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Factors Associated with Pulmonary Tuberculosis in Yogyakarta, Indonesia: A Matched Case-Control Study

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ABSTRACT

Background: Tuberculosis (TB) remains a public health problem in Indonesia, including in the city of Yogyakarta. The incidence of TB is influenced by various socioeconomic factors, individual characteristics, behavior, and the physical conditions of the home environment. Given these influences, this study aims to analyze the determinants of pulmonary tuberculosis incidence in Yogyakarta, Indonesia.

Subjects and Method: This was a matched case-control study. Cases were patients with pulmonary tuberculosis, matched 1:2 by age, sex, and health center area to non-TB controls. Among 168 respondents (56 cases and 112 controls). The study involved 18 community health centers in Yogyakarta, Indonesia, from April to May 2026. Variables included family income, knowledge, attitudes, nutritional status, smoking history, diabetes mellitus, household and close contact history, and housing characteristics. Data were analyzed using bivariate tests and multivariate conditional logistic regression.

Results: Family income below the Yogyakarta regional minimum wage (aOR= 0.30; 95% CI= 0.10–0.93), poor tuberculosis knowledge (aOR = 0.27; 95% CI= 0.08–0.95), history of diabetes mellitus (aOR= 0.07; 95% CI= 0.01–0.82), and a confirmed history of close contact with a tuberculosis patient (aOR= 5.12; 95% CI= 1.00–26.09) were independently associated with pulmonary tuberculosis. Respondents who were unaware of their close contact history also had higher odds of tuberculosis (aOR= 3.67; 95% CI= 0.82–16.30), although this association did not reach statistical significance.

Conclusion: The incidence of pulmonary tuberculosis in Yogyakarta is significantly associated with family income, tuberculosis-related knowledge, history of diabetes mellitus, and close contact with TB patients. These findings highlight the importance of strengthening active TB case finding through systematic contact investigation not only among household contacts but also in workplaces and industrial settings to facilitate early detection and reduce the risk of tuberculosis transmission

Keywords: contact investigation, education, knowledge, Tuberculosis.

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BACKGROUND

Tuberculosis (TB) remains one of the infectious diseases with the highest global burden. This disease is caused by Mycobacterium tuberculosis and primarily affects the lungs. However, it can also infect other organs such as the kidneys, meninges, bones, and lymph nodes. The World Health Organization reports that nearly a quarter of the world's population is infected with the TB bacterium. In 2023, the death toll among HIV-negative patients reached 1.09 million (WHO, 2024a). Most global deaths occur in countries with a high burden of tuberculosis, including India, Indonesia, Myanmar, and the Philippines.

Indonesia ranks second globally for tuberculosis cases, behind India. It accounts for approximately 10% of global cases (Ministry of Health of the Republic of Indonesia, 2024). In 2023, Indonesia's tuberculosis incidence rate was 387 per 100,000 people, while the mortality rate reached 44 per 100,000 people. Furthermore, reported cases rose from 821,200 in 2023 to 856,420 in 2024. Notably, the highest numbers were found in provinces with large populations, such as West Java, East Java, and Central Java.

The Special Region of Yogyakarta (DIY) is among the regions experiencing an increase in TB cases. The TB Case Notification Rate (CNR) in DIY rose from 159 per 100,000 population in 2023 to 170 per 100,000 population in 2024. Cases are managed using the DOTS (Directly Observed Treatment Short-course) strategy to ensure treatment success (Ministry of Health of the Republic of Indonesia, 2025). However, the city of Yogyakarta presents its own challenges. The number of confirmed cases has risen from 1,364 in 2022 to 6,497 in 2024. The treatment success rate remains low at 83.8% (Health Office of the Special Region of Yogyakarta, 2025). Tuberculosis control efforts in Yogyakarta City still face challenges. These include patient deaths, treatment dropouts, and treatment failure.

The city of Yogyakarta is an important context for study as an urban area with high population mobility and a center for education and tourism. This mobility can affect treatment continuity, patient follow-up, and case reporting, especially among patients who move or access health services in different regions. Additionally, population and housing density in some urban areas can increase the risk of TB transmission. Previous research in Yogyakarta has shown that population and housing density are significantly associated with TB incidence (Ardiyanti et al., 2021). However, the study is still limited to a few variables and has not yet incorporated a more comprehensive determinants approach or the latest spatial analysis methods.

Various studies indicate that tuberculosis distribution is not uniform across regions. A national study in Indonesia found variations in tuberculosis incidence among provinces, influenced by local contexts and spatial factors (Puspita et al., 2021). These conditions indicate that TB control strategies should take regional characteristics into account to make interventions more targeted. In this context, spatial analysis is important because it can identify patterns of distribution, clusters of cases, and geographically distributed risk factors. Previous research has shown that TB clusters in Indonesia are associated with population density and poverty (Wardani and Wahono, 2017). Another study in Bekasi Regency also found a positive spatial autocorrelation between TB cases and population density, with cluster patterns becoming more widespread year by year (Inggarputri et al., 2023).

