedroom and living room windows, altitude of residence, and TB incidence.

SUBJECTS AND METHOD

1. Study design

This quantitative study employed a case-control approach and was conducted in the working area of the Karanganyar Regency Health Office from April to June 2025.

2. Population and Sample

The population comprised all children under five years of age within the working area of the Karanganyar Regency Health Office from January to March 2025. The study sample included 200 children, consisting of 50 TB cases and 150 non-TB controls. Fixed disease sampling was applied to select participants, and random sampling was used within each group (case and control).

3. Study Variables

The dependent variable was TB incidence among children under five. Independent variables included nutritional status, family income, history of TB contact, household lighting, humidity, presence of living room

windows, bedroom windows, and residential altitude.

4. Operational Definition of Variables

Tuberculosis: Children aged 0–5 years with confirmed TB recorded cumulatively in the Karanganyar Health Office from January to March 2025.

Nutritional Status: Measured using anthropometric standards based on the Ministry of Health Regulation No. 2 of 2020, with weight-for-age (W/A) calculated using the WHO Anthro application.

Family Income: Average monthly family income over the last six months (IDR 2,288,366, based on the Karanganyar Regency minimum wage, Governor of Central Java Decree No. 561/57, 2024).

History of Contact: Children who had close contact with adult TB patients within the household or community.

Lighting: Natural or artificial light intensity in the main living space or child's room, ≥ 60 lux (MoH Regulation No. 2, 2023).

Humidity: Percentage of air moisture in the main living space or child's room, maintained between 40–60% (MoH Regulation No. 2, 2023).

Living Room Window: Presence of windows in the living room to facilitate ventilation and natural light (MoH Regulation No. 2, 2023).

Bedroom Window: Presence of windows in the bedroom to facilitate ventilation and natural light (MoH Regulation No. 2, 2023).

Residential Altitude: Elevation of residence according to data from the Central Statistics Agency (BPS) of Karanganyar Regency.

5. Study Instrument

TB data were obtained from the monthly TB Control Program reports of the Karanganyar Health Office from January to March 2025. Nutritional status was assessed using

questionnaires and the child health book. Lighting and humidity were measured using a lux meter and hygrometer. Family income, TB contact history, living room windows, bedroom windows, and residential altitude were collected through structured questionnaires.

6. Data Analysis

Univariate analysis described the frequency distribution of all variables. Bivariate analysis was conducted using simple logistic regression to examine associations between independent and dependent variables. Multivariate analysis employed path analysis to explore both direct and indirect relationships among variables.

7. Ethical Considerations

Participation of children was based on written informed consent from parents, following an explanation of the study’s purpose, benefits, procedures, and potential risks. Participant confidentiality was strictly maintained, and data were used exclusively for scientific purposes. This study was approved by the Research Ethics Committee of Dr. Moewardi Hospital, Surakarta, Indonesia (No. 762/IV/HREC-/2025, April 20, 2025).

majority were male (53.5%). Most mothers had completed senior high school (58.5%) and worked outside the home (52.5%). Fathers’ education was predominantly senior high school (51.5%), with the majority employed as self-employed (123 fathers, 61.5%). Most children had no history of contact with adult TB patients (72%) and lived in homes with bedroom windows (156 children, 78%) and living room windows (79.5%).

Table 2 summarizes the descriptive statistics for 200 children under five and their households. The mean age of the children was 24 months, ranging from 1 to 58 months. Mothers’ ages averaged 33 years, with a minimum of 18 years and a maximum of 42 years. Children had a mean body weight of 11.11 kg, ranging from 4 to 24 kg, and a mean Z-score of -1.46, with values spanning from -5 to 2.

Household environmental characteristics showed an average humidity of 55.4%, ranging from 40% to 77%, and an average lighting intensity of 70.8 lux, with a minimum of 40 lux and a maximum of 95 lux. The average residential altitude was 345.89 meters above sea level (m asl), ranging from 95 to 1,200 m asl. Family income averaged IDR 2,725,000 per month, with the lowest reported income at IDR 1,000,000 and the highest at IDR 8,000,000 per month.

