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Risk Factors for Pulomonary Tuberculosis in Adult in the Municipality of Bobonaro, Timor Leste

Eugenia Borges, RR Sri Ratna Rahayu, Yuni Wijayanti

Departement of Public Health, Faculty of Medicine, Universitas Negeri Semarang, Indonesia
*Email (corresponding author): eugeniamarros@students.unnes.ac.id

Abstract. *The prevalence of Pulmonary Tuberculosis in the Municipality of Bobonaro, Timor Leste, is still relatively high and requires serious attention in efforts to control infectious diseases. This study aims to analyze risk factors related to the incidence of Pulmonary Tuberculosis in adults. This study uses a quantitative approach with a case-control design and was conducted in June–July 2025. The sample consisted of 95 cases and 95 purposively selected controls. Data were analyzed using SPSS version 30. The results showed that smoking history was the most dominant factor with a risk of 6.685 times ($p < 0.001$), followed by occupancy density (OR = 4.313; $p < 0.001$), firewood use (OR = 3.515; $p = 0.003$), alcohol consumption (OR = 3.494; $p = 0.002$), inadequate home ventilation (OR = 3.061; $p = 0.007$), and history of close contact (OR = 2.667; $p = 0.018$). Nutritional status factors (OR = 1.916) and access to health services (OR = 2.135) showed risky but not significant trends. These findings emphasize the importance of interventions on behavioral and environmental factors in TB control strategies in Bobonaro.*

Keywords: *Pulmonary Tuberculosis; Environmental; Behavioral Risk Factors*

1. Introduction

Tuberculosis (TB) is an infectious disease caused by *Mycobacterium tuberculosis*. Although it can affect various organs of the body, TB most often attacks the lungs. The disease is characterized by the formation of granulomas in an immune response to infection. Various studies show that TB can cause serious complications, including chronic obstructive pulmonary disease, as well as have a major impact on public health globally (Jiang et al., 2024). TB is still one of the leading causes of morbidity and mortality, especially in low- and middle-income countries (Study et al., 2022). Globally, efforts to control TB have been outlined in the Sustainable Development Goals (SDGs) point 3.3 and the *End TB Strategy* from the World Health Organization (WHO), with a target of reducing TB incidence by 80% and mortality by 90% by 2030 compared to 2015 levels. However, based on the *Global Tuberculosis Report 2024*, the number of TB cases globally actually shows an increasing trend, with 10.8 million new cases and 1.25 million deaths due to TB recorded in 2023, and the global incidence rate reaching 134 cases per 100,000 population (WHO, 2024). A lack of progress and a reversal of trends global TB control efforts still face significant challenges, including gaps in early detection, treatment adherence, and addressing underlying social determinants of health.

In Timor-Leste, TB incidence decreased by 2.41% in the period from 2015 to 2021, from 498 to 486 cases per 100,000 population. However, this figure still places Timor-Leste as the country with the seventh highest TB burden in the world and the second highest in the Asian region (WHO, 2022). The Government of Timor-Leste has adopted national targets that are in

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line with the WHO's global strategy, namely to reduce TB incidence by 80% and reduce TB mortality by 90% by 2030 (Ministry of Health Timor-Leste, 2023). Nevertheless, the 2022 global report shows that the current achievement is still far from the target, underscoring the need for intensified and context-specific interventions. One of the areas with a high TB burden is Bobonaro Intermediate City. In 2023, there were 293 TB cases recorded in the region, making it one of the areas with the highest incidence in Timor-Leste (Bobonaro Health Office, 2024). This persistent burden highlights that local epidemiological patterns may differ from national averages, and thus require more granular analysis to inform tailored prevention strategies. Various studies show that the incidence of tuberculosis (TB) is influenced by five main risk factor groups, namely environmental, socio-economic, lifestyle, comorbidities, and cultural and social factors. Poor ventilation, exposure to cigarette smoke, use of firewood, low income and education, malnutrition, alcohol consumption, smoking, as well as comorbidities such as diabetes and HIV/AIDS contribute to an increased risk of TB. In the Madya Municipality of Bobonaro, many of these conditions are prevalent, including the use of traditional houses with inadequate ventilation, smoking and alcohol consumption during traditional activities, and limited access to health services in remote areas. Research by Diriba & Awulachew (2022) also shows that factors such as inadequate ventilation, low socio-economic status, smoking, and HIV/AIDS significantly increase the risk of TB. Building upon this, this study aims to analyze the risk factors that affect the incidence of pulmonary tuberculosis in the Madya City of Bobonaro, Timor-Leste. Unlike previous studies, this research is conducted in a different setting and timeframe, providing updated evidence that can guide local health authorities in formulating targeted interventions and policy measures to curb TB transmission effectively.