In addition to spatial factors, tuberculosis risk is shaped by social, economic,

behavioral, and environmental factors. A Banda Aceh, Indonesia study found that close contact with tuberculosis patients, low knowledge, comorbidities, poor preventive behaviors, low education levels, and unsanitary living conditions increase tuberculosis risk (Fahdhienie et al., 2024). A study in Bantul, Yogyakarta, Indonesia finds that knowledge and attitudes directly influence behavior, helping prevent the spread of tuberculosis (Sofiana et al., 2025). Meanwhile, a study in the urban area of Yogyakarta found that a family history of tuberculosis, smoking, and home ventilation are factors associated with tuberculosis incidence, with smoking being the dominant risk factor (Sulistyawati and Ramadhan, 2021). At the regional level, a spatial regression analysis in DIY shows links between population density, education, population growth rate, health facilities, and the tuberculosis incidence rate. The analysis also reveals spatial heterogeneity across regions (Trisnaningsih et al., 2023).

SUBJECTS AND METHOD

1. Study Design

This study employed an analytical observational design using a matched case-control approach, enabling analysis of the association between four groups of determinants: social, behavioral, and environmental, and the incidence of pulmonary tuberculosis.

2. Population and Sample

This matched case-control study included 168 respondents, consisting of 56 tuberculosis (TB) patients (cases) and 112 non-TB individuals (controls), with a case-to-control ratio of 1:2. A 1:2 ratio was employed to increase the statistical power and precision of the estimated associations while maintaining study feasibility.

All eligible TB patients reported by the Yogyakarta City Health Office from 18 primary healthcare centers (Puskesmas) during the study period were included using total sampling. Therefore, the number of cases (n= 56) was determined by the total number of registered TB patients who fulfilled the inclusion and exclusion criteria.

The control group (n= 112) was selected using purposive sampling from the same primary healthcare centers. Controls were recruited based on predefined inclusion and exclusion criteria and were individually matched to cases by age group, sex, and primary healthcare center catchment area to reduce potential confounding and ensure comparability between the two groups.

3. Study Variables

The dependent variable was pulmonary tuberculosis. The independent variables were socioeconomic factors, behavioral factors, medical history, exposure history, and home environmental conditions. Socioeconomic factors include family income, while behavioral factors encompass knowledge, attitudes, and smoking history. Health status factors cover nutritional status, history of diabetes mellitus (DM), and history of HIV. Exposure factors comprise a history of household contact and a history of close contact with a TB patient. Finally, home environmental factors include ventilation area, floor type, and wall type.

4. Operational Definition of Variables

Pulmonary tuberculosis (TB) defined as a confirmed diagnosis of pulmonary TB based on medical records from the Yogyakarta City Health Office and primary healthcare centers, including bacteriological confirmation by GeneXpert (TCM), smear microscopy, chest radiography, or physician diagnosis.

a. Family income was defined as the total monthly household income reported by respondents and categorized according to the 2025 Yogyakarta regional minimum

wage/ RMW (IDR 2,827,593) into <minimum wage and ≥ minimum wage.

b. Knowledge of tuberculosis was assessed using a structured questionnaire consisting of TB-related questions. The total score was categorized as poor (<14) and good (≥14).
c. Attitude toward tuberculosis was measured using a Likert-scale questionnaire comprising positive and negative statements. The total score was classified as negative (<31) and positive (≥31).
d. Nutritional status was determined using Body Mass Index (BMI), calculated as weight in kilograms divided by height in meters squared (kg/m²). BMI was categorized according to the Indonesian Ministry of Health criteria into underweight (<18.5 kg/m²), normal (18.5–25.0 kg/m²), and overweight/ obese (>25.0 kg/m²). For regression analysis, nutritional status was further dichotomized into underweight and normal/overweight.
e. Smoking history was defined as whether respondents had ever smoked or were current smokers and was categorized as yes or no.
f. History of diabetes mellitus (DM) was defined as a previous diagnosis of diabetes documented in medical records or reported by respondents as diagnosed by a healthcare professional. The variable was categorized as yes or no.
g. Household contact history was defined as living in the same household with an individual diagnosed with active pulmonary TB for at least the previous three months. This variable was categorized as yes or no.
h. Close contact history was defined as frequent exposure to an individual with active pulmonary TB without living in the same household, with an exposure duration comparable to household contact for at least four weeks. The variable was categorized as yes or no.
i. Home ventilation was assessed through direct household observation by measuring the total permanent ventilation area relative to the floor area. Ventilation was classified as adequate when the ventilation area was at least 10% of the floor area and inadequate when it was less than 10%.
j. Floor type was determined through direct household observation and categorized as adequate (waterproof materials such as ceramic, tile, cement, granite, or marble) or inadequate (soil floor or unplastered wooden floor).
k. Wall type was assessed by direct household observation and categorized as adequate (permanent walls made of brick, concrete, or plastered materials) or inadequate (non-permanent walls made of bamboo, wood, plywood, or other temporary materials).
l. Data on socioeconomic characteristics, behavioral factors, and contact history were collected using interviewer-administered questionnaires, while TB diagnosis and diabetes history were verified using medical records. Housing characteristics were assessed through direct observation using a standardized observation checklist.

