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Original Article

Risk factors of pulmonary tuberculosis in Indonesia: A case-control study in a high disease prevalence region

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Abstract

Tuberculosis (TB) remains one of the most widespread infectious diseases in the world, with high mortality and morbidity rates, contributing to a significant disease burden, particularly in developing countries. The aim of this study was to determine the risk factors of TB among the population aged 17 years (late adolescent) and above in one of the high TB prevalence countries, Indonesia. A case-control study was conducted in Banda Aceh, Indonesia, involving newly diagnosed pulmonary TB patients who visited one of the eleven community health centers in Banda Aceh. The controls were individuals matched by age and sex who lived near the cases and had no TB infection. A total of 16 risk factors were assessed. Hierarchical multivariable logistic regression models were used to examine the association between the risk factors and the occurrence of TB. A total of 196 cases and 196 controls were included in the study. Multivariable logistic regression analysis identified 11 independent predictors for the occurrence of TB after controlling possible confounders. Patients who lived in houses with insufficient light exposure were 77 times more likely to develop TB compared to those living in houses with sufficient light exposure (adjusted odds ratio (AOR): 77.69; 95%CI: 27.09, 222.79). The study also showed that people who had close contact with TB patients (AOR: 25.39; 95%CI: 2.10, 306.52), had poor knowledge of TB (AOR: 24.2; 95%CI: 6.89, 85.17), had comorbidities (AOR: 4.49; 95%CI: 1.35, 14.89), insufficient food utilization (AOR: 3.41; 95%CI: 1.51, 7.71), negative preventive behavior (AOR: 3.39; 95%CI: 1.49, 7.72), low education level (AOR: 3.08; 95%CI: 1.26, 7.55), and insufficient housing humidity (AOR: 2.89; 95%CI: 1.18, 7.12) were associated with increased the odds of having TB. Being employed, having income above minimum wage, and having good nutritional intake were protective factors for developing TB. In conclusion, the determinants of TB among people aged 17 years and older are a clear indication of the need for TB prevention programs targeting not only individual risk factors but also environmental risk factors, particularly providing adequate housing conditions. This study provided useful information that might help to develop and adopt effective policies for TB control in Indonesia.

Keywords: Tuberculosis, risk factors, Indonesia, case-control, determinant

Introduction

Tuberculosis (TB) is the most common infectious disease that primarily affects the lungs, caused by the infection of *Mycobacterium tuberculosis*. It is estimated that 25% of the world's population

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Received: June 6, 2024 - Accepted: August 5, 2024 - Published online: August 6, 2024

is infected with *M. tuberculosis*, and TB is expected to continue infecting millions of people and causing 1.6 million deaths annually [1]. Approximately 5–10% of those infected with pulmonary TB exhibit symptoms and transmit the disease [2]. World Health Organization (WHO) reported that India, Indonesia, and the Philippines are the countries that contributed the most to the increasing TB cases worldwide in 2020 and 2021 [3]. In these countries, the prevalence of TB rose by approximately 0.4 million cases and predominantly affects people with the range ages of 45 and 54 [3,4]. Indonesia contributed about 969,000 TB cases and 93,000 TB deaths annually, or 11 deaths per hour [3].

Individuals with a history of close contact with TB patients, smokers, and those with comorbidities like diabetes mellitus (DM) or human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) are susceptible to contracting TB [5-14]. People with low socioeconomic status also have a higher risk of TB infection due to limited access to education, knowledge, and healthcare [9,15-17]. Similarly, malnutrition also plays a major role in increasing the risk of contracting pulmonary TB, which weakens the immune system [18,19]. Furthermore, factors related to one's living environment, such as population density, humidity, light exposure, temperature, and ventilation, can indirectly accelerate the transmission of TB bacteria [20].

