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Intervention Model for Pulmonary Tuberculosis (TB) with a Positive Acid-Fast Bacilli (AFB+) in Peukan Bada Sub-district, Aceh Besar Regency

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Abstract

Pulmonary tuberculosis (TB) with positive Acid-Fast Bacilli (AFB+) remains one of the most transmissible infectious diseases worldwide. This disease poses a significant public health challenge in many countries. This study aimed to develop a risk-factor-based intervention model to reduce the incidence of Pulmonary TB (AFB+). A case-control approach was employed, with the case group comprising people diagnosed with Pulmonary TB (AFB+), and the control group consisting of non-TB individuals from the same neighborhoods. Binary logistic regression was used for bivariate analysis, and multivariate analysis utilized logistic regression. This study found that the social determinants model accounted for 34.9% of the variance in the incidence of Pulmonary TB (AFB+) ($R^2 = 0.349$). The biological determinants model showed an R^2 of 0.127, indicating that this model explains 12.7% of the variance in the disease. The third model, which focused on behavioral determinants, had an R^2 of 0.312, meaning that behavioral factors accounted for 31.2% of the variance. The fourth model, examining the physical condition of housing, showed an R^2 of 0.425, indicating that 42.5% of the variance in Pulmonary TB (AFB+) is explained by variables related to housing conditions. In conclusion, the physical condition of housing emerged as the strongest predictor of Pulmonary TB (AFB+). These findings suggest that improving housing conditions should be a key component of public health strategies to reduce the incidence of Pulmonary TB (AFB+). Targeted interventions to improve the household environment are crucial for reducing the risk and transmission of Pulmonary TB (AFB+).

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INTRODUCTION

Tuberculosis (TB) is one of the deadliest infectious diseases in the world, posing a significant public health problem, especially in countries that have high TB burdens.[1] Every year, around 10 million people are diagnosed with TB, leading to 1.5 million deaths annually.[1] The disease is caused by *Mycobacterium tuberculosis*, which primarily affects the lungs (pulmonary TB).[2] Among those with pulmonary TB, people who tested positive for Acid-Fast Bacilli (AFB+) are the most infectious, and they need immediate and appropriate treatments to prevent further transmission.[3]

To deal with this issue, the World Health Organization (WHO) initiated the "End TB Strategy Program", aiming to reduce TB incidence by 80% and TB mortality by 90% in 2035.[4] Indonesia, which ranks third globally for the TB burden, has adopted and implemented various national strategies in line with this global initiative.[1] In Indonesia, several policies and strategies have been developed by the Ministry of Health of the Republic of Indonesia to control TB, including the Directly Observed Treatment (DOTS), Short-Course (DOTS) program, case detection through active screening, and enhancing the laboratory-based surveillance system.[5] Despite these efforts, significant challenges persist, particularly in ensuring patient adherence to medication and combating the social stigma related to TB.

At the regional level, TB burden is one of the public health concerns in Aceh Province. Data from the Aceh Provincial Health Office showed that the TB incidence steadily increased, making this disease control a top priority in regional health planning.[6] In Aceh Besar Regency, the number of TB cases rose from 331 in 2020 to 355 in 2021, with a further increase to 437 cases in 2022. Peukan Bada Sub-district has emerged as the area with the highest number of confirmed TB cases. Various factors contribute to challenges in addressing TB in this area, including limited access to healthcare facilities, lack of knowledge of TB, and low medication adherence.[7,8]

Due to these challenges, developing an intervention model for pulmonary TB (AFB+) in Peukan Bada Sub-district to identify an effective strategy for controlling TB transmission is highly important. This model takes into consideration local variables, such as risk factors and population characteristics. By utilizing local epidemiological data, the model can project the impact of the implemented intervention on reducing Pulmonary TB (AFB+) cases over a specific period.

The objective of this study is to develop more targeted and evidence-based interventions, which focus on improving early detection, enhancing medication adherence, and reducing pulmonary TB (AFB+) in Peukan Bada Sub-district. This model is predicted to be able to contribute to achieving the TB elimination target more quickly and effectively. This model is also anticipated to support sustainable health program planning at the community level by taking into account local risk factors and social and economic characteristics of the community in Peukan Bada.