5. Study Instruments

The study used structured questionnaires and standardized observation checklists to collect primary data. Structured questionnaires were administered through face-to-face interviews to obtain information on respondents' sociodemographic characteristics, family income, tuberculosis-related knowledge, attitudes, smoking history, history of diabetes mellitus, household contact history, and close contact history. Standardized observation checklists were used during household visits to assess

environmental conditions, including ventilation area, floor type, and wall type.

The dependent variable, pulmonary tuberculosis status, was confirmed using the Tuberculosis Information System (SITB) maintained by the Yogyakarta City Health Office and verified against medical records at the participating primary healthcare centers. This verification process ensured the accurate classification of respondents into TB case and non-TB control groups in accordance with the National Tuberculosis Control Guidelines.

6. Data analysis

Data analysis was conducted using univariate, bivariate, and multivariate methods. First, univariate analysis was used to examine the frequency distribution of respondent characteristics and each study variable. Next, a bivariate analysis was performed using conditional simple logistic regression to examine the relationship between the independent variables and the incidence of pulmonary tuberculosis. Finally, multivariate analysis was performed using conditional multiple logistic regression to identify the dominant factors associated with pulmonary tuberculosis incidence. All statistical analyses were performed using Stata software.

7. Research Ethics

This study has received ethical approval from the Ahmad Dahlan University Research Ethics Committee under the number: REC-UAD/01/02/03-2026/092. All respondent data is kept confidential and is used solely for research purposes.

RESULTS

1. Sample Characteristics

The characteristics of the study participants by case and control groups are presented in Table 1. Based on Table 1, this study involved 168 respondents, comprising 56 TB cases and 112 controls, resulting in a case-to-control ratio of 1:2. The distribution of respondents by age, gender, and health center region showed similar proportions between the case and control groups, indicating that the matching process was conducted in accordance with the study design. Most respondents came from the service areas of the Danurejan and Mergangsan Community Health Centers, while several other community health centers had fewer respondents. However, the proportions of cases and controls in each community health center area remained consistent with the matching ratio.

Regarding social and behavioral characteristics, a higher proportion of TB cases was observed among respondents with a household income of ≥ minimum wage, good knowledge, and positive attitudes, compared with the comparison group. Additionally, respondents with a history of smoking also showed a slightly higher proportion of cases compared to non-smokers. Based on health status factors, the highest proportion of cases was found among respondents with a thin nutritional status compared to other nutritional status categories. Regarding the variable for diabetes mellitus history, a lower proportion of cases was observed among respondents with DM than among those without DM. All respondents with a history of HIV were in the TB case group.

A higher proportion of cases was found among respondents who had a history of household contact or close contact with a person with TB compared to respondents without such a history. A higher proportion of cases was found among respondents with inadequate home ventilation. The proportion of cases also tended to be higher among respondents with home floor and wall types that did not meet health standards than among those with homes that met health standards.

Table 1. Frequency Distribution of Respondent Characteristics

Variables	Case		Control	
	n	%	n	%
Age				
15-24 years	12	21.43	24	21.43
25-34 years	10	17.86	20	17.86
35-44 years	6	10.71	12	10.71
45-54 years	5	8.93	10	8.93
55-64 years	11	19.64	22	19.64
≥65 years	12	21.43	24	21.43
Sex				
Male	37	66.07	74	66.07
Female	19	33.93	38	33.93
Community Health Center				
Danurejan I	5	8.93	10	8,93
Danurejan II	7	12.50	14	12.50
Gedong Tengen	4	7.14	8	7.14
Gondokusuman I	2	3.57	4	3.57
Gondokusuman II	4	7.14	8	7.14
Gondomanan	1	1.79	2	1.79
Jetis	5	8.93	10	8.93
Kota Gede I	1	1.79	2	1.79
Kota Gede II	1	1.79	2	1.79
Kraton	5	8.93	10	8.93
Mantrijeron	3	5.36	6	5.36
Mergangsan	6	10.71	12	10.71
Ngampilan	1	1.79	2	1.79
Pakualaman	3	5.36	6	5.36
Tegalrejo	1	1.79	2	1.79
Umbulharjo I	3	5.36	6	5.36
Umbulharjo II	3	5.36	6	5.36
Wirobrajan	1	1.79	2	1.79
Highest Education Level				
Incomplete Primary School	2	3.57	4	3.57
Primary School	10	17.86	17	15.18
Junior High School	7	12.50	21	18.75
Senior High School	27	48.21	59	52.68
Diploma (D1/D3)	2	3.57	3	2.68
Bachelor's/Master's Degree	8	14.29	8	7.14
Occupation				
Civil Servant	3	5.36	1	0.89
Laborer	10	17.86	11	9.82
Freelance Worker	4	7.14	7	6.25
Homemaker	5	8.93	13	11.61
Private Employee	8	14.29	20	17.86
Entrepreneur	5	8.93	27	24.11
Student	8	14.29	13	11.61
Retired	3	5.36	6	5.36
Unemployed	10	17.86	14	12.50
Marital Status				
Never Married	22	39.29	30	26.79
Widowed	2	3.57	16	14.29
Divorced	4	7.14	5	4.46