The reduction in TB prevalence remains negligible in countries with a high disease burden even after implementing the WHO global TB control strategy, directly observed short-term treatment (DOTS) [21]. Indonesia has outlined its national strategy for eliminating TB. These strategies include strengthening commitment, improving access to TB services, optimizing TB promotion and prevention efforts, TB treatment, TB infection control, and utilizing research findings and technology [22]. However, these efforts have not optimally decreased TB prevalence in Indonesia. To effectively modify and adapt TB control plans, it is necessary to reevaluate patient characteristics and comprehend the contributing factors, particularly given the rising trend of TB, which primarily impacts developing nations. Therefore, the aim of this study was to determine TB risk factors contributing to the prevalence of TB. The findings of this study could inform public health policy on reducing TB transmission and improving TB prevention programs.

Methods

Research design and study population

The study employed a case-control design to assess the determinants of TB in a high-prevalence region in Indonesia, Aceh. The data for pulmonary TB cases was obtained from 11 community health centers in Banda Aceh, the capital of Aceh province. Cases included were the newly diagnosed pulmonary TB patients aged 17 years and older who visited one of the 11 community health centers in Banda Aceh and had either a clinical diagnosis or bacteriological confirmation of TB. Controls were individuals matched by sex and age and were selected based on the cases' residential area, meaning controls were selected from the case's neighbors, who did not have prior known TB and having TB. A total of 392 respondents were included in the study, with 196 pulmonary TB patients in the case group and 196 TB-free individuals in the control group. TB diagnoses were obtained from the community health center report for the case group, while for the control group, the health problem or prior known TB problem was obtained from the interviews.

Study instrument and study variables

The researchers developed the study instrument, which consisted of four parts: sociodemographic and health factors, food security, housing conditions, and local culture. The first part collected patients' sociodemographic and health data relevant to the study's objectives, including age, sex, marital status, education, occupation, income, social class, knowledge about TB, nutritional intake, smoking, comorbidities, and close contact with TB patients.

Level of education was categorized into three categories: (1) basic (completion of elementary school or junior high school); (2) secondary (completion of senior high school or equivalent); and (3) higher (college or university graduate) [23]. The occupation was categorized as employed and not employed [20]. Income was determined based on the minimum wage in Banda Aceh, IDR

3,255,000 (Indonesian rupiah) and categorized as above and below minimum wage [24]. Social class was measured using the index of social position (ISP), consisting of three determining factors: occupation, education, and income. The classification of social classes consists of three levels: (1) high social class (ISP value = 10–27); (2) middle social class (ISP value = 28–60); and (3) low social class (ISP value = 61–100) [25].

Knowledge about TB was assessed using 15 questions about TB cause, transmission, and prevention [26]. The correct response was scored one, and the incorrect one was scored zero. The total score knowledge was categorized as having good knowledge if the scores were equal and above the group average and having poor knowledge if the scores were below the group average.

Nutritional intake was assessed using the Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ) and categorized into normal, less, and more intake [27]. Smoking was measured by asking whether the respondent was a non-smoker, former smoker, or smoker. Having comorbidities was examined by asking the respondents about prior diagnoses or known diseases, including DM, lung cancer, HIV/AIDS, malnutrition, and other diseases. Close contact with TB patients was assessed by asking respondents whether family members, friends, or colleagues who live or share an enclosed space with a person who has pulmonary TB for one night or longer, or for frequent or prolonged periods during the day [6,28].

Food security factors consisted of food availability, food accessibility, and food utilization. Food availability was measured by assessing the availability of rice as the main or staple food in Indonesia and was categorized as sufficient if respondents had enough rice for 30 days and more, not sufficient if below 30 days [29]. Food accessibility has three aspects: physical, social, and economic access. It was categorized as sufficient if respondents had all the following indicators: (1) the distance between the house and the market was less than 2 kilometers; (2) the number of family members was less than seven people; (3) the head of household had education at a minimum of elementary school; and (4) the family has money or other means to buy food. If one indicator is missing, it will be considered insufficient food accessibility [29]. Food utilization was measured as sufficient if the respondents had all the following indicators: (1) able to consume protein, vegetables, and fruits daily; (2) had access to clean water; (3) had garbage disposal; (4) had closed wastewater disposal site; and (5) had latrines. One indicator missing would be considered insufficient food utilization [29,30].