MATERIALS AND METHODS

Study Design

This study utilized a case-control design to identify Pulmonary TB (AFB+) risk factors by comparing exposure to risk factors between case and control groups. Age and gender were matched, and the sample ratio was 1:1.

Population

The population consisted of 46 people, including 23 confirmed Pulmonary TB (AFB+) patients in the Peukan Bada Public Health Care Center's working area in 2023, representing the total number of TB (AFB+) cases in the area. The control group was 23 non-infected individuals residing in the same neighborhood.

Variable

Variables in this study were the incidence of pulmonary TB (AFB+), education, knowledge, food security, nutrition, smoking, close contact, housing density, humidity, lighting, and temperature.

Instrument

Interviews using a structured questionnaire were used to collect data. Only three variables were tested for validity and reliability. Validity was assessed using item-total correlation, with an r-table value of 0.209 as the threshold. Only one question from each variable (knowledge and stigma) was invalid and therefore excluded from further analysis. All items in the prevention behavior variable were valid.

The reliability test showed high internal consistency for all tested variables, with Cronbach's alpha values of 0.902 for knowledge, 0.943 for stigma, and 0.945 for prevention behavior.

Statistical Analysis

The data were analyzed using SPSS version 25. Univariate analysis was done to calculate the frequency distribution. In bivariate analysis, binary logistic regression was utilized to identify risk factors of pulmonary TB (AFB+) with a *P*-value < 0.005, and logistic regression was used in the multivariate stage.

RESULTS AND DISCUSSION

Respondent's Characteristics

The number of respondents (Table 1) in this study was 46 people. More than half of the respondents were males (56.5%), adults (39.1%), elderly (39.1%), and married (80.4%).

Table 1. Respondents' characteristics

Characteristics	n	%
Gender		
Male	26	56.5
Female	20	43.5
Age		
Adolescent (17-25 years old)	10	21.7
Adult (26-45 years old)	18	39.1
Elderly (>45 years old)	18	39.1
Marital status		
Married	37	80.4
Single	8	17.4
Widow/widower	1	2.2

Univariate Analysis

The univariate analysis (Table 2) reveals that 37% of respondents attended primary education, more than half had incomes below the regional standard, and 52.2% reported experiencing a low level of stigma. As many as 43.5% of respondents had poor knowledge related to Pulmonary TB (AFB+), 47.8% of respondents reported having poor food security, and 19.6% of them were undernutrition. The analysis also shows that 41.3% of respondents were smokers, 15.2% reported close contact with TB patients, 41.3% resided in high-density housing, 32.6% experienced poor humidity in their house, 32.6% had inadequate lighting, and 32.6% faced unsuitable temperatures in their homes.

Table 2. The result of univariate analyses of Pulmonary TB (AFB+)

Variables	n	%
Educational level		
High	16	34.8
Secondary	13	28.3
Primary	17	37.0
Income		
≥ Regional standard	19	41.3
< Regional standard	27	58.7
Stigmatization		
Low	24	52.2
High	22	47.8
Knowledge		
Good	26	56.5
Poor	20	43.5
Food security		
Good	24	52.2
Poor	22	47.8
Nutritional status		
Normal	30	65.2
Overnutrition	7	15.2
Undernutrition	9	19.6
Smoking Status		
No	27	58.7
Yes	19	41.3
Close contact		
No	39	84.8
Yes	7	15.2
Housing density		
Low	27	58.7
High	19	41.3
Humidity		
Good	31	67.4
Poor	15	32.6
Lighting		
Sufficient	31	67.4
Insufficient	15	32.6
Temperature		
Good	31	67.4
Unsuitable	15	32.6

Bivariate Analysis

The bivariate analysis of health determinants (Table 3) identifies several significant factors associated with Pulmonary TB (AFB+). These included primary education (*P*-value= 0.041; OR= 0.192; CI= 0.040-0.936), low income (*P*-value= 0.036; OR= 3.683; CI= 1.062-12.771), high level of stigma (*P*-value= 0.018; OR= 4.286; CI= 1.246-14.735), inadequate knowledge about TB (*P*-value= 0.017; OR= 4.407; CI= 1.260-15.414), and poor food security (*P*-value= 0.018; OR= 4.286; CI= 1.246-14.735).