Variables	Case		Control	
	n	%	n	%
Married	28	50	61	54.46
Income				
< RMW	38	67.86	93	83,04
≥ RMW	18	32.14	19	16,96
Knowledge				
Poor (Score <14)	13	23.21	56	50.00
Good (Score ≥14)	43	76.79	56	50.00
Attitude				
Negative (Score <31)	16	28.57	62	55.36
Positive (Score ≥31)	40	71.43	50	44.64
Nutritional Status				
Underweight	25	44.64	18	16.07
Normal	24	42.86	72	64.29
Overweight	5	8.93	12	10.71
Obese	2	3.57	10	8.93
Smoking				
Yes	24	42.86	41	36.61
No	32	57.14	71	63.39
Diabetes Mellitus				
Yes	1	1.79	12	10.71
No	55	98.21	100	89.29
HIV				
Yes	3	5.36	0	0
No	53	94.64	112	100
History of Household Contact				
Yes	22	39.29	17	15,18
No	34	60.71	95	84,82
History of Close Contact				
Yes	20	35.71	13	11.60
No	6	10.71	34	30.36
Unknown	30	53.57	65	58.04
Ventilation Area				
Inadequate (<10%)	37	66.07	47	41.96
Adequate (≥10%)	19	33.93	65	58.04
Floor Type				
Inadequate	26	46.43	44	39.29
Adequate	30	53.57	68	60.71
Wall Type				
Inadequate	14	25.00	21	18.75
Adequate	42	75.00	91	81.25
Total	56	100	112	100

2. Bivariate Analysis

Based on Table 2, bivariate analysis showed that household income, knowledge, attitude, nutritional status, history of household contact, history of close contact, and home ventilation were significantly associated with TB incidence ($p<0.05$). Respondents with household income below the minimum wage (OR= 0.44), poor knowledge (OR= 0.29), and negative attitudes (OR=0.33) had lower odds of TB compared with their respective reference groups. Underweight respondents had higher odds of TB than those with normal, overweight, or obese

nutritional status. A history of household contact (OR= 3.13), history of close contact (OR= 6.94), and inadequate home ventilation (OR=3.14) were associated with increased odds of TB. In contrast, smoking history, diabetes mellitus, floor type, and wall type were not significantly associated with TB incidence (p>0.05). Respondents with a smoking history had an OR of 1.46, while those with a history of diabetes mellitus had an OR of 0.15; however, neither association was statistically significant.

Table 2. Results of Bivariate Conditional Simple Logistic Regression Analysis of Tuberculosis Incidence

Variables	OR	95% CI	p
Income			
<RMW	0.44	0.20–0.93	0.032
≥RMW	Ref.	Ref.	Ref.
Knowledge			
Poor	0.29	0.14–0.61	0.001
Good	Ref.	Ref.	Ref.
Attitude			
Negative	0.33	0.16–0.66	0.002
Positive	Ref.	Ref.	Ref.
Nutritional Status			
Underweight	Ref.	Ref.	Ref.
Normal	5.18	2.06-14.14	<0.001
Overweight	1.28	0.40-3.47	0.639
Obese	0.50	0.17-4.51	0.897
Smoking			
Yes	1.46	0.66–3.26	0.352
No	Ref.	Ref.	Ref.
Diabetes Mellitus			
Yes	0.15	0.02–1.12	0.073
No	Ref.	Ref.	Ref.
History of Household Contact			
Yes	3.13	1.53–6.40	0.002*
No	Ref.	Ref.	Ref.
History of Close Contact			
Yes	6.94	2.34-20.57	<0.001
No	2.15	0.83-5.57	0.114
Unknown	Ref.	Ref.	Ref.
Floor Type			
Inadequate	1.34	0.70–2.56	0.378
Adequate	Ref.	Ref.	Ref.
Wall Type			
Inadequate	1.54	0.66–3.58	0.315
Adequate	Ref.	Ref.	Ref.
Ventilation Area			
Inadequate	3.14	1.48–6.67	0.003
Adequate	Ref.	Ref.	Ref.