Housing conditions consisted of housing density, humidity, light exposure, and temperature. Housing density was measured by calculating the ratio of the number of family members residing in the respondent's house to its floor area in square meters [31]. Housing density was categorized as less dense if the density was equal and above eight meters square, while below that criteria was considered more density. Humidity was measured using a hygrometer to determine the moisture level inside the respondent's house and categorized as sufficient if house humidity was above 60% relative humidity (RH); otherwise, it was considered insufficient house humidity [31]. Light exposure at home was measured using a lux meter inside the respondent's house and was categorized as sufficient light exposure if the value was equal and above 60 Lux, otherwise it was considered insufficient light exposure [31]. Finally, the house temperature was measured using a room thermometer by putting the room thermometer at the center of the room, away from sun exposure, and the thermometer was read after five minutes, allowing it to adjust with room temperature. The temperature was measured three times at one-minute intervals, and the result was averaged to mark the room temperature. It was categorized as optimal house temperature if it was between 18°C to 30°C and non-optimal if the temperature was below 18°C and above 30°C [31].

Factors of local culture included stigma and preventive behavior toward TB. Stigma was measured using 28 statements with a Likert scale (‘strongly disagree’, ‘disagree’, ‘agree’, and ‘strongly agree’) where 'strongly agree' and 'agree' indicate a perception of stigma (high score), and 'disagree' and 'strongly disagree' indicate no perception of stigma (low score) [32]. The respondents were categorized as low or high stigma using the mean as the cut-off point for both categories [32,33]. Behavior on TB prevention was measured using 20 statements with a Likert scale (‘strongly disagree’, ‘disagree’, ‘agree’, and ‘strongly agree’). Strongly agree would have a higher score for favorable statements, and strongly disagree would have a higher score for

unfavorable questions. The total score was categorized as positive behavior if the score was equal and above the group average and negative behavior if the score was below the group average [34].

Validation test of the questionnaire

In this study, out of the 16 individual risk factors assessed, only three factors (knowledge, stigma, and TB prevention behavior) underwent reliability and validity testing involving 88 respondents. Validity was assessed using the corrected item-total correlation (CITC), which measured the correlation between each item and the overall set of items. CITC values ranged from 0.32 to 0.66. Items with a CITC value below 0.209 were excluded from the analysis due to their insufficient correlation with the underlying construct. The validity test resulted for the knowledge variable, comprising 16 questions, revealed that only one question had a CICT value of -0.009. Consequently, this question was excluded, resulting in a final set of 15 questions for the knowledge. The stigma was assessed using 29 questions, and the analysis showed that one question was invalid with a CICT value of 0.170, leading to its exclusion from the final questionnaire. For the preventive behavior, the instrument consisted of 20 questions, all of which were valid. Therefore, these questions were deemed suitable for inclusion in the final questionnaire.

To evaluate the questionnaire's internal consistency and reliability, the Cronbach's alpha coefficient was computed. This statistic assessed whether the target construct was consistently measured by the questionnaire items within each variable. Every variable obtained a Cronbach's alpha value greater than 0.60, suggesting a satisfactory degree of dependability. The results of the reliability test indicated that variables of knowledge, stigma, and TB prevention behavior were reliable, with Cronbach's alpha of 0.902, 0.943, and 0.945, respectively.

Data collection

The data collection was conducted between February and August 2023. A trained data collection team conducted in-person interviews at respondents' houses using standardized questionnaires and housing measurements. All participants completed written informed consent before interviews and permission was obtained before measuring the house conditions.

Statistical analysis

The different proportions in sex, age, and marital status between the case and control group were assessed using the Chi-squared test. Univariate and multivariable logistic regression models were used to examine the association of socioeconomic and health factors, food security, housing conditions, and local culture variables with TB. An initial variable selection was performed for all items and those with a significance level as high as 0.25 were not included in the multivariable logistic regression [35]. A multiple regression analysis was used to identify variables significantly associated with TB prevalence and variances explained by the models. All analyses were performed using SPSS Statistics version 25 (IBM, New York, USA) [36].