The analysis of biological determinants found a significant association between comorbidity (*P*-value= 0.04; OR= 7.765; CI= 0.852-70.752) and Pulmonary TB (AFB+). Additionally, behavioural determinants linked to the disease included inadequate nutrition (*P*-value= 0.027; OR= 0.050; CI= 0.004-0.706), smoking (*P*-value= 0.036; OR= 3.683; CI= 1.062-12.771), and close contact with TB patients (*P*-value= 0.040; OR= 7.765; CI= 0.852-70.752).

The analysis also revealed that physical housing conditions were significantly associated with Pulmonary TB (AFB+), including high housing density (*P*-value= 0.036; OR= 3.683; CI= 1.062-12.771), poor humidity (*P*-value= 0.028; OR= 2.298; CI= 0.949-5.567), insufficient lighting (*P*-value= 0.028; OR= 4.352; CI= 1.125-16.854), and unsuitable temperature (*P*-value= 0.028; OR= 4.352; CI= 1.125-16.854).

Multivariate Analysis

The result of multivariate analysis (Table 4) in model 1 (social determinants) revealed that low income (OR= 1.701; CI= 0.138-20.916), high stigmatization (OR= 1.860; CI= 0.073-47.916), poor knowledge (OR= 2.698; CI= 0.659-11.045), and poor food security (OR= 1.198; CI= 0.041-34.940) were the most significant social determinant risk factors influencing Pulmonary TB (AFB+) incidence. This model has an R-square value of 34.9%, indicating that it accounts for 34.9% of the variability in the incidence of Pulmonary TB (AFB+).

Model 2 (biological determinants) revealed that comorbidity (OR = 7.765; CI = 0.852–70.752) was a factor influencing the incidence of Pulmonary TB (AFB+). This model had an R-squared value of 12.7%, suggesting that comorbidity explains 12.7% of the variation in the incidence of Pulmonary TB (AFB+).

Table 3. Bivariate analysis of the incidence of pulmonary TB (AFB+)

Variables	Cases (n=23)		Control (n=23)		*P*-value	OR (95% CI)
	n	%	n	%		
Social Determinants						
Education level						
Higher	5	21.7	11	47.8		
Secondary	5	21.7	8	34.8	0.012	0.140 (0.030-0.653)
Primary	13	56.5	4	17.4	0.041*	0.192 (0.040-0.936)
Income						
≥Regional standard	6	26.1	13	56.5		
< Regional standard	17	73.9	10	43.5	0.036*	3.683 (1.062-12.771)
Stigmatization						
Low	8	34.8	16	69.6		
High	15	65.2	7	30.4	0.018*	4.286 (1.246-14.735)
Knowledge						
Good	9	39.1	17	73.9		
Poor	14	60.9	6	26.1	0.017*	4.407 (1.260-15.414)
Food Security						
Good	8	34.8	16	69.6		
Poor	15	65.2	7	30.4	0.018*	4.286 (1.246-14.735)
Biological Determinants						
Gender						
Female	10	43.5	10	43.5		
Male	13	56.5	13	56.5	1.000	1.000 (0.312-3.209)
Age						
Adolescent (17-25 years old)	5	21.7	5	21.7		
Adult (26-45 years old)	9	39.1	9	39.1	1.000	1.000 (0.213-4.693)
Elderly (>45 years old)	9	39.1	9	39.1	1.000	1.000 (0.271-3.694)
Comorbidity						
No	17	73.9	6	26.1		
Yes	6	26.1	1	4.3	0.040*	7.765 (0.852-70.752)
Behavioral Determinants						
Nutrition						
Normal	13	56.5	17	73.9		
Overnutrition	2	8.7	5	21.7	0.037	0.096 (0.011-0.863)
Undernutrition	8	34.8	1	4.3	0.027*	0.050 (0.004-0.706)
Smoking						
No	10	43.5	17	73.9		
Yes	13	56.5	6	26.1	0.036*	3.683 (1.062-12.771)
Close contact						
No	17	73.9	22	95.7		
Yes	6	26.1	1	4.3	0.040*	7.765 (0.852-70.752)
The Physical Condition of The Housing						
Housing Density						
Low	10	43.5	17	73.9		
High	13	56.5	6	26.1	0.036*	3.683 (1.062-12.771)
Humidity						
Good	19	82.6	12	52.2		
Poor	4	17.4	11	47.8	0.028*	2.298 (0.949-5.567)
Lighting						
Sufficient	12	52.2	19	82.6		
Insufficient	11	47.8	4	17.4	0.028*	4.354 (1.125-16.854)
Temperature						
Good	12	52.2	19	82.6		
Unsuitable	11	47.8	4	17.4	0.028*	4.354 (1.125-16.854)

