ORIGINAL ARTICLE

OPEN ACCESS

MEDICA

(International Medical Scientific Journal)
Vol.8, No.10, October 2026, pp. 1181 – 1192
ISSN 2622-660X (Online), ISSN 2622-6596 (Print)
https://doi.org/10.53770/medica.v8i10.1141



Factors Associated with Tuberculosis Incidence from an Environmental Health Perspective: A Case-Control Study in Yogyakarta, Indonesia

Tri Wahyuni Sukesi[1]✉, Salwa Jasani Chaerunnisa[1], Rika Yulianti Fitri[2]

[1] Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2] Department of Occupational Health and Safety, Ibnu Sina University, Batam, Riau Islands, Indonesia

Article Info

Article History:
Received:
08 June 2026
Revised:
12 Oktober 2026
Accepted:
18 October 2026
Published:
31 October 2026

Keywords:
Attitude
Behavior
Environmental Health
Housing Ventilation
Tuberculosis

Citation:
Sukesi, T.W., Chaerunnisa, S.J., & Fitri, R.Y. (2026). Factors Associated with Tuberculosis Incidence from an Environmental Health Perspective: A Case-Control Study in Yogyakarta, Indonesia. *MEDICA (International Medical Scientific Journal)*, 8(10), 1181–1192. https://doi.org/10.53770/medica.v8i10.1141

Abstract

Tuberculosis (TB) remains a major public health problem in Indonesia, and the number of recorded cases in the Mantrijeron Primary Health Center area has continued to increase. This study aimed to analyze the associations of sociodemographic, behavioral, and housing environmental factors with TB incidence. A case-control study was conducted among 64 respondents (32 cases and 32 controls) matched for age, sex, and residential area. Data were collected through structured interviews and observation of housing conditions and were analyzed using the Chi-square test and binary logistic regression, with all eight study variables (gender, education, income, knowledge, attitude, behavior, ventilation, and housing density) entered simultaneously. In the bivariate analysis, TB incidence was significantly associated with knowledge ($p = 0.023$), attitude ($p = 0.022$), behavior ($p = 0.012$), ventilation ($p = 0.006$), and housing density ($p = 0.018$), but not with gender, education, or income. The multivariate model was significant as a whole ($p = 0.046$; Nagelkerke $R^2 = 0.291$); however, no variable remained independently significant after mutual adjustment. Inadequate ventilation showed the largest adjusted odds ratio (AOR = 3.616; 95% CI: 0.651–20.074; $p = 0.142$) and was the least attenuated after adjustment. These findings suggest that behavioral and housing environmental factors contribute jointly to TB occurrence, with ventilation being the most prominent factor. Improvements in housing conditions and TB-related health education are recommended, and larger studies are needed to confirm these associations.

COPYRIGHT & LICENSING
Copyright © 2026 MEDICA (International Medical Scientific Journal). Published by Borneo Scientific Publishing.
This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.

Corresponding Author:
✉ Tri Wahyuni Sukesi
Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
Email: yunisukesi.fkmuad@gmail.com

1. INTRODUCTION

Tuberculosis (TB) continues to be one of the leading causes of death from a single infectious agent worldwide (World Health Organization, 2023). According to the WHO Global Tuberculosis Report 2023, 7.5 million people were newly diagnosed with TB in 2022, up from 5.8 million in 2020 and 6.4 million in 2021 (World Health Organization, 2023). In Indonesia, the number of reported TB cases rose from 351,963 in 2020 to 397,377 in 2021, with a greater proportion of cases among men than among women (Kemenkes RI, 2022). At the local level, Yogyakarta City recorded 805 new TB cases in 2022, equivalent to an incidence rate of 194.6 per 100,000 population (Dinas Kesehatan Kota Yogyakarta, 2023). Taken together, these figures show that TB remains an important public health problem at the global, national, and local levels (Bai & Ameyaw, 2024).

In addition to its clinical impact, TB can impair patients' mental well-being and quality of life, and the combination of treatment costs and lost income can place a heavy financial burden on affected households (Kilale et al., 2022; Portnoy et al., 2023). TB is a multifactorial disease shaped by the interplay of environmental, socioeconomic, and behavioral factors. Housing conditions such as inadequate ventilation, poor lighting, high humidity, and overcrowding can facilitate TB transmission, especially in densely populated areas (Apriliani et al., 2020; Mathofani & Febriyanti, 2020). Socioeconomic characteristics, including income and education, also determine people's access to health information, health services, and healthy living practices (Muñoz et al., 2024; L. Wang et al., 2021).

People with higher educational attainment generally have better knowledge of disease prevention, whereas low income has repeatedly been linked to a higher TB burden because the disease is concentrated among disadvantaged groups (Bai & Ameyaw, 2024; Muñoz et al., 2024). Behavioral factors, including knowledge, attitudes, and practices related to TB prevention and treatment, may also be associated with TB status (Afrianto, 2024; Y. Wang et al., 2021). Although earlier studies have linked TB to a range of environmental, socioeconomic, and behavioral factors, their findings vary across populations and settings (Afrianto, 2024; Lee et al., 2022). Evidence that examines these factors together within a single population remains limited, particularly at the community level. Further research is therefore needed to clarify how these factors relate to TB status and to provide context-specific evidence for TB prevention.