3. Multivariable Analysis

Based on Table 3, multivariate analysis showed that household income, knowledge, history of diabetes mellitus, and history of close contact were significantly associated with TB incidence. Respondents with house-

hold income below the minimum wage (aOR= 0.30; 95% CI= 0.10–0.93; p= 0.037), poor knowledge (aOR= 0.27; 95% CI= 0.08–0.95; p=0.041), and a history of diabetes mellitus (aOR= 0.07; 95% CI= 0.01–0.82; p=0.035) had lower odds of TB compared with their respective reference groups. In contrast, respondents with a history of close contact had 5.119 times higher odds of TB than those without such contact (aOR= 5.12; 95% CI= 1.00–26.09; p= 0.049). Attitude, nutritional status, household contact history, and home ventilation were not significantly associated with TB incidence after adjustment (p>0.05), although inadequate home ventilation (aOR= 2.89; p=0.071) and underweight nutritional status (aOR=2.89; p=0.085) showed a tendency toward increased TB risk.

Table 3. Results of Multivariable Conditional Logistic Regression Analysis of Tuberculosis Incidence

Variable	aOR	95% CI	p-value
Income			
≥ RMW	Ref.	Ref.	Ref.
< RMW	0.30	0.096-0.93	0.037
Knowledge			
Good	Ref.	Ref.	Ref.
Bad	0.270	0.077-0.947	0.041*
Attitude			
Positive	Ref.	Ref.	Ref.
Negative	0.533	0.173-1.650	0.275
Nutritional Status			
Normal	Ref.	Ref.	Ref.
Underweight	2.891	0.865-9.659	0.085
Overweight	0.457	0.088-2.382	0.353
Obese	0.471	0.045-4.900	0.529
Diabetes Mellitus			
No	Ref.	Ref.	Ref.
Yes	0.066	0.005-0.822	0.035*
History of Household Contact			
No	Ref.	Ref.	Ref.
Yes	1.208	0.399–3.658	0.739
History of Close Contact			
No	Ref.	Ref.	Ref.
Yes	5.119	1.004–26.085	0.049*
Unknown	3.666	0.824–16.304	0.088
Ventilation Area			
Adequate	Ref.	Ref.	Ref.
Inadequate	2.889	0.913–9.142	0.071

DISCUSSION

Association Between Household Income and Tuberculosis Incidence

This study shows that household income is associated with tuberculosis incidence in Yogyakarta City. However, respondents with household incomes below the minimum wage had lower odds of developing tuberculosis than those with incomes at or above the minimum wage. These findings differ from the general theory and most previous studies, which suggest that low income increases vulnerability to tuberculosis.

Socioeconomic status affects tuberculosis risk. It influences nutrition, housing quality, health care access, and disease-

prevention behaviors (Deniati et al., 2022; Kusumaningrum et al., 2023). The World Health Organization also emphasizes that the TB epidemic is closely linked to socio-economic inequalities (WHO, 2025a). Low income is often associated with limited access to nutritious food, inadequate housing, and delays in seeking medical treatment.

Several studies have shown that undernutrition is a major risk factor for tuberculosis because it weakens the body's immune system (Franco et al., 2024b; Saunders et al., 2025). In addition, economic constraints can force families to live in homes with poor ventilation, inadequate lighting, and high occupancy rates conditions that facilitate the spread of tuberculosis (Duarte et al., 2021; Lee et al., 2022). Economic barriers can also lead to delays in diagnosis and treatment, due to indirect costs such as transportation and lost income during treatment.

The differing associations in this study may result from the case-control design, which used matching to control for several baseline traits. Income categories based on minimum wage may not fully reflect socio-economic status. People in higher-income groups may have more mobility and social contact, increasing TB exposure. Although the odds ratio shows lower TB risk in lower-income groups, this does not mean low income is protective. Instead, it highlights other factors affecting TB in Yogyakarta.

Association Between Knowledge and Tuberculosis Incidence

This study shows that knowledge level is associated with tuberculosis incidence in Yogyakarta. However, people with limited knowledge had lower odds of developing tuberculosis than those with good knowledge. The study's odds ratio supports this. These findings go against the theory that low knowledge increases tuberculosis risk due to delayed diagnosis and poor prevention.

Knowledge plays a crucial role in recognizing tuberculosis symptoms, understanding how it spreads, and deciding whether to seek medical care. WHO explains that TB symptoms often develop gradually, so individuals who are unaware of the early symptoms may experience a delay in diagnosis, which can prolong the period of transmission (Makgopa and Madiba, 2021). Good knowledge is also linked to preventive behaviors such as wearing masks, cough etiquette, and early screening (Rahmawati and Rahmaniati, 2020).