RESULT

Table 1 presents the characteristics of the study sample. Among the 200 children under five, 50 (25%) were TB cases, and 150 (75%) were non-TB controls. The

Table 1. Sample Characteristics of Categorical Data

Variables	Category	n	%
Tuberculosis	Yes	50	25
	No	150	75
Gender	Male	107	53.50
	Female	93	46.50
Maternal education	Not attend school	4	2.00
	Low-level education (elementary school, junior high school)	43	21.50
	Senior High School	117	58.50
	High education (Diploma, College)	36	18.00

Variables	Category	n	%
Maternal employment	Housewives	95	47.50
	Worked outside home	105	52.50
Paternal education	Not attend school	7	3.50
	Low-level education (elementary school, junior high school)	62	31.00
	Senior High School	103	51.50
	High education (Diploma, College)	28	14.00
Paternal employment	Unemployed	8	4.00
	Civil servants/police	26	13.00
	Self-employed	123	61.50
History of TB contact	Farmer/fisherman	43	21.50
	No	144	72.00
Bedroom window	Yes	56	28.00
	No	44	22.00
Livingroom window	Yes	156	78.00
	No	41	20.50
	Yes	159	79.50

Table 2. Sample characteristics of continuous data

Variable	Mean	SD	Minimum	Maximum
Child age (months)	24.09	14.16	1	58
Maternal age (years old)	33.21	6.15	18	42
Child weight (kg)	11.11	3.18	4	24
Nutritional status (WHZ)	-1.46	2.20	-5	2
Humidity (%)	55.4	9.91	40	77
Room lighting (lux)	70.8	10.75	40	95
Highland (elevation above sea level)	345.89	256.77	95	1200
Income (Indonesian Rupiah)	2,725,000	1,121,680	1,000,000	8,000,000

2. Bivariate analysis

Table 3 shows that good nutritional status (OR = 0.43; 95% CI = 0.22–0.82; p = 0.011), high family income (OR = 0.10; 95% CI = 0.04–0.20; p < 0.001), adequate indoor lighting (OR = 0.23; 95% CI = 0.11–0.46; p = 0.011), the presence of windows in the family living room (OR = 0.02; 95% CI = 0.01–0.06; p < 0.001), the presence of windows in the bedroom (OR = 0.01; 95% CI = 0.01–0.04; p < 0.001), and residence in highland areas (OR = 0.31; 95% CI =

0.16–0.60; p < 0.001) were associated with a reduced risk of tuberculosis among young children.

In contrast, children with a history of contact with tuberculosis patients (OR = 10.72; 95% CI = 5.14–22.34; p < 0.001) and those living in homes with high indoor humidity (OR = 13.50; 95% CI = 3.16–57.74; p = 0.011) had a significantly higher risk of developing tuberculosis.

Table 3. Results of Simple Logistic Regression Analysis of Determinants of Tuberculosis in Children

Variables	Odds Ratio (OR)	95% CI		P
		Lower limit	Upper limit	
Good nutritional status (WHZ)	0.43	0.22	0.82	0.011
High family income	0.10	0.04	0.20	<0.001
Had a history of contact	10.72	5.14	22.34	<0.001

Variables	Odds Ratio (OR)	95% CI		p
		Lower limit	Upper limit	
Poor room lighting	0.23	0.11	0.46	<0.001
Humidity	13.5	3.16	57.74	<0.001
Living room window	0.02	0.01	0.06	<0.001
Bedroom window	0.01	0.01	0.04	<0.001
Highland (elevation above sea level)	0.31	0.16	0.60	<0.001