The Mantrijeron Primary Health Center serves an area of Yogyakarta City in which TB cases have risen steadily in recent years. A preliminary study conducted on March 29, 2023, recorded 16 confirmed TB cases in 2021, 32 in 2022, and 45 in 2023 (Puskesmas Mantrijeron, 2023). Although these data show an increase in recorded cases, they do not by themselves demonstrate an increase in population-based incidence. Nevertheless, this local trend highlights the need to investigate the factors associated with TB in this setting.

To date, few studies have examined these factors simultaneously from an environmental health perspective in the Mantrijeron Primary Health Center service area. Therefore, this study aimed to analyze the associations of housing environmental factors, education, income, knowledge, attitudes, and behaviors with TB status among residents of the Mantrijeron Primary Health Center service area, Yogyakarta City.

2. METHODS

This quantitative observational study used a case-control design. It was conducted in the service area of the Mantrijeron Primary Health Center, Yogyakarta City, Indonesia, which covers the Gedongkiwo, Suryodiningratan, and Mantrijeron subdistricts. Data were obtained through structured questionnaire-based interviews and direct observation of respondents' housing conditions. The study population consisted of patients with smear-positive (BTA+) pulmonary TB who had been treated at the Mantrijeron Primary Health

Center; individuals living outside the service area were excluded. A total of 64 respondents participated, comprising 32 cases and 32 controls. Cases were patients with BTA+ pulmonary TB, whereas controls were individuals without TB who lived in the same neighborhoods as the cases. All eligible cases were included (total sampling), and controls were selected by simple random sampling. Cases and controls were matched at a 1:1 ratio for age, sex, and residential location.

Data were collected using a structured questionnaire and an observation checklist adapted from the Indonesian Ministry of Health's healthy housing assessment criteria. The dependent variable was TB status (case = BTA+ pulmonary TB; control = no TB). Eight independent variables were analyzed, all in dichotomous form: (1) gender (male or female); (2) education level, classified as low (no schooling to junior high school) or high (senior high school or higher); (3) income level, classified as low (below the Yogyakarta City minimum wage) or high (at or above the minimum wage); (4) knowledge (poor or good), (5) attitude (negative or positive), and (6) behavior (poor or good) regarding TB prevention, each classified using the median total questionnaire score as the cut-off point; (7) ventilation, measured as the total ventilation area of the house and classified as inadequate (< 10% of the floor area) or adequate (≥ 10% of the floor area); and (8) housing density, classified as inadequate (< 8 m² per occupant) or adequate (≥ 8 m² per occupant). Ventilation and housing density were assessed by direct observation and measurement in each respondent's house.

Data were analyzed at the univariate, bivariate, and multivariate levels. Univariate analysis described the frequency and percentage distributions of TB status and the eight independent variables. Bivariate analysis applied the Chi-square test with Yates' continuity correction (all expected cell frequencies were ≥ 5) to assess the association between each independent variable and TB status, and crude odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. The reference categories were female, high education, high income, good knowledge, positive attitude, good behavior, adequate ventilation, and adequate housing density. Multivariate analysis employed binary logistic regression with the Enter method: all eight independent variables were entered into the model simultaneously, irrespective of their bivariate p-values, so that each estimate was adjusted for all the others. Gender, as a matching variable, was retained in the model to account for the matched design. The results were reported as regression coefficients (B), standard errors (S.E.), Wald statistics, adjusted odds ratios (AORs), and 95% CIs. Model performance was evaluated using the omnibus likelihood-ratio test, −2 log likelihood, Nagelkerke R^2, and overall classification accuracy, and multicollinearity was assessed using variance inflation factors (all < 3.0). Statistical significance was set at $p < 0.05$. This study received ethical approval from the Research Ethics Committee of Universitas Ahmad Dahlan, Indonesia (Approval Number: 012311308) before data collection began.

3. RESULTS AND DISCUSSION

Table 1. Distribution of respondent characteristics and study variables.

Variables	Frequency (n)	Percentage (%)
Tuberculosis		
Case	32	50.0 %
Control	32	50.0 %
Gender		
Male	26	40.6 %
Female	38	59.4 %

Variables	Frequency (n)	Percentage (%)
Education Level		
Low	22	34.4 %
High	42	65.6 %
Income Level		
Low	45	70.3 %
High	19	29.7 %
Knowledge		
Poor	36	56.3 %
Good	28	43.8 %
Attitude		
Negative	38	59.4 %
Positive	26	40.6 %
Behavior		
Poor	33	51.6 %
Good	31	48.4 %
Ventilation		
Inadequate	36	56.3 %
Adequate	28	43.8 %
Housing Density		
Inadequate	22	34.4 %
Adequate	42	65.6 %

As shown in Table 1, the case and control groups were of equal size (32 respondents each; 50.0%). Most respondents were female (59.4%), had a high level of education (65.6%), and had a low income (70.3%). More than half had poor knowledge (56.3%) and negative attitudes (59.4%) toward TB, and slightly over half demonstrated poor preventive behavior (51.6%). With respect to the housing environment, 56.3% of respondents lived in houses with inadequate ventilation, while about one-third (34.4%) lived in houses with inadequate occupancy density. Overall, poor knowledge, negative attitudes, and inadequate ventilation were common in the study population, and socioeconomic disadvantage was reflected mainly in low income rather than in low education.