*P-value < 0.05: Significant

Table 4. The result of the multivariate analysis of the incidence of pulmonary TB (AFB+)

Variables	Model 1 AOR (95% CI)	Model 2 AOR (95% CI)	Model 3 AOR (95% CI)	Model 4 AOR (95% CI)
Social Determinants				
Education level				
High	Ref			
Secondary	0.195 (0.034-1.128)			
Primary	0.303 (0.053-1.724)			
Income				
≥ Regional Standard	Ref			
< Regional Standard	1.701 (0.138-20.916)*			
Stigmatization				
Low	Ref			
High	1.860 (0.073-47.162)*			
Knowledge				
Good	Ref			
Poor	2.698 (0.659-11.045)*			
Food Security				
Good	Ref			
Poor	1.198 (0.041-34.940)*			
Biological Determinants				
Comorbidity				
No		Ref		
Yes		7.765 (0.852-70.752)*		
Behavioral Determinants				
Nutritional status				
Normal			Ref	
Overnutrition			0.147 (0.015-1.466)	
Undernutrition			0.068 (0.004-1.095)	
Smoking				
No			Ref	
Yes			2.141 (0.531-8.633)*	
Close contact				
No			Ref	
Yes			6.008 (0.528-68.430)*	
Physical Condition of Housing				
Housing density				
Low				Ref
High				3.674 (0.761-17.743)*
Humidity				
Good				Ref
Poor				0.065 (0.006-0.696)
Lighting				
Sufficient				Ref
Insufficient				1.493 (0.281-7.921)*
Temperature				
Good				Ref
Unsuitable				8.721 (0.805-94.452)*
R2	**34.9%**	**12.7%**	**31.2%**	**42.5%**

*P-value < 0.05: Significant

In the third model (behavioral determinants), smoking habit (OR = 2.141; CI = 0.531–8.633) and history of close contact (OR = 6.008; CI = 0.528–68.430) significantly influenced the incidence of Pulmonary TB (AFB+), with the model explaining 31.2% of the variation in TB incidence. These findings underscore the importance of behavioral factors in shaping TB risk within the studied population.

Model 4 (the physical condition of housing determinants) revealed that high-density housing (OR= 3.674; CI= 0.761-17.743), insufficient lighting (OR= 1.493; CI= 0.281-7.921), and unsuitable temperature (OR= 8.721; CI= 0.805-94.452) significantly influenced the incidence of Pulmonary TB (AFB+). This model shows an R-squared of 42.5%, indicating 42.5% of Pulmonary TB (AFB+) is explained by variables in this model. This model is reasonably good at explaining almost half of the variation in TB incidence based on the examined risk factors.

Discussion

The relationship between education and the incidence of pulmonary TB (AFB+)

Respondents with a higher level of education tend to have better knowledge related to TB, including its transmission methods, symptoms, and the importance of proper treatment. Their understanding of TB encourages them to seek medical treatment immediately if they experience TB symptoms. Education level is also associated with healthier lifestyle choices. People with a good educational background are more likely to adopt good personal hygiene, ensure adequate ventilation at home, and practice a lifestyle that minimizes the risk of TB infection.[9]

People having a high level of education have more access to healthcare services to prevent TB and to seek treatment. They are more aware of the existence and the significance of TB programs offered by governments or health organizations.[10] Furthermore, a higher education level is also linked to a better economic status, which allows individuals to access healthcare facilities and medications easily.[11]

Highly educated people commonly live in areas with improved sanitation and housing, further reducing the risk of TB transmission.[12] Education has a significant role in reducing the stigma associated with TB. People who have a better knowledge related to TB are less likely to discriminate against TB patients. This encourages TB patients to seek medical care without fear of judgment or social exclusion.[12] Education plays a crucial role in reducing pulmonary TB incidence by improving knowledge, awareness, and access to healthcare resources. Pulmonary TB incidence is also influenced by economic and social conditions. Thus, interventions aimed to reduce TB prevalence often include an educational component and efforts to improve health literacy.