2. Methods

This research using primary data was conducted in the Middle City of Bobonaro, Timor Leste which consists of 6 sub-districts, 50 urban villages with implementation in June 2025. This study is an analytical observational study with a case-control design, aiming to identify and analyze risk factors associated with the incidence of tuberculosis. Research information was collected through interviews at the respondents' homes using questionnaires and home measurements. All participants completed written consent prior to the interview and permission was obtained prior to measuring the ventilation of the home. The study population included 190 respondents, consisting of 95 groups that had TB or were cases and 95 groups that did not have TB or served as controls. Sampling in the case used total sampling while in control using purposive sampling considered inclusion and exclusion criteria.

The variable studied in this study was the incidence of pulmonary tuberculosis. The independent variables included sociodemographic factors (gender, age, education level), nutritional factors and risk behaviors (nutritional status, smoking history, alcohol consumption), physical environmental factors (house ventilation, residential density, firewood use), exposure and access to services (close contact with TB patients, access to health services), medical factors (comorbidities). Data processing was performed with SPSS 30.0 using the chi-square statistical test, odds ratio (OR), and multivariate logistic regression to analyze data at the 95% confidence level (=0.05). It was hypothesized that various independent variables influence the incidence of adult pulmonary tuberculosis in Bobonaro Municipality, Timor Leste.

3. Results and Discussion

The number of respondents in this study was 190 adults. The characteristics of the respondents are described in Table 1. Most of the respondents were male as many as 134 people (70.5%), and in the age group of >45 years (non productive age) as many as 109 people (54,2%), which is an non active age group and at higher risk of tuberculosis transmission. Most of the respondents had a malnourished status of 81 people (42.6%), which is one of the risk factors for tuberculosis. Respondents who had a history of smoking as many as 79 people (41.6%) also showed a higher risk group. In addition, there were 89 respondents (46.8%) who consumed alcohol, which was also a risk factor. A total of 90 respondents (47.4%) had a history of close contact with people with tuberculosis, which increased the potential for transmission. In terms of environmental factors, most of them lived in houses with unqualified ventilation as many as 113 people (59.5%), and dense housing as many as 108 people (56.8%), both of which were physical conditions of the house that supported TB transmission. Most respondents also stated that access to health services was not easy as many as 105 people (55.3%), who were at risk of causing delays in TB diagnosis and treatment. In addition, 132 respondents (69.5%) still use firewood as their primary fuel, which can affect respiratory conditions and increase susceptibility to lung infections, including tuberculosis. Although most respondents had no comorbidities (63.2%) and were poorly educated (59.5%), some of the other factors mentioned above suggest that the majority of respondents had one or more conditions that may increase the risk of tuberculosis incidence.

Table 1. Subject Characteristics

Characteristic	Frequency	Presentase
Gender		
Male	103	54,2 %
Female	87	45,8 %
Age		
<45 Productive Age	81	42,6%
>45 Unproductive Age	109	57,4 %
Nutritional Status		
Malnutrition	81	42.6 %
Normal	109	57.4 %
Smoking History		
Smoke	79	41.6 %
No Smoking	111	58.4 %
Alcohol Consumption		
Yes	89	46.8 %
No	101	53.2 %
Close Contact		
Yes	90	47.4 %
No	100	52.6 %
Comorbidities		
Comorbidities	70	36.8 %
No Comorbidities	120	63.2 %
Education Level		