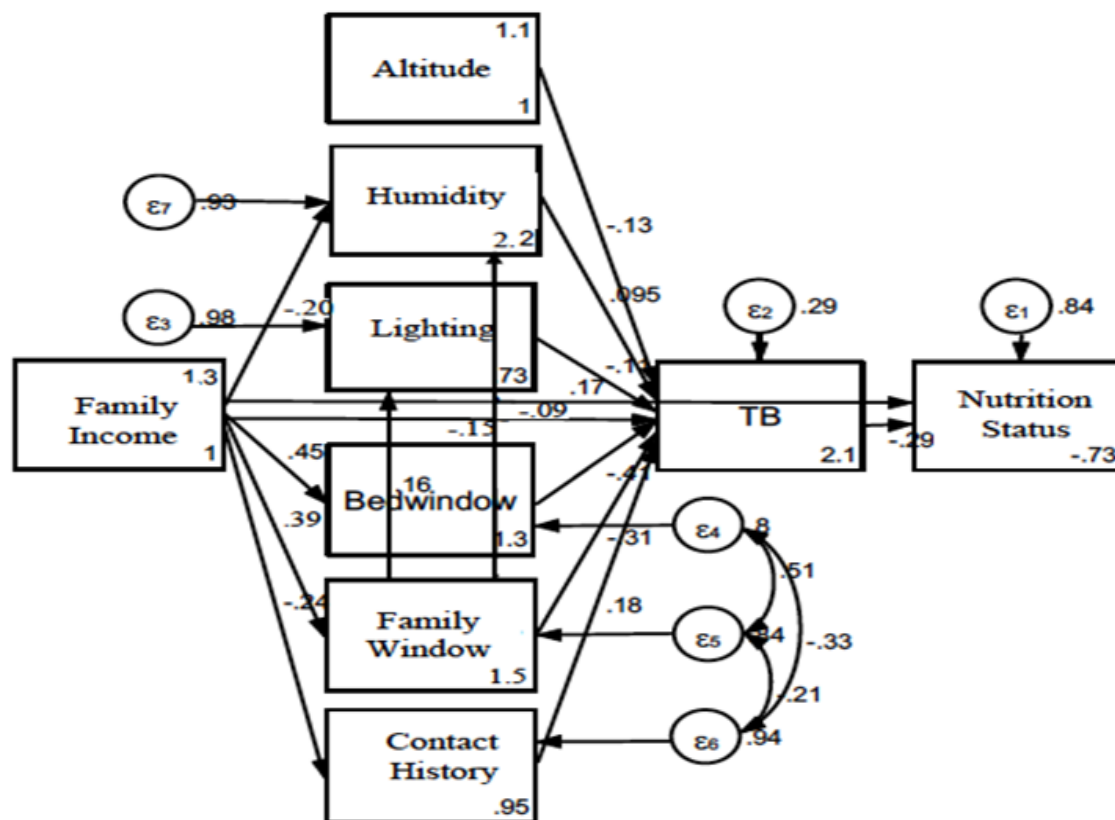


Figure 1. Estimated Path Analysis Model

3. Multivariate analysis

Figure 1 illustrates the path analysis model of the determinants of tuberculosis incidence among young children in Karanganyar District. Table 4 shows that the path analysis model demonstrated good goodness-of-fit, as all fit indices met the recommended criteria. The chi-square test indicated an acceptable fit ($p = 0.068$). The RMSEA value was 0.05, which is below the recommended threshold of 0.08. The comparative fit index (CFI) and Tucker-Lewis index (TLI) were 0.98 and 0.96,

respectively, both exceeding the recommended value of 0.90. In addition, the standardized root mean square residual (SRMR) was 0.048, indicating a good model fit. The coefficient of determination (CD) was 0.33. The results of the path analysis indicate that young children with TB were more likely to experience poor nutritional status compared with those without TB ($b = -0.30$; 95% CI = -0.43 to -0.15 ; $p < 0.001$).

The path analysis results indicate that children from high-income families were

more likely to have better nutritional status compared with those from low-income families ($b = 0.17$; 95% CI = 0.03–0.31; $p = 0.016$). In addition to this direct effect, there was an indirect effect mediated through TB of 0.03, resulting in a total effect of family income on nutritional status ranging from 0.20 to 0.24. These findings indicate that higher family income is associated with better nutritional status among children under five.

Children living in homes with adequate lighting were less likely to develop tuberculosis ($b = -0.11$; 95% CI = -0.19 to -0.03; $p = 0.005$). Children living in highland areas were less likely to develop TB compared with those residing in lowland areas ($b = -0.13$; 95% CI = -0.21 to -0.06; $p < 0.001$). In addition, children living in homes with bedroom windows had a lower likelihood of TB compared with those living in homes without bedroom windows ($b = -0.41$; 95% CI = -0.51 to -0.31; $p < 0.001$). Similarly, the presence of windows in the living room was associated with a reduced likelihood of TB among young children ($b = -0.31$; 95% CI = -0.41 to -0.22; $p < 0.001$).

Children with a history of contact with tuberculosis patients had a higher likelihood of developing TB compared with those without such contact ($b = 0.18$; 95% CI = 0.10 to 0.26; $p < 0.001$). Children living in homes with poor indoor humidity conditions were more likely to develop TB compared with those living in homes with adequate humidity ($b = 0.09$; 95% CI = 0.01 to 0.17; $p = 0.019$).