The difference in the direction of the association in this study is likely due to knowledge being assessed after respondents were identified as cases or controls. Case participants likely received health education during the diagnosis and treatment process, resulting in a higher level of knowledge than control participants. In this context, an odds ratio above one suggests that cases had more knowledge than controls, possibly due to post-diagnosis education. Furthermore, good knowledge does not necessarily lead to optimal preventive behavior, as it is still influenced by other factors such as living conditions, contact history, nutritional status, and access to health services. Even so, health education remains crucial for tuberculosis control in Yogyakarta City. Increasing public knowledge should go hand in hand with active screening and contact investigation, since subclinical tuberculosis cases are still being found in Yogyakarta (Main et al., 2022; Ananda et al., 2023).

Association Between Attitude and Tuberculosis Incidence

The results of the study indicate that attitude is associated with tuberculosis incidence in bivariate analysis, but this association is no longer significant after multivariate analysis. These findings suggest that attitude is

associated with the incidence of TB in the initial analysis; however, its influence may change after controlling for other factors such as nutritional status, contact history, family income, and home environmental conditions.

Attitudes play a role in shaping health behaviors, including behaviors to prevent transmission, seeking health care, and adherence to treatment. Previous research has shown that positive attitudes toward TB are associated with better preventive practices, such as mask use, cough etiquette, and early screening when symptoms appear (Zhang et al., 2024). Research in Indonesia also shows that negative attitudes are associated with an increased risk of tuberculosis and suboptimal preventive behaviors (Marsyah et al., 2024; Sanjethro, Shabrina and Lukas, 2025).

In this study, respondents with negative attitudes had lower odds of developing TB than those with positive attitudes. However, since attitudes were measured after case and control identification, the observed association may reflect changes resulting from disease diagnosis and subsequent health education rather than a direct protective effect of negative attitudes. Positive attitudes, similarly, may not directly cause preventive behaviors, as the adoption of such behaviors depends on environmental conditions, contact history, family support, and access to healthcare services.

Although the association with attitude was not statistically significant in the multivariate analysis, attitude remains important in tuberculosis control because it is linked to acceptance of screening, treatment adherence, and behaviors that prevent transmission. Therefore, strengthening health education and behavior change communication remains necessary as part of the tuberculosis control strategy in Yogyakarta.

Association Between Nutritional Status and Tuberculosis Incidence

Nutritional status was associated with TB incidence in the bivariate analysis. Respondents with normal and overweight nutritional status had lower odds of TB incidence compared to respondents with underweight nutritional status. Although this association was no longer significant in the multivariate analysis, the direction of the relationship still indicates that undernutrition increases susceptibility to TB. Undernutrition can weaken the immune system, thereby increasing the risk of infection and the development of active TB. The WHO states that undernutrition is one of the major risk factors for TB globally (WHO, 2024b). The meta-analysis also showed that individuals with a low body mass index have a higher risk of tuberculosis than those with good nutritional status (Franco et al., 2024b; Saunders et al., 2025).

The lack of significance of the association in the multivariate analysis may be influenced by other variables such as family income, contact history, diabetes mellitus, and household environmental conditions. Nevertheless, this study's results underscore the importance of nutritional status assessment and nutritional support in tuberculosis control programs.

Association Between Smoking History and Tuberculosis Incidence

This study indicates that a history of smoking is not significantly associated with the incidence of tuberculosis in Yogyakarta. However, respondents with a history of smoking tended to have higher odds of developing tuberculosis compared to non-smokers. These findings suggest that although the statistical association is not significant, the direction of the association remains consistent with the theory that smoking may increase susceptibility to tuberculosis.

Exposure to cigarette smoke can damage the lung's defense system, disrupt mucociliary function, and reduce the ability of alveolar macrophages to control Mycobacterium tuberculosis. The WHO states that tobacco use is one of the key risk factors in the epidemiology of tuberculosis (WHO, 2025a). A meta-analysis in Indonesia also found that smokers have a higher risk of tuberculosis than non-smokers (Dana et al., 2024). The findings of this study align with previous research in Yogyakarta, showing that smoking, poor home ventilation, and a family history of contact all increase tuberculosis risk (Sulistyawati and Ramadhan, 2021). In addition to increasing the risk of infection, smoking is also associated with delayed healing and an increased risk of TB recurrence (Vidyasagaran et al., 2024).

No significant association with smoking may be due to the limited measurement of exposure intensity. Smoking's effect on TB incidence is also shaped by other factors such as nutrition, contact history, ventilation, and socioeconomic conditions. Nonetheless, smoking cessation education remains crucial for TB control in Yogyakarta, as smoking can worsen TB outcomes.

Association Between Diabetes Mellitus History and Tuberculosis Incidence

The results of this study indicate that a history of diabetes mellitus is associated with the incidence of tuberculosis in multivariate analysis. However, respondents with a history of diabetes mellitus had lower odds of developing tuberculosis compared to those without a history of diabetes mellitus. These findings differ from the general theory and most previous studies, which suggest that diabetes mellitus is a risk factor for tuberculosis.