Characteristic	Frequency	Presentase
Low	115	59.5 %
High	75	40.5 %
Home Ventilation		
Not Eligible	113	59.5 %
Qualify	77	40.5 %
Occupancy Density		
Dense	108	56.8 %
Not Solid	82	43.2 %
Access to health services		
Not Easy to Access	105	55.3 %
Easy to Access	85	44.7 %
History of the Use of Firewood		
Using	132	69.5 %
Not Using	58	30.5 %

Table 2 outlines the characteristic determinants of subjects with tuberculosis. There are ten independent variables analyzed using *the Chi Square Tes*

Table 2. Determinants of the incidence of Tuberculosis

Variables	Tuberculosis Incident				P value	OR	CI 95%
	Tuberculosis		No Tuberculosis				
	Σ	%	Σ	%			
Nutritional Status							
Malnutrition	50	61,7	31	38,3	0,008*	2.294	1.274-4.131
Normal	45	41.3	64	58,7			
Smoking History							
Smoke	60	75,9	19	24,1	<0,001	6,857	3,569-
No Smoking	35	31,5	76	68,5	*		13,176
Alcohol Consumption							
Yes	53	59,6	36	40,4	0,020*	2,068	1,159-3,692
No	42	41,6	59	58,4			
Close Contact							
Yes	53	58,9	37	41,1	0,029*	1,978	1,110-3,526
No	42	42,0	58	58,0			
Comorbidities							
Comorbidities	38	54,3	32	35,7	0,452	1,313	0,727-2,371
No Comorbidities	57	47,5	63	52,5			
Education Level							
Low	55	48,7	58	51,3	0,768	0,877	0,491-1,566
High	40	51,9	37	48,1			
Home Ventilation					0,039*	1,938	1,076-3,490
Not Eligible	64	56,6	49	43,4			

Qualify	31	40,3	46	59,7			
Occupancy Density							
Dense	69	63,9	39	36,1	<0,001	3,811	2,073-7,004
Not Solid	26	31,7	56	68,3	*		
Access to health services							
Not Easy to Access	60	57,1	45	42,9	0,041*	1,905	1,067-3,041
Easy to Access	35	41,2	50	58,8			
History of the Use of Firewood							
Using	79	59,8	53	40,2	<0,001 *	3,913	1,997-7,668
Not Using	16	27,6	42	72,4			
Bivariant Analysis Confounding Variavel							
Gender							
Male	59	57,3	44	42,7	0,041	1,900	1,065-3,387
Female	36	41,4	51	58,6			
Age							
<45 Produktive Age	37	45,7	44	54,3	0,379	1,352	0,760-2,408
>45 Unproductive Age	58	53,2	51	46,8			

*=*p-value <0.05*

Based on the results of the bivariate analysis, there were eight variables that met the criteria for inclusion in the multivariate logistic regression analysis, namely nutritional status (p = 0.008), smoking history (p < 0.001), alcohol consumption (p = 0.020), history of close contact (p = 0.029), house ventilation (p = 0.039), residential density (p < 0.001), access to health services (p = 0.041), and use of firewood (p < 0.001). All of these variables had a p value <0.25 in the bivariate analysis, so according to the rules for selecting variables according to Hosmer and Lemeshow, they were eligible to be included in the final multivariate analysis model. Before multivariate analysis, it is necessary to consider the possibility of confounder variables, which are variables that are simultaneously related to the independent and dependent variables, so that they can affect or change the actual magnitude of the relationship. Identification of confounders is done by monitoring changes in the OR value of the main variable when other variables are included or excluded from the model. If the OR change was ≥10%, the variable was retained in the model even if the p value was not significant, as its presence was important for maintaining the validity of the estimated relationship. Considering the potential influence of confounders, these eight candidate variables will be further analyzed to identify factors that independently influence the incidence of Pulmonary Tuberculosis.

Table 3 presents estimates from multivariate logistic regression analysis for datasets that include tuberculosis variables and explanatory variables.