The relationship between income and the incidence of pulmonary TB (AFB+)

Individuals with low income may face significant barriers to accessing pulmonary TB healthcare services, including delays in diagnosis and treatment. This situation can lead to an increase in transmission.[13] Additionally, low income is often associated with inadequate nutritional status, which compromises the immune system and raises the risk of becoming infected with TB or developing active TB.[14]

Furthermore, low-income individuals are more likely to reside in densely populated and unhealthy environments, such as slum areas or locations with insufficient ventilation, which further facilitates the spread of TB.[15] Particular occupations or economic conditions may also elevate exposure to TB risk factors, such as close contact with infected persons, working in high-risk environments, or being employed in informal sectors lacking adequate social protections.[16]

Moreover, low income is associated with lower educational attainment, which negatively affects knowledge and awareness regarding TB. A limited understanding of TB symptoms, the significance of treatment, and preventive measures can exacerbate transmission rates.[17] Additionally, low-income individuals may not have the opportunity to take time off work to isolate when ill, thereby increasing the likelihood of TB transmission.[10] Low income influences various factors that elevate the risk of TB infection, ranging from environmental conditions to healthcare access, all of which contribute to an increased TB risk. Therefore, effective TB prevention strategies should employ a multi-sectoral approach that addresses the socio-economic determinants of health.

The relationship between stigmatization and the incidence of pulmonary TB (AFB+)

TB Stigma causes a TB sufferer to be reluctant to seek medical treatment. The fear of social exclusion delays visiting a healthcare facility.[18] Stigmatizing TB patients is less likely to adhere to their medical regimen because they may feel embarrassed to pick up a prescription publicly or to attend regular medical appointments. Consequently, this results in medical failure and an increase in drug resistance.[19]

Stigmatization can also cause TB patients to experience social isolation. TB patients may face discrimination, such as from their families, friends, and communities. This influences their mental health status and reduces motivation to recover.[20] When a TB sufferer delays medication due to stigmatization, the risk of TB transmission increases significantly, and this worsens TB incidence in the community.[21]

Stigmatization also reduces social support for TB patients. Patients receiving adequate social support have more motivation to recover, to adhere to their medication regimes, and to complete their treatment.[22] Furthermore, stigmatization can lessen the effectiveness of public health programs. Early detection and treatment initiatives may be less successful if the people in the community are reluctant to participate due to stigma.[23] To overcome this, a holistic approach, such as mass education to dispel myths and baseless fears in the community, psychosocial support for TB patients, and health policies that promote equitable and stigma-free access to healthcare services, is highly required.

The relationship between knowledge and the incidence of pulmonary TB (AFB+)

Knowledge related to TB among people and healthcare workers influences the early detection of TB cases in the community. This is highly important because the earlier TB suspects receive diagnoses, the higher the chance for them to recover from TB and lower the risk of transmitting TB in the community.[24] Having sufficient knowledge related to TB helps individuals to identify early symptoms of TB, access timely medical treatment, and reduce the risk of TB transmission, including the understanding of transmission methods, symptoms, and preventive measures, such as vaccination and good hygiene practices.[25]

An effective education program is required to increase people's awareness about TB and encourage people to actively participate in TB prevention and control programs.[26] Insights resulting from studies related to TB contribute significantly to the design of a more effective health policy and increase advocacy for better resources in eliminating this disease.[27]

Lack of knowledge about TB results in social stigmatization of the sufferer, and this hampers efforts to find new cases and provide adequate treatment.[20] Knowing that TB is caused by *Mycobacterium tuberculosis* bacteria and is spread through the air can encourage individuals to adopt preventive methods, such as wearing masks and having adequate ventilation.[7] Generally, sufficient knowledge related to TB not only directly influences individuals in preventing and managing this disease but also contributes to the efforts to control this disease in a broader context at the community and national levels.