Diabetes mellitus is a significant comorbidity associated with tuberculosis. The World Health Organization states that the risk of TB is higher among people with diabetes than among those without diabetes, making diabetes one of the conditions contributing to the global burden of TB (WHO, 2024b). These findings are supported by a meta-analysis showing that diabetes mellitus is associated with an increased risk of tuberculosis across various populations and study designs (Foe-Essomba et al., 2021; Franco et al., 2024a).

Biological mechanisms shape the relationship between diabetes mellitus and tuberculosis. Imagine the body as a fortress: in diabetes, chronic hyperglycemia weakens the immune system, impairing both innate and adaptive immunity. Consequently, macrophage function, phagocytosis, antigen presentation, and T-cell responses to *Mycobacterium tuberculosis* are reduced. As a result, infections are harder to control, raising the risk of active TB. Importantly, this relationship is bidirectional: diabetes increases susceptibility to TB, while TB can worsen glycemic control (Byers and Guy, 2024).

The differing directions of the associations found in this study were likely influenced by the relatively small number of respondents with a history of diabetes mellitus, as well as by limitations in the diabetes variable, which was based solely on medical history and did not assess glycemic control, duration of diabetes, or adherence to treatment. Additionally, people with diabetes tend to interact more frequently with healthcare facilities, thereby having a greater opportunity to receive health education, clinical monitoring, and early disease detection. Therefore, the results of this study cannot be interpreted to mean that diabetes mellitus is protective against TB, but rather indicate that the relationship between diabetes mellitus and TB incidence is influenced by various other factors in the study population. Nevertheless, integrating TB-

DM services through screening, health education, and blood sugar monitoring remains important for TB control efforts (Rizkika et al., 2025).

Association Between Household Contact History and Tuberculosis Incidence

This study shows that a history of household contact is associated with tuberculosis incidence in bivariate analysis, but is no longer significant in multivariate analysis. However, respondents with a history of household contact still have higher odds of developing TB compared to those without such a history. Household contact is a key factor in TB transmission because exposure to *Mycobacterium tuberculosis* occurs repeatedly and over a longer duration within the home environment. The WHO classifies household contacts as a priority group for TB screening and preventive therapy due to their higher risk of infection and progression to active TB (WHO, 2025b).

The findings of this study are in line with previous research in Yogyakarta, which demonstrated that household contact investigations not only identify active TB cases and latent TB infections among family members of TB patients but may also influence ongoing transmission dynamics within households, as both detection and subsequent treatment or prevention can affect outcomes for multiple members (Nababan et al., 2024; Oktaviana et al., 2024). Other studies have also noted that household contacts are a high-risk group for latent TB infection and progression to active disease (Karbito and Maisaroh, 2023).

The association's lack of significance in the multivariate analysis may be due to more dominant factors, such as a history of close contact, home ventilation, nutritional status, and environmental conditions. Furthermore, exposure intensity within households can vary based on contact duration, housing density, and ventilation. Nevertheless, household contact investigation remains crucial for tuberculosis control in Yogyakarta, achieved through active screening, education on transmission prevention, and provision of preventive therapy to at-risk groups.

Association Between Close Contact History and Tuberculosis Incidence

This study shows that a history of close contact is significantly associated with tuberculosis incidence in Yogyakarta, both in bivariate and multivariate analyses. Respondents with a history of close contact had higher odds of developing tuberculosis compared to those without such a history. These findings indicate that close contact plays a significant role in the transmission of tuberculosis within the community.

TB is transmitted through the air when a person with pulmonary TB releases droplet nuclei containing Mycobacterium tuberculosis. Individuals who have close contact with a person with TB, especially over a long period of time and in enclosed spaces, are at higher risk of becoming infected or developing active TB. The WHO identifies close contacts as a priority group for TB screening and preventive therapy because they are at high risk of transmission (WHO, 2025a).

The findings of this study are consistent with previous research in the Special Region of Yogyakarta, which showed that contact tracing identified active TB cases and latent TB infection among close contacts (Nababan et al., 2024; Oktaviana et al., 2024). Close contact is one of the main risk factors for tuberculosis because it increases the likelihood of exposure to sources of infection (Velleca et al., 2021; Sagili et al., 2022).

The risk of transmission among close contacts can be influenced by several factors, such as duration of exposure, frequ-

ency of contact, room ventilation, housing density, mask use, and the infectious status of the TB patient. In addition, the presence of subclinical TB cases and undiagnosed cases can also lead to transmission occurring unnoticed. The findings of this study underscore the importance of strengthening close contact investigation in the TB control program in Yogyakarta. Active screening, education regarding TB symptoms and transmission, and the provision of preventive TB therapy to contact groups need to be strengthened to detect cases earlier and break the chain of transmission in the community.