Results

Characteristics of respondents

This study included 196 cases and 196 controls in total. Males (56.6%) had a higher prevalence of pulmonary TB than females (**Table 1**). Older adults (42.9%) and adults (41.8%) accounted for more than half of the pulmonary TB cases. In case and control groups, most respondents were married, 70.9% and 74%, respectively. There was no difference in the proportion of sex, age groups, and marital status in the case and control groups (**Table 1**).

Table 1. Characteristics of respondents

Characteristics	Cases (n=196)	Control (n=196)	Total (n=392)	*p*-value
	n (%)	n (%)		
Sex				
Male	111 (56.6)	111 (56.6)	222	1.000
Female	85 (43.4)	85 (43.4)	170	
Age				
Youth (17–25)	30 (15.3)	28 (14.3)	58	

Characteristics	Cases (n=196)	Control (n=196)	Total (n=392)	*p*-value
	n (%)	n (%)		
Adults (26–45)	82 (41.8)	87 (44.4)	169	0.873
Older adults (≥46)	84 (42.9)	81 (41.3)	165	
Marital Status				
Single	44 (22.4)	41 (20.9)	85	
Married	139 (70.9)	145 (74)	284	0.732
Widowed	13 (6.6)	10 (5.1)	23	

Analyzed using chi-square test

Risk factors of tuberculosis

The univariate analysis revealed that insufficient light exposure (OR: 34.6; 95%CI: 19.5, 61.56) and insufficient housing humidity (OR: 6.65; 95%CI: 3.97, 11.17) were closely linked with the occurrence of pulmonary TB (**Table 2**). A history of close contact with pulmonary TB patients was related to pulmonary TB occurrence (OR: 18.52; 95%CI: 2.44, 140.58). Previous smokers were twice as likely to experience TB than non-smokers (OR: 1.66; 95%CI: 1.02, 2.70). However, the risk of previous smokers was lower than daily smokers, who were six times more likely to experience TB than non-smokers (OR: 6.04; 95%CI: 2.06, 17.7). Those patients living in denser houses were almost four times more likely to develop TB compared to people living in less dense houses (OR: 3.92; 95%CI: 2.23, 6.88). Similarly, having comorbidities was found to be an important risk factor for developing TB by nearly three times (OR: 2.99; 95%CI: 1.59, 5.64).

Table 2. Risk factors of pulmonary tuberculosis

Domain	Variable	Case		Control		Odds ratio (95%CI)	*p*-value
		n	%	n	%		
Sociodemographic and health factors	Education						
	Higher	35	17.9	46	23.5	Ref	
	Secondary	110	56.1	104	53.1	0.69 (0.38, 1.24)	0.214
	Basic	51	26	46	23.5	0.95 (0.59, 1.54)	0.848
	Occupation						
	Unemployed	89	45.4	74	37.8	Ref	
	Employed	107	54.6	122	62.2	0.72 (0.48, 1.09)	0.124
	Income						
	≥minimum wage	113	57.7	43	21.9	Ref	
	<minimum wage	83	42.3	153	78.1	0.206 (0.13, 0.32)	0.001**
	Knowledge						
	Good	38	19.4	77	39.3	Ref	
	Poor	158	80.6	119	60.7	2.69 (1.71, 4.24)	0.001**
	Nutritional intake						
	Normal	155	79.1	181	92.3	Ref	
	More	30	15.3	7	3.6	0.623 (0.24, 1.59)	0.321
	Less	11	5.6	8	4.1	3.12 (0.91, 10.63)	0.069
	Smoking						
	Non-smoker	143	73	137	69.9	Ref	
	Previous smokers	19	9.7	5	2.6	1.66 (1.02, 2.70)	0.043*
	Daily smokers	34	17.3	54	27.6	6.04 (2.06, 17.7)	0.001**
	Comorbidity						
	No	157	80.1	181	92.3	Ref	
	Yes	39	19.1	15	7.7	2.99 (1.59, 5.64)	0.001**
	Close contact						
	No	179	91.3	195	99.5	Ref	
	Yes	17	8.7	1	0.5	18.52 (2.44, 140.58)	0.001**
Food security	Food availability						
	Sufficient	166	84.7	181	92.3	Ref	
	Insufficient	30	15.3	15	7.7	2.18 (1.13, 4.20)	0.017*
	Food accessibility						
	Sufficient	187	95.4	191	97.4	Ref	
	Insufficient	9	4.6	5	2.6	1.84 (0.61, 5.59)	0.276
	Food utilization						
	Sufficient	98	50	136	69.4	Ref	
	Insufficient	98	50	60	30.6	2.27 (1.50, 3.43)	0.001**
Housing conditions	Housing density						
	Less density	19	9.7	58	29.6	Ref	
	More density	177	90.3	138	70.4	3.92 (2.23, 6.88)	0.001**
	Humidity						
	Sufficient	23	11.7	92	46.9	Ref	