Table 2. Bivariate analysis of factors associated with tuberculosis incidence.

Variable	Tuberculosis				Total	p-value	OR	CI
	Case		Control					
	n	%	n	%				
Gender								
Male	13	40.6%	13	40.6%	40.6%	1.000	1.000	0.369–2.712
Female	19	59.4%	19	59.4%	59.4%		Ref	
Education Level								
Low	13	40.6%	9	28.1%	34.4%	0.430	1.749	0.615–4.971
High	19	59.4%	23	71.9%	65.6%		Ref	
Income Level								
Low	25	78.1%	20	62.5%	70.3%	0.274	2.143	0.712–6.451
High	7	21.9%	12	37.5%	29.7%		Ref	
Knowledge								
Poor	23	71.9%	13	40.6%	56.3%	0.023	3.735	1.314–10.618
Good	9	28.1%	19	59.4%	43.8%		Ref	

Variable	Tuberculosis				Total	p-value	OR	CI
	Case		Control					
	n	%	n	%				
Attitude								
Negative	24	75.0%	14	43.8%	59.4%	0.022	3.857	1.334–11.157
Positive	8	25.0%	18	56.3%	40.6%		Ref	
Behavior								
Poor	22	68.8%	11	34.4%	51.6%	0.012	4.200	1.478–11.936
Good	10	31.3%	21	65.6%	48.4%		Ref	
Ventilation								
Inadequate	24	75.0%	12	37.5%	56.3%	0.006	5.000	1.709–14.629
Adequate	8	25.0%	20	62.5%	43.8%		Ref	
Housing Density								
Inadequate	16	50.0%	6	18.8%	34.4%	0.018	4.333	1.405–13.363
Adequate	16	50.0%	26	81.3%	65.6%		Ref	

Note: *p-values were obtained from the Chi-square test with Yates' continuity correction; OR = crude odds ratio for the first category of each variable compared with the second (reference) category; CI = 95% confidence interval. Percentages for cases and controls are column percentages (n = 32 each); Total is the percentage of all 64 respondents.*

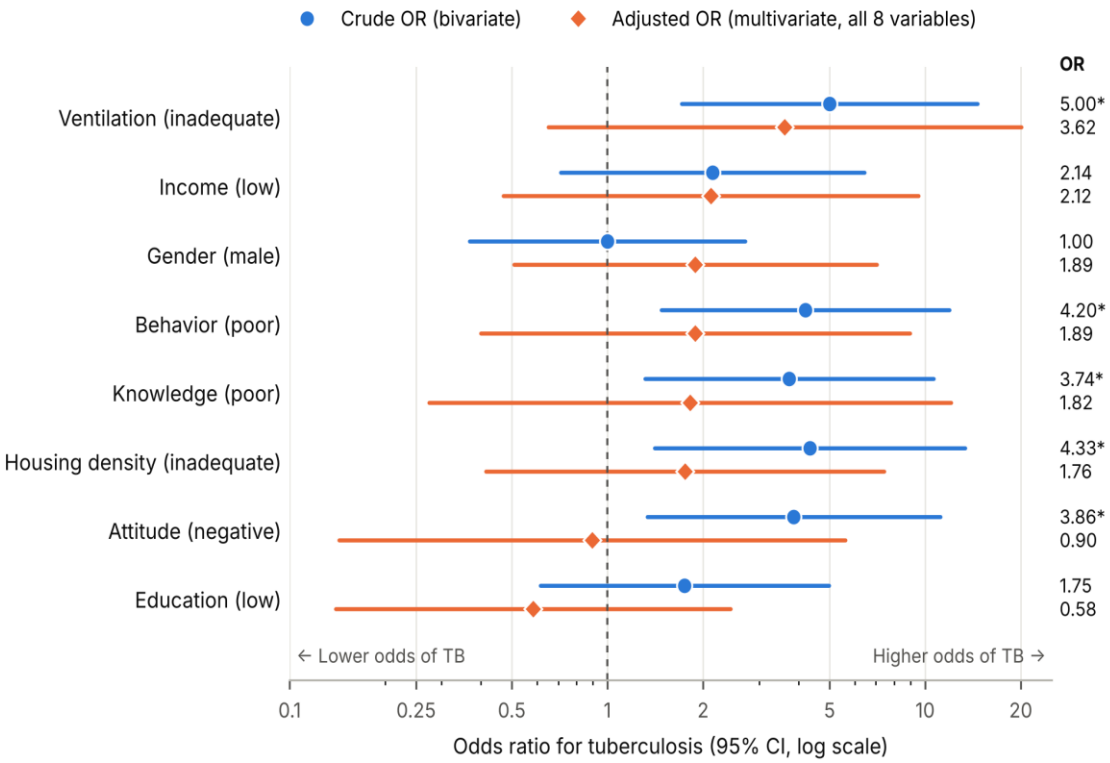
Table 2 shows that gender was distributed identically in the case and control groups (40.6% male in each; p = 1.000; OR = 1.000), consistent with matching by sex. Neither education level (p = 0.430) nor income level (p = 0.274) was significantly associated with TB, although low education and low income were more common among cases than among controls. By contrast, knowledge, attitude, behavior, ventilation, and housing density were significantly associated with TB ($p < 0.05$). The strongest crude association was observed for inadequate ventilation (OR = 5.000; 95% CI: 1.709–14.629; p = 0.006), which was found in 75.0% of cases compared with 37.5% of controls. This was followed by inadequate housing density (OR = 4.333; 95% CI: 1.405–13.363; p = 0.018), poor behavior (OR = 4.200; 95% CI: 1.478–11.936; p = 0.012), negative attitude (OR = 3.857; 95% CI: 1.334–11.157; p = 0.022), and poor knowledge (OR = 3.735; 95% CI: 1.314–10.618; p = 0.023). Before adjustment for the other variables, respondents in these categories therefore had approximately four to five times higher odds of being TB cases than those in the corresponding reference categories.