The relationship between food security and the incidence of pulmonary TB (AFB+)

Good food security ensures access to enough nutritious food, which is essential for maintaining a strong immune system and fighting off pathogens.[28] Inadequate nutrition weakens the immune system and increases the risk of TB infection. Poor or unstable food security often leads to malnutrition, which negatively affects the immune system's ability to protect the body from TB infection.[29]

Poor or inadequate food security is able to influence individuals' ability to meet their nutritional needs. Food rich in nutrients, such as vitamins and minerals, can support the immune system to eliminate infection, including TB.[30] Moreover, Poor food security is commonly associated with inadequate access to healthcare services. This delays diagnoses and prompt treatment of TB.[29]

Furthermore, poor food security is commonly associated with poverty and unhealthy living conditions. These factors elevate the risk of TB spreading, particularly in densely populated areas or regions with limited healthcare access.[31] Efforts to improve food security can involve public health programs that can also strengthen efforts to prevent and control infectious diseases such as TB. Therefore, good food security contributes to reducing Pulmonary TB risk by enhancing nutrition, strengthening the immune system, and supporting overall public health initiatives.

The relationship Between Comorbidity and the incidence of pulmonary TB (AFB+)

Comorbidity and TB incidence are influenced by various physiological mechanisms, immunological factors, and other elements that affect individual vulnerability to TB infection.[23] Comorbidities weaken the immune system, making the body more susceptible to infection. For example, HIV/AIDS significantly weakens the immune system, thereby increasing the risk of TB infection.[32] Comorbidities such as diabetes can influence the immune system's ability to prevent infection, including TB. Diabetes causes changes in how the immune system responds to infectious diseases, increasing the body's vulnerability to pulmonary TB infection.[33] Some comorbidities, such as chronic kidney disease or cancer, may require immunosuppressive medication, which weakens the immune system and increases the risk of TB.[34]

Lung diseases, such as chronic obstructive pulmonary disease or lung fibrosis, damage lung tissues and create a supportive environment where TB bacteria can easily multiply.[35] Unhealthy lifestyles, such as smoking and excessive alcohol consumption, also increase the risk of TB infection. For instance, smoking damages lung tissues and disrupts the lung's defense mechanisms against infection.[36]

Some comorbidities are commonly found in the low socioeconomic population, which also has a high risk of TB infection. Factors such as housing density, lack of access to healthcare, and malnutrition are worsening the situation.[37] Some individuals may have a genetic vulnerability to TB infection, which can be influenced by other comorbidities.[38] Overall, comorbidities affect the incidence of TB in multifaceted ways, influencing the immune system, metabolic changes, medications, and lifestyle and socioeconomic factors. Taking a comprehensive approach to treating TB patients with comorbidities is crucial for improving medication outcomes and reducing further transmission.

The association between nutrition status and the incidence of Pulmonary TB (AFB+)

Lack of adequate nutritional intake, such as protein, vitamins A and D, and minerals, including Zinc, weakens the immune system and makes an individual more susceptible to TB infection after exposure to *Mycobacterium tuberculosis* [39]. Vitamin D plays an important role in how the body responds to infection. Vitamin D deficiency has been associated with an increase in the risk of developing TB.[40]

Malnourished individuals, including people suffering from chronic malnutrition and a medical condition causing significant weight loss, are more susceptible to TB.[41] Adequate nutrition intake strengthens the immune system, especially for people living with TB infection.[42] TB sufferers experience loss of appetite and weight loss, leading to malnutrition. Malnutrition delays the healing and recovery processes of TB patients.[29] A sufficient nutrition intake and adequate nutrition status are essential in TB prevention and management. An effective TB prevention program should consider these aspects to improve the overall public health status.

The association between smoking and the incidence of pulmonary TB (AFB+)

A smoking habit damages the mucosa and cilia in the lungs. These lung components act as an initial defense against infection. Thus, smoking makes the lungs more susceptible to TB infection.[37,43] Nicotin and other cigarette contents suppress the immune system, allowing *Mycobacterium tuberculosis* to multiply and cause an active infection.[25] Cigarettes cause chronic inflammation and damage lung tissues, which creates a more favorable environment for the growth of *Mycobacterium tuberculosis*.[43]

TB-infected smokers are more likely to experience complications and have a greater mortality rate compared to non-smokers.[44,25] Smoking disrupts the body's response to TB medication, therefore delaying the recovery process and causing ineffectiveness of TB medication.[45] Smoking is a significant risk factor for TB infection and the development of active TB. Thus, implementing an effective intervention to reduce smoking habits in the population prevents TB transmission in the community.