Domain	Variable	Case		Control		Odds ratio (95%CI)	*p*-value
		n	%	n	%		
	Insufficient light exposure	173	88.3	104	53.1	6.65 (3.97, 11.17)	0.001**
	Sufficient	21	10.7	158	80.6	Ref	
	Insufficient	175	89.3	38	19.4	34.6 (19.50, 61.56)	0.001**
	Temperature						
	Optimal	12	6.1	27	13.8	Ref	
	Non-optimal	184	93.9	169	86.2	2.45 (1.20, 4.99)	0.011*
Local culture	Stigma						
	Low	90	45.9	118	60.2	Ref	
	High	106	54.1	78	39.8	1.78 (1.19, 2.66)	0.005**
	Preventive behavior						
	Positive	58	29.6	79	40.3	Ref	
	Negative	138	70.4	117	59.7	1.61 (1.06, 2.44)	0.027*

* Significance at $p<0.05$
** Significance at $p<0.01$

The results of multivariate analysis with multiple logistic regression (**Table 3**) indicated that having a basic education level (AOR: 3.08; 95%CI: 1.26, 7.55), poor knowledge about TB (AOR: 24.2; 95%CI: 6.89, 85.17), having comorbidity (AOR: 4.49; 95%CI: 1.35, 14.89), history of close contact with TB patients (AOR: 25.39; 95%CI: 2.10, 306.52), insufficient food utilization (AOR: 3.41; 95%CI: 1.51, 7.71), insufficient house humidity (AOR: 2.89; 95%CI: 1.18, 7.12), insufficient light exposure at house (AOR: 77.69; 95%CI: 27.1, 222.79), and negative preventive behaviour (AOR: 3.39; 95%CI: 1.49, 7.72) were associated with TB prevalence. Respondents who were employed, had income above minimum wage, and had good nutritional intake were less likely to develop TB than their counterparts. This combined model explains 76.7% of the variance in TB prevalence.

Table 3. Multivariate analysis of pulmonary TB prevalence

Domain	Variable	Adjusted OR (95%CI)	*p*-value
Sociodemographic and health factors	Education		
	Higher	Ref	
	Secondary	0.95 (0.29, 3.09)	0.932
	Basic	3.08 (1.26, 7.55)	0.014*
	Occupation		
	Unemployed	Ref	
	Employed	0.25 (0.10, 0.59)	0.002**
	Income		
	≥minimum wage	Ref	
	<minimum wage	0.20 (0.08, 0.49)	0.001**
	Knowledge		
	Good	Ref	
	Poor	24.2 (6.89, 85.17)	<0.001**
	Nutritional intake		
	Normal	Ref	
	More	0.05 (0.01, 0.26)	<0.001**
	Less	0.74 (0.108, 5.01)	0.754
	Smoking		
	Non-smoker	Ref	
	Previous smoker	1.75 (0.67, 4.53)	0.252
	Daily smoker	1.95 (0.29, 12.86)	0.489
	Comorbidity		
	No	Ref	
	Yes	4.49 (1.35, 14.89)	0.014*
	Close contact		
	No	Ref	
	Yes	25.39 (2.10, 306.52)	0.011*
Food Security	Food Availability		
	Sufficient	Ref	0.683
	Insufficient	0.77 (0.22, 2.74)	
	Food Utilization		
	Sufficient	Ref	0.003**
	Insufficient	3.41 (1.51, 7.71)	
Housing conditions	Housing density		
	Less density	Ref	