Table 3. Multivariate Analysis of Factors Associated with Tuberculosis Incidence

Variable	B	S.E	Wald	p-value	AOR (Exp B)	95% CI
Gender (male)	0.637	0.671	0.901	0.342	1.891	0.508–7.045
Education level (low)	-0.539	0.730	0.545	0.460	0.584	0.140–2.439
Income level (low)	0.750	0.768	0.953	0.329	2.116	0.470–9.530
Knowledge (poor)	0.600	0.965	0.387	0.534	1.823	0.275–12.077
Attitude (negative)	-0.110	0.936	0.014	0.907	0.896	0.143–5.606
Behavior (poor)	0.637	0.794	0.644	0.422	1.891	0.399–8.961
Ventilation (inadequate)	1.285	0.875	2.160	0.142	3.616	0.651–20.074
Housing density (inadequate)	0.563	0.737	0.584	0.445	1.756	0.414–7.441
Constant	-2.130	0.821	6.734	0.009	0.119	–

Note: *Binary logistic regression, Enter method; all eight variables were entered simultaneously. Reference categories: female, high education, high income, good knowledge, positive attitude, good behavior, adequate ventilation, and adequate housing density. Omnibus test $\chi^2 = 15.737$, df = 8, p = 0.046; −2 log likelihood = 72.986; Nagelkerke $R^2 = 0.291$; overall classification accuracy = 70.3%.*

Table 3 presents the multivariate model, in which all eight variables were entered simultaneously. The model was statistically significant overall (omnibus $\chi^2 = 15.737$, df = 8, p = 0.046), explained 29.1% of the variation in TB status (Nagelkerke $R^2 = 0.291$), and correctly classified 70.3% of respondents. After mutual adjustment, however, no individual variable remained statistically significant (all p > 0.05). Inadequate ventilation had the largest adjusted effect (AOR = 3.616; 95% CI: 0.651–20.074; p = 0.142); that is, respondents living in poorly ventilated houses had approximately 3.6 times higher odds of being TB cases after controlling for the other factors, although the confidence interval included 1. Low income (AOR = 2.116; 95% CI: 0.470–9.530; p = 0.329), male gender (AOR = 1.891; 95% CI: 0.508–7.045; p = 0.342), poor behavior (AOR = 1.891; 95% CI: 0.399–8.961; p = 0.422), poor knowledge (AOR = 1.823; 95% CI: 0.275–12.077; p = 0.534), and inadequate housing density (AOR = 1.756; 95% CI: 0.414–7.441; p = 0.445) showed positive but non-significant associations, whereas negative attitude (AOR = 0.896) and low education (AOR = 0.584) had adjusted odds ratios below 1. The wide confidence intervals reflect the small sample relative to the number of variables (32 cases for eight variables) and the overlap among the behavioral variables (knowledge, attitude, and behavior). Hence, the factors that were significant in the bivariate analysis are not independent of one another, and their combined rather than individual contributions should be emphasized.



* p < 0.05. Reference categories: female, high education, high income, good knowledge, positive attitude, good behavior, adequate ventilation, adequate density.

Figure 1. Crude and adjusted odds ratios of factors associated with tuberculosis incidence.

Figure 1 compares the crude odds ratios from the bivariate analysis with the adjusted odds ratios from the multivariate model for all eight variables. In the crude

analysis, the confidence intervals of five variables (ventilation, housing density, behavior, attitude, and knowledge) lay entirely above 1. After mutual adjustment, all estimates moved toward 1 and every confidence interval crossed 1, indicating that much of each factor's crude association was shared with the other factors. Attenuation was greatest for attitude (OR 3.857 to AOR 0.896), housing density (4.333 to 1.756), behavior (4.200 to 1.891), and knowledge (3.735 to 1.823), suggesting that poor knowledge, negative attitudes, and poor behavior tend to occur in the same respondents and that high occupancy density partly overlaps with poor ventilation. In contrast, ventilation was the least attenuated (5.000 to 3.616) and retained the highest adjusted estimate, indicating that its association with TB was the least explained by the other variables and that it was the most prominent single factor in this population. As expected for a matching variable, gender shifted from no association (OR = 1.000) to a non-significant AOR of 1.891.