The association between close contact and the incidence of pulmonary TB (AFB+)

Pulmonary TB spreads through small droplets containing *Mycobacterium tuberculosis*, which are released when an active TB sufferer (especially AFB+) coughs, sneezes, or talks. Individuals in close contact with pulmonary TB (AFB+) sufferers, such as family members or friends living together or working closely with them, have a higher risk of being exposed to this bacterium.[46] The longer the duration of contact with TB sufferers, the greater the chance of being infected by *Mycobacterium tuberculosis*. Repeated or continued close contact with an infected TB individual increases the risk of transmission.[47] Densely populated areas, poor ventilation, and inadequate sanitation facilities also elevate the risk of TB transmission, particularly in close contact.[48]

People with weakened immune systems, such as children, the elderly, or individuals with medical conditions like HIV/AIDS, are more vulnerable to TB infection after close contact with TB sufferers.[49] It is recommended that individuals who have been in close contact with people with Pulmonary TB (AFB+) undergo TB screening, such as a Tuberculin skin test or blood test, to determine the likelihood of infection.[50]

If close contact is not identified and intervened upon, the risk of TB transmission in the community increases. This results in more cases of active TB, which becomes a source of new transmissions.[51] Close contact with Pulmonary TB (AFB+) is the main risk factor in TB transmission. Thus, case identification, screening, and intervention in close contact with individuals need to be done to control TB cases in the community.

The association between housing density and the incidence of pulmonary TB (AFB+)

Living in dense housing means that many people live in a small space, increasing the likelihood of close and prolonged contact between individuals. Tuberculosis (TB) is an infectious disease that spreads through the air when someone with active TB coughs, sneezes, or talks. In a high-density environment, there is a significantly increased chance of an individual inhaling droplets containing *Mycobacterium tuberculosis*.[52] In such crowded living conditions, it is challenging to isolate TB-infected individuals from other family members, which in turn raises the risk of TB transmission within the household.[53]

A dense room tends to have poor ventilation, which reduces airflow and increases the concentration of TB bacteria in the air. This raises the risk of TB transmission, especially if an occupant is suffering from active TB.[54] High-density housing is often linked to poor lifestyle, such as poor hygiene, inadequate sanitation, and lack of access to health facilities. All of these factors weaken an individual's immune system, making them more susceptible to being infected by *Mycobacterium tuberculosis*.[55]

Living in densely populated areas with low socioeconomic status can limit people's access to healthcare services. This can result in delays in diagnosing and treating tuberculosis (TB), as well as prolonging the period during which an infected individual can spread the disease to others.[56] When one person in a community is infected with *Mycobacterium tuberculosis*, there is a higher risk of transmission to others in the community. This can lead to a cluster of TB cases that are difficult to control if living conditions do not improve.[57] High residential density is a significant risk factor for TB transmission. To reduce TB in densely populated areas, it's important to decrease residential density, improve ventilation, provide better access to healthcare services, and promote health awareness related to TB.

The association between humidity and the incidence of pulmonary TB (AFB+)

Bacteria that cause TB live longer in humid air. In high humidity conditions, droplets or aerosol particles containing *Mycobacterium tuberculosis* bacteria remain suspended in the air longer, increasing the risk of transmission if inhaled by susceptible individuals.[58] An environment with low humidity causes dryness in the respiratory tract and makes people more susceptible to infection, including TB. On the other hand, high humidity can cause breathing to become heavier or trigger other conditions that affect the respiratory system.[59]

In high-humidity areas, such as tropical regions, there are more cases of TB. This is connected to other factors like crowded living spaces, inadequate ventilation, and low socioeconomic status, all of which worsen sanitation conditions and make it easier for TB to spread.[60] High humidity is linked to poor living conditions, like overcrowded houses and insufficient ventilation, which increase TB transmission because infected and non-infected people live closely together for extended periods in closed spaces.[61] Overall, the relationship between humidity and TB incidence is complex and influenced by various environmental, social, and biological factors. Humidity affects how long bacteria can survive in the air and can also impact respiratory health, ultimately contributing to TB transmission patterns.