The path analysis results indicate that children from high-income families were less likely to develop TB compared with those from low-income families ($b = -0.09$; 95% CI = -0.18 to -0.01; $p = 0.036$). In addition to this direct effect, family income exerted indirect effects through several pathways, with the largest effects operating via the presence of bedroom windows (-0.185) and living room windows (-0.121), followed by indoor lighting (-0.007), household humidity (-0.018), and contact history (-0.043). The total indirect effect was -0.37, resulting in an overall effect of family income on TB incidence of approximately -0.20.

Table 4. Results of Path Analysis Examining the Effects of Nutritional Status, Family Income, Contact History, Indoor Lighting, Humidity, Living Room Windows, Bedroom Windows, Residence Area Elevation, and Tuberculosis Incidence among Young Children

Study Variables		b	95% CI		P
			Lower limit	Uper limit	
Direct effect					
Nutritional status	← TB	-0.30	-0.43	-0.15	<0.001
	← Family income	0.17	0.03	0.31	0.016
Indirect effect					
TB	← Room lighting	- 0.11	-0.19	-0.03	0.005
	← Humidity	0.09	0.01	0.17	0.019
	← Highland	-0.13	-0.21	-0.06	<0.001
	← Bedroom window	-0.41	-0.51	-0.31	<0.001
	← History of TB contact	0.18	0.10	0.26	<0.001
	← Living room window	-0.31	-0.41	-0.22	<0.001
	← Family income	-0.09	-0.18	-0.01	0.036
Room lighting	← Living room window	0.16	0.02	0.29	0.023

Study Variables	b	95% CI		P	
		Lower limit	Uper limit		
Humidity	← Family income	-0.20	-0.34	-0.06	0.033
	← Living room window	-0.15	-0.30	-0.01	0.004
Living room window	← Family income	0.45	0.34	0.55	<0.001
History of TB contact	← Family income	-0.24	-0.37	-0.12	<0.001
Living room window	← Family income	0.39	0.27	0.50	<0.001

N Observation = 200
Log likelihood = -1192.514
Chi Square p= 0.068 (>0.05).
RSMEA=0.052 (<0.08); CFI=0.981 (>0.90).
TLI=0.960 (>0.90); SRMR=0.048 (<0.05); CD= 0.332

DISCUSSION

Tuberculosis (TB) is a chronic infectious disease caused by *Mycobacterium tuberculosis* and remains a major global public health problem. According to the World Health Organization (WHO, 2023), TB is among the ten leading causes of death worldwide, with young children representing one of the most vulnerable populations due to their immature immune systems. TB transmission primarily occurs through airborne droplets released when individuals with pulmonary TB cough or sneeze, highlighting the critical role of both individual and environmental factors in determining infection risk.

Nutritional status plays a crucial role in determining susceptibility to tuberculosis among young children. The analysis indicates that children with good nutritional status had a significantly lower risk of developing TB compared with malnourished children (OR = 0.43; 95% CI = 0.22–0.82). This finding is consistent with the study by Azilah et al. (2025), which reported that malnourished children had a fourfold increased risk of pulmonary TB. Nutritional status is a key indicator of child well-being and is closely linked to immune function (UNICEF, 2023). Malnutrition compromises immune responses by reduc-

ing antibody production and lymphocyte activity, thereby increasing vulnerability to *Mycobacterium tuberculosis* infection (Atalell et al., 2022). This relationship is bidirectional, as TB can further deteriorate nutritional status through increased metabolic demands, reduced appetite, and impaired nutrient absorption (Aghnia et al., 2018). Therefore, good nutrition serves as a protective factor, while poor nutritional status increases the risk of TB and its complications.

Family income was found to be a significant determinant of TB risk among young children. The results showed that children from high-income families were less likely to develop TB (OR = 0.10; 95% CI = 0.04–0.20). Higher income enables families to meet nutritional needs, access healthcare services, and maintain better housing conditions. In contrast, low-income households face constraints in fulfilling basic needs, which increases vulnerability to TB (Susilowati et al., 2023). Aufa et al. (2024) demonstrated that limited purchasing power reduces access to nutritious food, weakens immune defence, and elevates infection risk. Moreover, low income is often associated with overcrowded housing, inadequate lighting, and poor ventilation, all of which facilitate TB

transmission (WHO, 2021; Razak et al., 2025). Thus, family income influences TB risk both directly and indirectly through nutritional and environmental pathways.