This study found no significant association between education level and TB incidence. Education may shape a person's ability to obtain and understand health information, but TB occurrence also depends on environmental conditions, socioeconomic status, access to health services, and health behaviors (Bai & Ameyaw, 2024; L. Wang et al., 2021). Moreover, the adoption of preventive behaviors is driven not only by knowledge but also by psychological, social, and economic factors, which may weaken the direct effect of educational attainment on TB risk (Afrianto, 2024). This finding is consistent with that of Widiati and Majdi (2021), who reported no significant association between education level and TB incidence ($p = 0.133$), but differs from that of Agustian et al. (2022), who found a significant relationship. Such inconsistencies suggest that the influence of education on TB varies across populations and settings according to socioeconomic conditions, access to health care, and local TB control programs (L. Wang et al., 2021).

Income level was likewise not significantly associated with TB incidence. Although income can affect access to health care, nutrition, and living conditions, TB risk is shaped by multiple factors that may dilute the direct effect of income alone (Bai & Ameyaw, 2024; Muñoz et al., 2024). In the present sample, most respondents in both groups had a low income (70.3% overall), which may also have limited the ability to detect a difference. This result agrees with that of Rini et al. (2023), who found no significant association between income and TB incidence ($p = 1.000$), whereas Fahdhienie et al. (2020) reported a significant relationship ($p = 0.030$). This discrepancy suggests that the effect of income on TB varies with local socioeconomic conditions and underlines the importance of locally tailored TB prevention and control strategies.

Poor knowledge was significantly associated with TB status in the bivariate analysis. Limited understanding of TB symptoms, transmission, and prevention can delay care seeking and prolong the period during which the disease can be transmitted to others (Makgopa & Madiba, 2021), whereas adequate knowledge can encourage preventive behaviors and timely health-care seeking (Armaita et al., 2024). This finding is in line with that of Darmawansyah and Wulandari (2021), who reported a strong association between knowledge level and pulmonary TB ($p < 0.001$). Raising TB awareness and promoting early screening and diagnosis therefore remain essential strategies for TB prevention and control, particularly in high-burden settings (Makgopa & Madiba, 2021; Y. Wang et al., 2021).

Negative attitudes were also significantly associated with TB status in the bivariate analysis. Attitudes can influence a person's willingness to adopt preventive behaviors, undergo screening, and adhere to treatment, and individuals with negative attitudes toward TB prevention are less likely to take protective measures (Loh et al., 2023). This result is consistent with that of Ginting and Fentiana (2023), who found a significant association between attitude and the risk of TB transmission ($p = 0.002$), and with that of

Nuraini et al. (2022), who reported a significant association between attitude and TB incidence in South Purwokerto, Banyumas ($p = 0.038$). However, after adjustment for the other variables, the adjusted odds ratio for attitude fell below 1, suggesting that its crude association largely reflected its overlap with knowledge and behavior. Differences in cultural, social, and health-care contexts may also shape TB-related beliefs and preventive practices across settings (Loh et al., 2023; L. Wang et al., 2021).

Poor behavior was associated with TB status in the bivariate analysis (OR = 4.200; 95% CI: 1.478–11.936; $p = 0.012$), indicating that respondents with poor health behavior had higher odds of being TB cases than those with good behavior. Health behavior is closely linked to knowledge, attitudes, and environmental conditions. Preventive practices such as keeping the house well ventilated and following proper cough etiquette are key elements of TB prevention (Kemenkes RI, 2022). This finding agrees with those of Pratiwi and Sudiadnyana (2021) and Sulrieni et al. (2023), both of whom reported a significant association between behavior and pulmonary TB incidence. In addition, patients who continued to smoke during anti-TB treatment have been shown to be more likely to experience recurrence, underscoring the importance of healthy behavior in TB prevention and control (Lin et al., 2021).

Ventilation showed the strongest crude association with TB status (OR = 5.000; 95% CI: 1.709–14.629; $p = 0.006$). In the multivariate model including all eight variables, inadequate ventilation retained the largest adjusted odds ratio (AOR = 3.616; 95% CI: 0.651–20.074; $p = 0.142$). Although no longer statistically significant, its estimate was attenuated less than those of the other variables (Figure 1), suggesting that the association between ventilation and TB was the least explained by the sociodemographic and behavioral factors examined. Poor ventilation may allow airborne infectious particles to accumulate indoors and thereby facilitate the transmission of *Mycobacterium tuberculosis* (Pratiwi & Sudiadnyana, 2021). This finding is consistent with those of Zuraidah and Ali (2020) and Fadhilah et al. (2023), who reported significant associations between ventilation and TB incidence ($p < 0.001$ and $p = 0.022$, respectively). Evidence from ventilation studies further indicates that adequate air exchange is important for reducing the risk of airborne transmission in occupied rooms (Deol et al., 2021). Accordingly, TB prevention and control efforts should include improving household ventilation and lighting, reducing overcrowding, and promoting clean and healthy living behaviors (Rokhmalia et al., 2025).