Table 3. Multivariate Regression Analysis of Risk Factors for Tuberculosis

Variabel	B	Wald	*p-value*	OR	CI 95 %
Nutritional Status	0,650	2,813	0,094	1,916	0,896-4,097
Smoking History	1,900	21,384	<0,001*	6,685	2,988-14,955
Alcohol Consumption	1,251	9,393	0,002*	3,494	1,570-7,776
History of Close Contact	0,981	5,611	0,018*	2,667	1,184-6,005
Home Ventilation	1,119	7,360	0,007*	3,061	1,364-6,870
Occupancy density	1,462	13,269	<0,001*	4,313	1,964-9,470
Access to health services	0,758	3,746	0,53	2,135	0,990-4,601
History of the Use of Firewood	1,257	9,076	0,003*	3,515	1,552-7,964
Constant	-13,916	40,692	<0,001	0,000	

*=*p-value <0.05*

The results of multivariate logistic regression analysis showed that several variables had a statistically significant relationship with the incidence of pulmonary tuberculosis in adults in Bobonaro Madya City. Smoking history was the most dominant risk factor, with *a p* <0.001 and an odds ratio (OR) of 6.685 (95% CI: 2.988-14.955), suggesting that individuals with a history of smoking had about 6.7 times greater risk of developing TB than non-smokers. Similarly, alcohol consumption was significantly associated with the incidence of TB (p = 0.002; OR = 3,494; CI 95%: 1,570-7,776), signifies a more than threefold increased risk in individuals who consume alcohol**.** A history of close contact with people with TB also showed a meaningful association (p = 0.018; OR = 2,667; CI 95%: 1,184-6,005). From the environmental aspect, poor ventilation of the house (p = 0.007; OR = 3.061; CI 95%: 1.364-6.870) and high occupancy density (p < 0.001; OR = 4,313; CI 95%: 1,964-9,470) shows a significant contribution to an increased risk of TB. In addition, the use of firewood as cooking fuel was also significantly related (p = 0.003; OR = 3,515; CI 95%: 1,552-7,964). Meanwhile**,** nutritional status and access to health services did not show statistical significance with p = 0.094 and p = 0.053, respectively. Nonetheless, both had fairly high ORs, of 1.916 (95% CI: 0.896–4.097) and 2.135 (95% CI: 0.990–4.601), respectively, suggesting that both still have the potential to be clinically or contextually important risk factors, and need to be considered in public health interventions.

This study indicates that smoking history is the main risk factor related to the incidence of Pulmonary Tuberculosis in Bobonaro Intermediate City. These findings indicate that individuals with a history of smoking have nearly seven times the likelihood of developing TB compared to non-smoking individuals. The results of this study are in line with the findings of a meta-analysis conducted by (Burusie et al., 2020), which affirm that smoking is one of the significant determinants in increasing the risk of TB infection, worsening the immune response, and contributing to the high burden of TB disease, especially in developing countries. Another study conducted by (Feldman et al., 2024) also supports this argument, suggesting that exposure to cigarette smoke can damage the mucociliary system of the respiratory tract, decrease the function of alveolar macrophages, as well as cause disruptions in the local immune system that increase susceptibility to Mycobacterium tuberculosis

infection. In addition, the World Health Organization (World Health Organization, 2021) confirms that smoking contributes to more than 20% of total TB cases in countries with a high burden of disease. Therefore, smoking control interventions should be seen as a crucial component of TB prevention and control strategies, not only at the individual level but also in the context of broader public health policies, including through the promotion of healthy lifestyles, anti-smoking campaigns, and the regulation of smoke-free environments.