Domain	Variable	Adjusted OR (95%CI)	*p*-value
	More density	0.69 (0.26, 1.83)	0.003**
	Humidity		
	Sufficient	Ref	
	Insufficient	2.89 (1.18, 7.12)	0.020*
	light exposure		
	Sufficient	Ref	
	Insufficient	77.69 (27.1, 222.79)	<0.001**
	Temperature		
	Optimal	Ref	
	Non-optimal	2.85 (0.88, 9.22)	0.080
Local Culture	Stigma		
	Low	Ref	
	High	0.47 (0.21, 1.01)	0.054
	Preventive behavior		
	Positive	Ref	
	Negative	3.39 (1.49, 7.72)	0.004**
R^2 = 0.767			

* Significance at $p<0.05$
** Significance at $p<0.01$

Discussion

This study examined various risk factors associated with pulmonary TB, including sociodemographic and health factors, food security, housing conditions, and local culture. When assessing sociodemographic and health determinants, the result indicated that close contact with TB patients was the strongest risk factor for the occurrence of pulmonary TB after controlling other sociodemographic and health factors. Transmission of pulmonary TB occurs directly from a person with active pulmonary TB to healthy individuals in their vicinity [37]. TB bacteria spread through airborne droplets when individuals with active TB cough, sneeze, or speak [38]. Small particles containing the bacteria can linger in the air and be inhaled by others in close proximity [5]. The duration of exposure becomes a crucial factor in TB transmission; the longer someone is exposed to TB bacteria, the greater the risk of infection [39]. Close contacts are those (family members, friends, or coworkers) who share the same enclosed space or residence with a person with pulmonary TB for one night or more or for frequent or extended daytime periods within the three months before the beginning of the current treatment [28]. Children, older adults, people with chronic diseases, and those in close contact groups have weakened immune systems and are more vulnerable to TB infection. Contact investigation is crucial in detecting pulmonary TB cases and is an effective strategy for TB control programs in the community [7]. Every person with a history of close contact must be screened or examined; if transmission is detected, the individual should be treated. However, if there is no transmission, eligible individuals should receive tuberculosis preventive therapy (TPT) [40,41].

This study also indicated that knowledge about TB was significantly associated with the occurrence of pulmonary TB. Individual knowledge levels do not directly influence their risk of TB infection, but they can help individuals identify symptoms earlier and seek treatment more quickly [42]. A study in Nepal revealed that TB patients who lack adequate TB knowledge did not use DOTS services appropriately [43]. Knowledge gaps and misconceptions exist among TB patients. Accurate knowledge about TB is necessary for both patients and healthy individuals to protect themselves and others [44-46]. Research findings in South Africa revealed that many TB patients were still unaware of the causes of TB transmission [47]. Knowledge can raise awareness among individuals and communities about preventing and controlling TB. Community awareness and positive perceptions of TB and its management are crucial for any pulmonary TB control strategy [47]. Knowledge is inextricably linked to individual and community health, and it plays a critical role in determining the success of a program for the mitigation and prevention of pulmonary TB [48].

This study found that respondents who had comorbidities had a higher risk of developing TB than those without comorbidities. One of the important comorbidities is DM [49]. DM occurs when blood glucose levels exceed the normal threshold (>126 mg/dL). Individuals with DM have glucose metabolism disruptions, which can promote the growth of TB bacteria. DM can cause long-term tissue damage by increasing mucus production, allowing TB bacteria to enter the

respiratory system [9,10]. Individuals with DM are more likely to contract TB, as DM impairs the human immune system's function by disrupting the production and function of immune cells such as macrophages and T cells, which are crucial in fighting TB infection [11]. Identifying comorbidities is essential to preventing or reducing the complications of pulmonary TB. To reduce the risk of TB infection in individuals with DM, it is important to maintain good blood sugar control and adhere to appropriate treatment recommendations [49].