High housing density was significantly associated with TB in the bivariate analysis. Crowded dwellings often have poor ventilation, inadequate lighting, and high humidity, all of which favor the spread of *Mycobacterium tuberculosis* (Lee et al., 2022). When household members share a small space, the likelihood of exposure to airborne infectious particles increases considerably. Limited living space may also degrade indoor air quality and environmental conditions, supporting the survival and transmission of TB bacteria (Irawati, 2020). These findings are consistent with those of Konde et al. (2020), who found a significant association between housing density and TB incidence ($p = 0.002$), and Effendi et al. (2020), who reported a similar association ($p < 0.001$). In the multivariate model, however, the effect of housing density was markedly attenuated, which is consistent with its overlap with poor ventilation. Improving housing conditions, reducing overcrowding, and ensuring adequate ventilation should therefore be integral components of comprehensive TB prevention and control strategies, and access to affordable, healthy housing may help reduce TB transmission and improve patient outcomes (Lee et al., 2022).

When all eight variables were analyzed together, the model remained significant overall, but no single variable was independently significant. This pattern indicates that

the factors associated with TB in this study are interrelated: respondents with poor knowledge also tended to have negative attitudes and poor preventive behavior, and crowded houses often had inadequate ventilation. As a result, the effect of each factor cannot be fully separated from that of the others, and TB prevention is likely to be more effective when behavioral and housing interventions are implemented together rather than separately (Lee et al., 2022; Rokhmalia et al., 2025). This study has several limitations. First, the sample was small relative to the number of variables in the multivariate model (32 cases for eight variables), which reduced statistical power and produced wide confidence intervals. Second, although cases and controls were matched for age, sex, and residential location, matched-pair identifiers were not available for analysis; therefore, unconditional logistic regression was used, with gender retained in the model. Future studies with larger samples and a conditional (matched) analysis are recommended to confirm the independent effect of each factor.

4. CONCLUSION

In the bivariate analysis, knowledge, attitude, behavior, ventilation, and housing density were significantly associated with TB status, whereas gender, education, and income were not. When all eight variables were considered together, the multivariate model was significant overall, but no factor remained independently significant; inadequate ventilation had the largest adjusted odds ratio and was the least attenuated. These findings indicate that behavioral and housing environmental factors jointly contribute to TB status in the study population, with ventilation as the most prominent factor. TB health education programs should be strengthened to improve community knowledge, attitudes, and healthy living behaviors. In addition, improving housing conditions, particularly by ensuring adequate ventilation and reducing residential density, should be prioritized as a practical measure to support TB prevention and control in the Mantrijeron Primary Health Center area.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICAL CONSIDERATIONS

This study received ethical approval from the Research Ethics Committee of Universitas Ahmad Dahlan, Indonesia (Approval Number: 012311308) before data collection began. This study was also conducted in accordance with the ethical principles of the Declaration of Helsinki.

AUTHOR CONTRIBUTIONS

Tri Wahyuni Sukesi contributed to conceptualization, supervision, writing (original draft and review), editing, translation, and manuscript submission. Salwa Jasani Chaerunnisa contributed to data collection, data acquisition, and writing (original draft). Rika Yulianti Fitri contributed to data processing, statistical analysis, data interpretation, and writing (review and editing). All authors reviewed and approved the final version of the manuscript.

ACKNOWLEDGEMENT

The authors thank Universitas Ahmad Dahlan and everyone involved in conducting this study.

FUNDING

This research received no external funding and was fully self-funded by the authors.

DECLARATION OF ARTIFICIAL INTELLIGENCE USE

The authors used ChatGPT (OpenAI) and Claude (Anthropic) solely to assist with grammar correction, paraphrasing, language editing, and readability during manuscript preparation. The authors reviewed and revised all AI-assisted text and take full responsibility for the accuracy, originality, and integrity of the final manuscript. These tools were not used to replace the authors' scientific judgment, data analysis, or interpretation of the findings.

REFERENCES

Afrianto, I. (2024). Environmental and behavioral determinants of tuberculosis: A narrative review. *Jurnal Riset Kualitatif dan Promosi Kesehatan*, 3(1), 26–40. https://doi.org/10.61194/jrkpk.v3i1.673

Agustian, M. D., Masria, S., & Ismawati, I. (2022). Hubungan usia, jenis kelamin dan tingkat pendidikan dengan kejadian TB paru di wilayah kerja Puskesmas Cibadak Kabupaten Sukabumi. *Bandung Conference Series: Medical Science*, 2(1), 1120–1125.