A history of close contact with adult TB patients was identified as a major risk factor for TB transmission in young children. This study found that children with household contact had a 10.72-fold higher risk of TB compared with those without such exposure (Atalell et al., 2022). TB transmission via airborne droplets places children living with smear-positive pulmonary TB patients at particularly high risk (Kliegman et al., 2020). The Indonesian Ministry of Health (2023) reports that approximately 4–5% of household contacts progress to active TB within 1–2 years, with the highest risk observed among children under five years of age. Repeated exposure in crowded home environments further increases the likelihood of infection. A large cohort study by Martinez et al. (2020), involving over 137,000 children, also confirmed a significantly elevated risk of TB following household exposure.

Adequate household lighting was identified as a protective factor against TB. Children living in well-lit homes had a 77% lower risk of developing TB (OR = 0.23; 95% CI = 0.11–0.46). Sunlight, particularly ultraviolet radiation, has been shown to reduce the viability of *Mycobacterium tuberculosis* (Baun et al., 2023). Dark, damp, and poorly ventilated housing conditions allow the bacteria to survive longer in the environment (Putra et al., 2024). Apriyani et al. (2018) reported that insufficient lighting increased TB risk by four times among young children. Therefore, access to natural lighting through windows and proper ventilation is a critical component of healthy housing for TB prevention.

Household humidity also significantly influenced TB risk. Children living in homes with poor humidity conditions had a 13.5-fold higher risk of TB compared with those living in healthy environments (Baun et al., 2023). High humidity supports the survival of infectious droplets and creates favorable conditions for bacterial persistence (Budi et al., 2024). Conversely, excessively low humidity can prolong the airborne suspension of infectious particles, further increasing transmission risk (Xu et al., 2020). Sihan et al. (2023) reported that high humidity increased the risk of pulmonary TB in children by up to 5.8 times. Maintaining indoor humidity within the recommended range of 40–60% is therefore essential for TB prevention.

The presence of windows in the living room significantly reduced TB risk among young children. Children residing in homes with living room windows had a substantially lower likelihood of developing TB (OR < 0.01). Windows function as natural ventilation sources, improving air circulation, reducing humidity, and providing natural lighting (WHO, 2021). Danuarta et al. (2022) demonstrated that natural light exposure from windows had a strong protective effect against TB. Adequate ventilation also lowers the concentration of infectious droplets in indoor air (Escombe et al., 2019). Thus, incorporating windows into living room design is an important strategy for preventing TB in children.

Similarly, bedroom windows were associated with a reduced risk of TB. The presence of bedroom windows lowered TB risk to 0.01 times compared with homes without windows (Putri et al., 2025). Windows facilitate air exchange and natural lighting, thereby reducing exposure to infectious droplets (Rosyid, 2023). Given that bedrooms are spaces with prolonged and close contact, adequate ventilation is

particularly critical for preventing TB transmission.

Geographic elevation was also identified as a protective factor. Children living in highland areas had a lower risk of TB compared with those residing in lowland regions (OR = 0.31; 95% CI = 0.16–0.60). This protective effect may be attributed to lower population density, better air circulation, and higher ultraviolet exposure in highland areas (Boere et al., 2017; Corbett et al., 2022). Ultraviolet radiation not only inactivates *Mycobacterium tuberculosis* in the air but also enhances vitamin D synthesis, which plays an important role in immune regulation (Escombe et al., 2019). In contrast, lowland areas are often characterized by higher population density, poorer ventilation, and greater humidity, all of which increase TB risk (Ministry of Health of Indonesia, 2023). These findings indicate that geographic factors contribute to the spatial distribution of TB among young children.

AUTHOR CONTRIBUTION

All authors made substantial contributions to data analysis and the preparation of the final manuscript.

FUNDING AND SPONSORSHIP

This study was fully self-funded by the principal investigator.

CONFLICT OF INTEREST

The authors declare that this study was conducted without any conflict of interest.

ACKNOWLEDGMENT

The authors sincerely thank the mothers of the participating children for their involvement in this study. Appreciation is extended to all individuals who contributed to the preparation of this manuscript.

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