Association Between Floor Type and Tuberculosis Incidence

This study indicates that the type of flooring is not significantly associated with tuberculosis incidence in Yogyakarta. However, respondents living in homes with substandard flooring tended to have higher odds of developing TB compared to those with standard flooring. Floor type is one indicator of a home's physical quality that can reflect the condition of the living environment. Floors that are not waterproof, damp, and difficult to clean may be associated with unhealthy housing conditions. Previous studies have shown that poor physical housing quality, including floor type, is associated with an increased risk of tuberculosis, particularly when accompanied by poor ventilation, high humidity, and high housing density (Lee et al., 2022). Research in Indonesia also reports that homes with substandard flooring have a higher risk of tuberculosis than homes with permanent, waterproof flooring (Huda et al., 2025; Oktavia et al., 2025).

Floor type showed no significant effect in this study, likely because most urban homes in Yogyakarta have similar permanent flooring. Floor type may be less influential on TB incidence than factors such as close contacts and ventilation. Still, improving home conditions, including floors, supports environment-based TB prevention in Yogyakarta.

Association Between Wall Type and Tuberculosis Incidence

Wall type does not significantly affect tuberculosis incidence in Yogyakarta. However, people in homes with substandard wall types had higher odds of tuberculosis than those in standard homes. Wall type reflects the physical condition of the housing and can affect indoor conditions such as humidity and air quality. Prior studies show that poor housing conditions, such as inadequate wall type, ventilation, lighting, or density, increase tuberculosis risk (Lee et al., 2022). Research in Indonesia also reports that homes with substandard walls have a higher risk of tuberculosis than homes with permanent, easily cleanable walls (Sipayung et al., 2023; Wijayanti et al., 2024).

Wall type showed little significance, likely because most homes in urban Yogyakarta have similar, permanent walls. Factors such as close contact history and poor ventilation are more strongly associated with TB incidence. Still, improving home conditions, including using waterproof, easy-to-clean walls, supports a healthier environment and can help reduce TB risk.

Association Between Home Ventilation and Tuberculosis Incidence

This study shows that ventilation area is associated with tuberculosis incidence in the bivariate analysis, although this association is no longer significant in the multivariate analysis. Respondents living in homes with inadequate ventilation have a higher odds ratio for tuberculosis incidence compared to respondents with adequate ventilation. Ventilation plays a crucial role in air circulation and in reducing the concentration of

infectious droplets indoors. Poor ventilation impedes air circulation, allowing droplet nuclei containing *Mycobacterium tuberculosis* to remain airborne for longer periods (Lee et al., 2022). Previous studies in Yogyakarta and several other regions in Indonesia have also shown that poor home ventilation is associated with an increased risk of tuberculosis (Sulistyawati and Ramadhan, 2021; Jusmini et al., 2025).

The lack of significance of the association in the multivariate analysis may be due to interactions among ventilation and other factors, such as housing density, lighting, and a history of close contact. Nevertheless, home ventilation remains an important environmental factor that should be considered in efforts to prevent tuberculosis transmission.

Thi study conclude that the incidence of pulmonary tuberculosis in Yogyakarta is influenced by socioeconomic, behavioral, clinical, and environmental factors. Bivariate analysis showed significant associations between TB incidence and family income, tuberculosis-related knowledge, attitude, nutritional status, household contact history, close contact history, and home ventilation. However, after adjustment using conditional logistic regression, only family income, tuberculosis-related knowledge, history of diabetes mellitus, and history of close contact remained independently associated with pulmonary tuberculosis.

Among these factors, a history of close contact with a TB patient was the strongest predictor of pulmonary tuberculosis. These findings highlight the importance of strengthening tuberculosis prevention strategies through early identification of high-risk individuals, improving public knowledge about tuberculosis, and enhancing diabetes screening and management. In addition to routine household contact investigation, active TB contact screening should also be expanded to workplaces and industrial settings, where prolonged close contact may contribute to disease transmission, thereby facilitating earlier case detection and reducing community transmission.

Study limitations

This study has several limitations. First, the matched case-control design identifies associations between risk factors and pulmonary tuberculosis but does not establish causal relationships. Second, several variables, including family income, smoking history, knowledge, attitude, and contact history, were collected through interviewer-administered questionnaires and were therefore subject to recall and reporting bias. Third, although matching was performed on age, sex, and primary healthcare center catchment area, other potential confounding factors were not assessed and may have influenced the observed associations. In addition, the study was conducted in Yogyakarta, which may limit the generalizability of the findings to other settings with different epidemiological and socioeconomic characteristics. Nevertheless, the validity of the pulmonary tuberculosis classification was strengthened through confirmation in the Tuberculosis Information System (SITB) and medical record verification at the participating primary healthcare centers, while direct household observations improved environmental assessment.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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