Apriliani, N. A., Rahayu, U., & Narwati. (2020). Hubungan kondisi fisik rumah dengan kejadian penyakit TBC paru di wilayah kerja Puskesmas Simomulyo Kota Surabaya tahun 2019. *Gema Lingkungan Kesehatan*, 18(1), 33–38. https://doi.org/10.36568/kesling.v18i1.1103

Armaita, A., Marni, L., Nisa, S., Lucintarillova, B., & Aprihatin, Y. (2024). The relationship of the level of community knowledge in the family environment with tuberculosis prevention efforts. *Jurnal Penelitian Pendidikan IPA*, 10(2), 714–719. https://doi.org/10.29303/jppipa.v10i2.6856

Bai, W., & Ameyaw, E. K. (2024). Global, regional and national trends in tuberculosis incidence and main risk factors: A study using data from 2000 to 2021. *BMC Public Health*, 24, 12. https://doi.org/10.1186/s12889-023-17495-6

Darmawansyah, D., & Wulandari, W. (2021). Hubungan tingkat pengetahuan dengan kejadian TB paru di wilayah kerja Puskesmas Padang Serai Kota Bengkulu. *Journal of Nursing and Public Health*, 9(2), 18–22. https://doi.org/10.37676/jnph.v9i2.1790

Deol, A. K., Scarponi, D., Beckwith, P. G., Yates, T. A., Karat, A. S., Yan, A. W. C., Baisley, K., Grant, A. D., White, R. G., & McCreesh, N. (2021). Estimating ventilation rates in rooms with varying occupancy levels: Relevance for reducing transmission risk of airborne pathogens. *PLoS ONE*, 16(6), e0253096. https://doi.org/10.1371/journal.pone.0253096

Dinas Kesehatan Kota Yogyakarta. (2023). *Tuberkulosis atau TB masih menjadi masalah kesehatan di Kota Yogyakarta*. https://kesehatan.jogjakota.go.id/berita/id/450/tuberkulosis-atau-tb-masih-menjadi-masalah-kesehatan-di-kota-yogyakarta/

Effendi, S. U., Khairani, N., & Izhar. (2020). Hubungan kepadatan hunian dan ventilasi rumah dengan kejadian TB paru pada pasien dewasa yang berkunjung ke Puskesmas Karang Jaya Kabupaten Musi Rawas Utara. *CHMK Health Journal*, 4(2), 140–148.

Fadhilah, A. H., Nurmaladewi, & Saktiansyah, L. O. A. (2023). Pengaruh lingkungan fisik rumah dan perilaku terhadap kejadian tuberkulosis paru BTA positif: Sebuah studi kasus kontrol. *Jurnal Ilmu Kesehatan Masyarakat*, 19(1), 38–47. https://doi.org/10.19184/ikesma.v19i1.30255

Fahdhienie, F., Agustina, A., & Ramadhana, P. V. (2020). Analisis faktor risiko terhadap kejadian penyakit tuberkulosis di wilayah kerja Puskesmas Pidie Kabupaten Pidie tahun 2019. *Sel Jurnal Penelitian Kesehatan*, 7(2), 52–60. https://doi.org/10.22435/sel.v7i2.3735

Ginting, D., & Fentiana, N. (2023). Hubungan pengetahuan, sikap dan dukungan keluarga

dengan risiko penularan TB paru. *Jurnal Ilmu Kesehatan dan Gizi (JIG)*, 1(4), 88–93.

Irawati, I. (2020). Hubungan kepadatan hunian dan sosial ekonomi dengan kejadian penyakit TB paru di Kelurahan Pecung (wilayah kerja Puskesmas Belakang Padang) Kecamatan Belakang Padang Kota Batam tahun 2019. *Dinamika Lingkungan Indonesia*, 7(1), 8–12. https://doi.org/10.31258/dli.7.1.p.8-12

Kemenkes RI. (2022). *Profil Kesehatan Indonesia 2021*. Kementerian Kesehatan Republik Indonesia.

Kilale, A. M., Pantoja, A., Jani, B., Range, N., Ngowi, B. J., Makasi, C., Majaha, M., Manga, C. D., Haule, S., Wilfred, A., Hilary, P., Mahamba, V., Nkiligi, E., Muhandiki, W., Matechi, E., Mutayoba, B., Nishikiori, N., & Ershova, J. (2022). Economic burden of tuberculosis in Tanzania: A national survey of costs faced by tuberculosis-affected households. *BMC Public Health*, 22, 600. https://doi.org/10.1186/s12889-022-12987-3

Konde, C. P., Asrifuddin, A., & Langi, F. L. F. G. (2020). Hubungan antara umur, status gizi dan kepadatan hunian dengan tuberkulosis paru di Puskesmas Tuminting Kota Manado. *Jurnal Kesmas*, 9(1), 106–113.

Lee, J.Y., Kwon, N., Goo, G.Y., & Cho, S.I. (2022). Inadequate housing and pulmonary tuberculosis: A systematic review. *BMC Public Health*, 22, 622. https://doi.org/10.1186/s12889-022-12879-6

Lin, H., Lin, Y., Xiao, L., Chen, Y., Zeng, X., & Chang, C. (2021). How do smoking status and smoking cessation efforts affect TB recurrence after successful completion of anti-TB treatment? A multicenter, prospective cohort study with a 7-year follow-up in China. *Nicotine & Tobacco Research*, 23(12), 1995–2002. https://doi.org/10.1093/ntr/ntab117