As expected, the findings showed that smoking was a risk factor for developing pulmonary TB. Smoking can damage the respiratory tract and impair the immune system function. Smokers are more vulnerable to TB infection when exposed to TB bacteria. TB patients who smoke are more likely to develop a severe form of active TB, which exacerbates their symptoms [11,15]. TB control has reduced mortality and morbidity rates, but some predisposing factors must be modified to alleviate the burden of TB. All risk factors for TB infection and active TB, including DM, smoking, alcohol use, and other drug use, can also contribute to poor TB treatment outcomes. Smoking increases the risk of TB transmission and recurrent TB and hinders the response to TB treatment [12]. The majority of smokers worldwide live in developing countries, where TB infection rates are also high. Smokers are nine times more likely to contract pulmonary TB than non-smokers [13]. Smoking cessation and avoiding secondhand smoke are critical steps toward TB control and reducing indoor air pollution exposure [50,51]. Awareness of the impact of smoking and considering quitting, mainly if someone resides in a high-TB risk area or has been exposed to TB, is one of the preventive measures for pulmonary TB. Additionally, it can reduce the risk of TB complications and help with TB recovery [52].

The level of education was also found to be associated with the occurrence of pulmonary TB. Individuals with lower levels of education may be more likely to contract pulmonary TB and experience more severe consequences if infected. Individuals with higher levels of education tend to have better access to TB information, making them more likely to understand TB risks and preventive measures [16]. They are more aware of symptoms and seek treatment sooner. There is evidence that education level influences TB diagnosis and treatment [53-56]. Educational status has been shown to help TB patients change their lifestyles and improve their living environments to prevent the spread of communicable diseases [17]. Individuals with lower levels of education may have limited access to healthcare, resulting in delays in TB diagnosis and treatment, as well as restricted access to healthy housing and inadequate dietary intake [57,58].

Food utilization was also found to be associated with the occurrence of pulmonary TB in this study. Food utilization is closely related to an individual's nutritional intake. Nutritional intake refers to the quantity and types of nutrients entering an individual's body through the food they consume. The way individuals utilize food influences the availability of nutrients they receive [18,19]. Consuming high-quality food is crucial for achieving a balanced nutritional intake. Some nutrients may be better absorbed by the body when consumed with certain foods. For example, vitamin D regulates the immune system and stimulates the immune response to infections. l the body is exposed to TB bacteria, the immune system produces *cathelicidins*, which are antimicrobial peptides that help combat the infection [30,59]Understanding the significance of proper food utilization will aid in achieving a healthy and nutritionally balanced diet. By eating a well-balanced diet and selecting high-quality foods, individuals can prevent diseases such as pulmonary TB.

Housing conditions such as humidity, light exposure, and temperature are associated with the occurrence of pulmonary TB. Light exposure may not be directly related to TB occurrence but can influence prevention and control efforts [60]. Poor lighting conditions can create damp spaces, allowing TB bacteria to survive longer [61,62]. Lighting can be natural or artificial. Light levels (lux) that are too low or too high can affect health, with an ideal minimum size of ≥60 lux. Ultraviolet radiation can prevent the spread of TB bacteria [63]. The prevalence of pulmonary TB is significantly related to housing density, lighting, and humidity [20,64]. Adequate lighting in the home is beneficial for TB prevention. It is part of a comprehensive strategy to reduce TB risk alongside health education, screening, and appropriate medical care.