Multivariate analysis in Bobonaro Madya City shows that alcohol consumption is a statistically significant factor in the incidence of certain health diseases, especially Pulmonary Tuberculosis. Wald values of 9.393, p = 0.002, and OR = 3.494 (95% CI: 1.570–7.776) indicate that individuals who consume alcohol have almost three times the risk of developing TB compared to those who do not consume alcohol. These results are in line with the findings of a study in Lautem City, Timor Leste, which showed that alcohol consumption increased the risk of pulmonary TB by 4.7 times (OR = 4.702; 95% CI: 1.522–14.531; p = 0.007) (Amaral et al., 2022). Biologically, alcohol can affect the immune system, decrease the ability of alveolar macrophages to kill bacteria, and is often associated with other risky behaviors such as low adherence to medication. These findings are also consistent with a global meta-analysis conducted by (Simou et al., 2018), which reported an OR of ≈ 1.90 (95% CI: 1.63–2.23) for individuals who consumed alcohol compared to those who did not, with OR values remaining in the range of 1.60–1.90 even in studies with strict confounder control. A recent systematic review (Heshmati et al., 2025) showed similar results, namely the risk of TB treatment failure of OR = 2.33 (95% CI: 1.72–3.16) in patients who consumed alcohol. Overall, these data confirm that alcohol consumption, especially in moderate to heavy amounts, is a *modifiable risk factor* and plays an important role in the epidemiology of tuberculosis. Alcohol consumption not only increases the risk of primary infection, but is also associated with reactivation of latent TB as well as decreased treatment effectiveness, which is largely due to low patient adherence and impaired immune function. A study by (Bryazka et al., 2022) confirms that alcohol consumption is a significant contributor to the global burden of infectious diseases, including TB. Therefore, public health interventions for TB prevention and control should explicitly include a component of reducing alcohol consumption. These strategies can include community-based educational campaigns on the impact of alcohol on the immune system and TB risk, as well as the integration of screening and treatment of alcoholism problems into primary TB services

Multivariate analysis of the results of the study showed that a history of close contact with TB patients is a significant risk factor for the incidence of Pulmonary Tuberculosis in Bobonaro Madya City. The Wald value of 5.611, with p = 0.018, and an Odds Ratio (OR) of 2.667 (95% CI: 1.184–6.005), illustrates that individuals with a history of close contact have an approximately 2.7 times higher risk of developing TB than those without such a history. The findings of this study are in line with a study in Lautem City, Timor Leste, which reported that close contact with people with TB increased the risk of pulmonary TB by up to 8.7 times (OR = 8,704; 95% CI: 2,390–31,699; p = 0.01) (Amaral et al., 2022)). This risk-enhancing mechanism is associated with repeated exposure to droplets containing *Mycobacterium tuberculosis* in a closed environment, especially in poorly ventilated households or workplaces. Research in Kapanewon Depok found that family contact history had the highest risk of TB prevalence, namely OR = 8.438 (95% CI: 5.737–12.410, p = 0.000), while close contact history showed OR = 3.881 (95% CI: 2.49–6.051; p = 0.000) (Wira Oktaviana et al., 2024) This reinforces the role of close contacts, especially in the home environment, as one of the main determinants

of active TB transmission. Furthermore, a study in Semarang showed that family members who were in close contact with active TB patients had a high prevalence of latent TB infection in 63.8% of participants. Significant contributing factors included contact duration ≥5 hours/day (aOR = 4.70; 95% CI: 1.33–16.66) and inadequate bedroom density (aOR = 5.33; 95% CI: 2.44–12.71) (Karbito et al., 2022). It confirms that the duration and intensity of close contact, bellum not only the frequency but also the micro-environment of residence, reinforces the risk of TB transmissibility.

Inadequate home ventilation has been shown to be significantly related to the incidence of Pulmonary Tuberculosis in the Municipality of Bobonaro. The results of this study showed that poorly ventilated homes had more than three times the risk of developing TB (p = 0.007; OR = 3.061; 95% CI: 1,364-6,870). These findings are in line with the results of international and national research. A study in Uganda by Du et al. (2020), which used *the carbon dioxide (CO_2) decay* measurement method, found that individuals exposed in a room with CO_2 levels >1000 ppm had *an adjusted hazard ratio* of 32.8 (95% CI: 2.0-540; p = 0.0145). When ventilation interventions are carried out up to CO_2 <1000 ppm, the incidence of active TB can decrease by almost 97%. In Indonesia, Sinaga et al. (2016) reported that 96.7% of homes with TB patients had unqualified ventilation, while Istiqomah and Nurjazuli (2018) found that non-standard ventilation increased the risk of TB incidence by 6.25 times (p = 0.001). In addition, (Rahayu et al., 2021) in a study in Semarang City highlighted the importance of TB service infrastructure conditions, including air circulation in health service rooms, which are considered less than optimal by patients and can affect the effectiveness of TB treatment. This suggests that poor ventilation, both at home and in health facilities, is an important factor that supports disease transmission. Thus, improving the quality of home ventilation must be an integral part of an environment-based TB control strategy, especially in areas such as Bobonaro Madya City. Suggested interventions include public education on the importance of cross-ventilation, promotion of healthy homes, and strengthening regulations of the residential environment in preventing TB transmission