Loh, S. Y., Zakaria, R., & Mohamad, N. (2023). Knowledge, attitude, and stigma on tuberculosis and the associated factors for attitude among tuberculosis contacts in Malaysia. *Medeniyet Medical Journal*, 38(1), 45–53. https://doi.org/10.4274/MMJ.galenos.2023.14478

Makgopa, S., & Madiba, S. (2021). Tuberculosis knowledge and delayed health care seeking among new diagnosed tuberculosis patients in primary health facilities in an urban district, South Africa. *Health Services Insights*, 14, 11786329211054035. https://doi.org/10.1177/11786329211054035

Mathofani, P. E., & Febriyanti, R. (2020). Faktor-faktor yang berhubungan dengan kejadian penyakit tuberkulosis (TB) paru di wilayah kerja Puskesmas Serang Kota tahun 2019. *Jurnal Ilmiah Kesehatan Masyarakat: Media Komunikasi Komunitas Kesehatan Masyarakat*, 12(1), 1–10. https://doi.org/10.52022/jikm.v12i1.53

Muñoz, V., Ayala, A., Vargas, C., Vivanco, E., Elorrieta, F., & Maddaleno, M. (2024). Tuberculosis profile in Chile: Effect of migration, overcrowding and income on tuberculosis and its spatial distribution. *Revista Médica de Chile*, 152(7), 748–758. https://doi.org/10.4067/s0034-98872024000700748

Nuraini, N., Suhartono, S., & Raharjo, M. (2022). Hubungan faktor lingkungan fisik dalam rumah dan perilaku kesehatan dengan kejadian TB paru di Purwokerto Selatan Banyumas. *Jurnal Kesehatan Lingkungan Indonesia*, 21(2), 210–218. https://doi.org/10.14710/jkli.21.2.210-218

Portnoy, A., Yamanaka, T., Nguhiu, P., Nishikiori, N., Baena, G., Floyd, K., & Menzies, N. A. (2023). Costs incurred by people receiving tuberculosis treatment in low-income and middle-income countries: A meta-regression analysis. *The Lancet Global Health*, 11(10), e1640–e1647. https://doi.org/10.1016/S2214-109X(23)00369-8

Pratiwi, A. I. R. D., & Sudiadnyana, I. W. (2021). Hubungan perilaku dan kualitas fisik rumah dengan kejadian TBC paru di wilayah kerja Puskesmas Kediri 1 tahun 2020. *Jurnal Kesehatan Lingkungan (JKL)*, 11(1), 13–17. https://doi.org/10.33992/jkl.v11i1.1403

Puskesmas Mantrijeron. (2023). *Profil Puskesmas Mantrijeron 2023*. Puskesmas

Mantrijeron.

Rini, W. N. E., Halim, R., & Ritonga, A. B. (2023). Hubungan karakteristik individu dan kondisi fisik rumah dengan kejadian tuberkulosis paru. *Gema Wiralodra*, 14(1), 82–95. https://doi.org/10.31943/gw.v14i1.338

Rokhmalia, F., Khambali, & Rachmaniyah. (2025). Assistance in the prevention of TBC transmission with the application of appropriate technology using cyclone ventilator modification (CVM) in the houses of pulmonary TB and ISPA patients as well as PHBS activities in Wonokusumo District. *Frontiers in Community Service and Empowerment*, 4(2), 250–259. https://doi.org/10.35882/ficse.v4i2.84

Sulrieni, I. N., Dewi, A., & Masdalena, M. (2023). Hubungan kondisi lingkungan fisik rumah dan perilaku dengan kejadian TB paru di wilayah kerja Puskesmas IV Koto Kinali Kabupaten Pasaman Barat. *Behavioral Science Journal*, 1(1), 59–69.

Wang, L., Xu, C., Hu, M., Qiao, J., Chen, W., Li, T., Qian, S., & Yan, M. (2021). Spatio-temporal variation in tuberculosis incidence and risk factors for the disease in a region of unbalanced socio-economic development. *BMC Public Health*, 21, 1817. https://doi.org/10.1186/s12889-021-11833-2

Wang, Y., Gan, Y., Zhang, J., Mei, J., Feng, J., Lu, Z., Shen, X., Zhao, M., Guo, Y., & Yuan, Q. (2021). Analysis of the current status and associated factors of tuberculosis knowledge, attitudes, and practices among elderly people in Shenzhen: A cross-sectional study. *BMC Public Health*, 21, 1163. https://doi.org/10.1186/s12889-021-11240-7

Widiati, B., & Majdi, M. (2021). Analisis faktor umur, tingkat pendidikan, pekerjaan dan tuberkulosis paru di wilayah kerja Puskesmas Korleko, Kabupaten Lombok Timur. *Jurnal Sanitasi dan Lingkungan*, 2(2), 173–184.

World Health Organization. (2023). *Global tuberculosis report 2023*. World Health Organization. https://www.who.int/publications/i/item/9789240083851

Zuraidah, A., & Ali, H. (2020). Hubungan faktor lingkungan rumah terhadap kejadian TB paru BTA positif di wilayah Puskesmas Nusa Indah Kota Bengkulu. *Journal of Nursing and Public Health*, 8(1), 1–10. https://doi.org/10.37676/jnph.v8i1.1004