The study suggested that house humidity was linked to pulmonary TB. House humidity can influence TB transmission. Damp and poorly ventilated places tend to become breeding grounds for TB bacteria. High or low humidity can allow TB bacteria to survive longer in the air, increasing

the risk of exposure for individuals living in such environments [65]. High indoor humidity can promote the growth of fungi and bacteria, causing lung tissue damage. Damaged lung tissue is more vulnerable to TB infection. Maintaining ideal humidity levels between 40% and 60% RH causes cough particles to settle more quickly and not linger, reducing the risk of pulmonary TB transmission [66]. Optimal humidity can inhibit the growth of TB bacteria. Adequate ventilation will result in a healthy level of humidity [67]. A humidity-optimal household environment can maintain respiratory health. Low humidity can cause dry mucous membranes in the respiratory tract, increasing the risk of infection. In contrast, high humidity can serve as a breeding ground for bacteria affecting respiration [68]. Ideal humidity can help prevent the spread of pulmonary TB, but this must be combined with healthy living conditions and adequate ventilation.

The study found that house temperature was correlated with pulmonary TB. Household temperature and thermal conditions inside the house, such as indoor air quality, cleanliness, and respiratory health, can influence the occurrence of pulmonary TB. Temperatures that are too low or too high can cause health problems. Changes in indoor temperature are influenced by inadequate ventilation, population density, geographical conditions, and other factors [66]. Poor housing facilitates the transmission of TB. TB cases increase significantly with extreme hot and cold temperatures. An ideal indoor temperature range of 18°C to 30°C significantly lowers the risk of pulmonary TB [69]. High-altitude regions have fewer pulmonary TB cases, whereas higher-temperature areas have more [70]. Although the house's temperature is not a direct cause of pulmonary TB, it is essential to maintain good thermal conditions and ensure adequate ventilation for respiratory health. A suitable indoor temperature and air quality can contribute to a healthier environment and help prevent pulmonary TB.

Local culture in terms of preventive behavior was significantly associated with pulmonary TB prevalence. Both individual and community prevention behaviors can influence the spread of pulmonary TB. One of the most effective preventive measures is the Bacille Calmette-Guérin (BCG) vaccination. Active TB patients should cover their mouth and nose when coughing or sneezing with a tissue or their elbow to reduce the spread of airborne droplets containing TB bacteria [71]. Regular soap and water handwashing is an essential practice for reducing the risk of TB transmission. Individuals who have had close contact with active TB patients should keep a safe distance. Recognizing TB symptoms, following medical recommendations for treatment, and adhering to TB treatment are keys to successful treatment, preventing disease spread, and developing more severe TB [34]. Creating an environment that supports pulmonary TB prevention behaviors is crucial, and it can be achieved by enhancing education for individuals and communities.

The limitations of this research include recall bias due to several past risk factors highly reliant on respondents' memory. The control group was more likely to provide limited information because they were not ill. Furthermore, as the case-control study, there was a limitation in assessing causation or direction of association between the risk factors and TB.

Conclusion

The primary factors associated with the occurrence of TB were insufficient housing humidity, insufficient light exposure, low educational level, poor knowledge of TB, having comorbid, close contact with TB patients, insufficient food utilization, and negative preventive behaviors. It is crucial to raise awareness of TB transmission among patients, families, and at-risk communities. Strategies that are not only focused on individual risk factors but also environmental risk factors, particularly in improving adequate housing conditions, are required for TB control policy. This study provided useful information that might help to develop and adopt effective policies for TB control in Indonesia.

Ethics approval

This research received ethical authorization from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Syiah Kuala, by authorization number No: 011/EA/FK/2023. Additionally, informed consent forms were used to obtain consent from participants before their involvement in the research.

Acknowledgments

We appreciate the assistance with the data collection procedure provided by the people in charge of overseeing the TB programs at each community health center.

Competing interests

All the authors declare that there are no conflicts of interest.

Funding

This study received no external funding.

Underlying data

The Indonesian version of the questionnaire is available at: https://doi.org/10.6084/m9.figshare.26066605.

How to cite

Fahdhienie F, Mudatsir M, Abidin TF, Nurjannah N. Risk factors of pulmonary tuberculosis in Indonesia: A case-control study in a high disease prevalence region. Narra J 2024; 4 (2): e943 - http://doi.org/10.52225/narra.v4i2.943.

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