The results of this study strengthen the evidence that housing density is a significant risk factor for the incidence of tuberculosis (TB) in the adult population**.** Multivariate analysis showed that the occupancy density variable had a Wald value of 13.269 with a significance level of p < 0.001 and an *odds ratio (OR)* of 4.313 (95% CI: 1.964-9.470). This means that individuals living in dense housing have more than four times the risk of being infected with TB compared to those living in non-dense housing. These findings are in line with the global literature showing that residential density creates environmental conditions that facilitate the transmission of *Mycobacterium tuberculosis* through the air, particularly in enclosed spaces with poor ventilation. Nationally, a study by (Sari et al., 2024) in Indonesia identified that housing density, inadequate lighting, and poor ventilation are physical environmental determinants that support the occurrence of TB in the adult population. In addition, (Syukur et al., 2024) found a significant association between uninhabitable housing conditions and increased TB incidence, reinforcing the importance of housing-based interventions in disease control strategies. The implications of these findings confirm that interventions that focus only on curative aspects are not effective enough**,** if they are not accompanied by improvements in social and physical environmental aspects, especially housing. Therefore, TB control efforts in Bobonaro Madya City and areas with similar characteristics should consider structural intervention programs such as the construction of healthy houses, overcrowding reduction, and ventilation improvements as integral parts of public health policies.

The results of this study showed a significant association between firewood use and the incidence of tuberculosis (TB) in Bobonaro Intermediate City, where firewood users had a 3.5 times higher risk of developing TB than non-users (OR = 3.515; p = 0.003; 95% CI: 1.552-7.964), consistent with findings in Dili, Timor-Leste, which reported that 80% of households were dependent on firewood, especially the ampupu type (Freitas, 2023), as well as studies in Mongolia (adjusted OR=1.8-3.0) and Pakistan (mOR=3.0; 95% CI: 1.1-4.9) (Dorjravdan et al., 2021) (Rabbani et al., 2017). Its biological mechanisms include damage to the mucociliary system of the airways due to PM2.5 particles from wood burning, chronic inflammation, and suppression of local immunity against Mycobacterium tuberculosis (Yadav et al., 2024) (Tang et al., 2024), while sociodemographic factors such as housing density and poor ventilation exacerbate their impact. The high risk in Bobonaro may also be influenced by the dominance of certain types of wood (such as Ampupu in Dili) that produce high emissions, so interventions such as clean energy substitution and home ventilation education are needed to reduce the burden of TB related to biomass exposure (Roy, 2021).

Conclusions

This study identified smoking as the main risk factor for pulmonary tuberculosis (TB) in Bobonaro Intermediate City, with a 6.7 times higher risk in smokers. Other factors such as alcohol consumption, close contact with people with TB, poor ventilation, housing density, and the use of firewood also significantly increase the risk of TB. Although nutritional status and access to health services are not statistically significant, they both show an increased risk trend. These findings confirm the importance of behavioural prevention approaches (smoking/alcohol control) and environmental interventions (ventilation improvements, reduction of occupancy density) in TB control strategies in the region.

Based on the findings of this study, it is recommended to the Bobonaro Regency Health Office and related parties to focus more on a more comprehensive TB prevention program through a community-based approach, including behavioral education, improvement of the residential environment, and active screening of at-risk groups in the Bobonaro Madya City. To deepen our understanding of the determinants of incidence of Pulmonary Tuberculosis, further research is suggested to include expanding variables to include psychosocial factors such as stress levels, depression, and social support, which have the potential to influence susceptibility to TB through mechanisms of immune system degradation or changes in health behaviors. The addition of these variables can provide a more holistic understanding of health determinants. the use of longitudinal design to trace the dynamics of key risk factors such as smoking, alcohol consumption, and environmental conditions over time to strengthen causal relationships; These results are expected to be a reference in policy-making for a more integrated and data-based pulmonary tuberculosis reduction program

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Conflicts of Interest

The authors declare no conflict of interest.

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