The association between Lighting and the incidence of pulmonary TB (AFB+)

Vitamin D, which is produced by the body through exposure to sunlight, is essential in supporting the immune system. A deficiency of vitamin D weakens the immune system, increasing the risk of developing TB. People who live in environments with low natural light, for example, crowded areas or homes that do not have enough access to sunlight, may be more susceptible to vitamin D deficiency.[57]

Poor lighting is often associated with poor ventilation, especially in enclosed environments such as homes or workplaces. Poor ventilation can lead to the accumulation of moist, stagnant air, which increases the risk of spreading *Mycobacterium tuberculosis*. TB is spread through droplets in the air, and rooms with inadequate ventilation are more likely to become a place for the spread of TB.[52]

Damp, dark environments with insufficient lighting are a supportive environment for microorganisms to grow, including bacteria that cause respiratory infections such as TB.[61] Poor lighting is commonly found in low socioeconomic households, where access to health facilities, adequate lighting, and ventilation may be limited. This increases the risk of TB transmission, especially in densely populated areas.[62] Although poor lighting does not directly cause TB, it contributes to the risk of TB transmission. Therefore, adequate lighting, in addition to good ventilation, plays a crucial role in TB prevention and control programs.

The association between temperature and the incidence of pulmonary TB (AFB+)

Mycobacterium tuberculosis, which causes TB, lives in low temperatures and high humidity. Low temperature increases the bacteria's resistance in the environment, allowing them to survive longer in the air or on surfaces, increasing the chance of infection.[63] In some countries, TB cases increase during the winter. This is due to a combination of factors, such as people spending more time indoors with poor ventilation, which increases the risk of transmission through droplets containing TB bacteria in the air.[58]

Extremely low temperature affects the human immune system, making it more susceptible to infections, including TB. The respiratory system is more vulnerable to infection by bacteria in cold temperatures due to reduced activity as the body's defense mechanism.[64] In tropical areas with higher temperatures, although the incidence of TB is also high, the main risk factors are more related to population density, poverty, and poor sanitation, rather than temperature.[65]

In regions with cold climates, people tend to spend more time indoors with limited ventilation. This increases the risk of TB transmission because poor air circulation prolongs the exposure time to bacteria in the air.[66] In countries with colder climates, homes often have less ventilation during the winter, increasing the risk of transmission of TB. In addition, crowded living conditions and a lack of access to adequate health facilities can also worsen the situation.[67] Temperature may play a role in influencing TB incidence by interacting with environmental factors and human behavior. However, it is important to note that TB is a complex disease, influenced by various factors such as social, economic, and biological elements that contribute to its transmission.

STRENGTH AND LIMITATION

This study has a number of significant strengths. It employs a comprehensive approach that was used to analyse various determinants of Pulmonary TB (AFB+), including social, biological, behavioral factors, and physical condition of housing. The use of Logistic regression analysis in the multivariate stage allows for the identification of influencing factors while controlling for confounding variables. In addition, this study also has a high local relevance because it was focused on a high TB burden area. Therefore, findings of this study can be utilized in planning and development of public health programs in Peukan Bada Sub-district of Aceh Besar Regency. However, this study also has limitations. The Sample size of this study is considered small, limiting the generalization of the results.

CONCLUSIONS

Our study reveals that various factors are linked to the incidence of Pulmonary TB (AFB+). These factors include health determinants (such as education, income, stigma, lack of knowledge, and food security), biological determinants (comorbidities), behavioral determinants (nutrition, smoking, and close contact), and physical condition of housing determinants (housing density, humidity, lighting, and temperature).

To address this issue, it is essential to enhance community outreach and education programs, improve sanitation, offer healthy home renovation programs, build stronger partnerships with the private sector and NGOs, provide comprehensive health worker training, launch campaigns to reduce stigma, and involve local communities in planning and executing TB intervention programs.

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ETHICAL CLEARANCE

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CONFLICT OF INTEREST

The authors stated that there is no conflict of interest regarding this manuscript.

AUTHOR CONTRIBUTION

F.F. designed the research, data, and wrote the manuscript. W was responsible for literature review, manuscript editing, and translation.

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